Effect of Real-Time Audio Ventilation Feedback Device on Survival Rate and Outcomes of Patients with Out-of-Hospital Cardiac Arrest: Prospective randomized controlled study. [Address of organization]

Ji Jae Gu (ws1234@naver.com)  
Inje University Busan Paik Hospital

Lee Eun Dong  
Inje University Busan Paik Hospital

Jang Yun Deok  
Inje University Busan Paik Hospital

Kim Yang Weon  
Inje University Busan Paik Hospital

Kang Ji Hun  
Inje University Busan Paik Hospital

Seo Yong Song  
Inje University Busan Paik Hospital

Yoon Yoo Sang  
Inje University Busan Paik Hospital

Han Kang  
Inje University Busan Paik Hospital

Research Article

Keywords: Out-oof-hospital cardiac arrest, Advanced cardiac life support, Audio-visual ventilation feedback, Cerebral performance category, Emergency medical department

Posted Date: August 3rd, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3191407/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

Background

The purpose of this study was to conduct the effect of real-time audio ventilation feedback on the survival of out-of-hospital cardiac arrest (OHCA) patients during advanced cardiac life support (ACLS) performed by paramedics.

Methods

This study was a prospective randomized controlled study in Busan, South Korea from July 2022 to December 2022. The patients of this study were 121 aged 19 years or older who were transferred to the study institution excluding 91 patients who withholding CPR under doctor's direction and 'Do not resuscitation (DNR) state among 212 adult CA patients. OHCA patients were randomly assigned to compare clinical prognosis using a randomized a general manual defibrillator (NVF) group (N = 58) and a manual defibrillator with audio ventilation feedback (AVF) group (N = 63). To verify the primary outcome, the cerebral performance category (CPC), return of spontaneous consciousness (ROSC), 30 hours survival, and survival discharge were compared. And multivariate logistic regression was conducted to analyze the association of us between the audio-feedback manual defibrillator (AVF) and the ROSC of OCHA patients.

Results

This study analyzed 121 patients among 212 OCHA patients. The ROSC (AVF group: 32 {26.4%} vs. NVF group: 21 {17.3%}), 24-hour survival (AVF group: 24 {19.8%} vs. NVF group: 11 {9.0%}), and survival discharge (AVF group: 12 {9.9%} vs. NVF group: 6 {4.9%}) were higher AVF group than NVF group. But, analyzed CPC scores in surviving patients between the two groups, there was no significant difference (AVF group: 4.1 ± 1.23 vs. NVF group: 4.7 ± 1.23, p = 1.232). Multivariate logistic regression analysis showed that the use of AVF was associated with a higher ROSC (odds ratio (OR), 0.46; 95% confidence interval (CI), 0.23–0.73; P < 0.01) and higher survival at 30 hours (OR, 0.63; 95% CI, 0.41–0.98; p = 0.01).

Conclusion

The use of the audio ventilation feedback has been associated with a higher ROSC and higher survival at 30 hours after CA.

1. Introduction

High-quality CPR is a key clinical procedure performed on patients with cardiac arrest (CA)[1]. Because high-quality cardiopulmonary resuscitation (CPR) has an important effect on the resuscitation of cardiac arrest patients and has a good outcome on neurological prognosis[2, 3]. CPR provided to CA patients consists of chest compression and artificial respiration, and the number of chest compression and the method of respiration could be different depending on whether or not professional advanced airway device is inserted[4].
The recommendation of the American Heart Association is that in situations where specialized instrumental intubation has not been performed, 30 chest compressions should be performed at a depth of 5cm at one-half of the breastbone and complete relaxation should be performed at a speed of 100 to 120 times\[4\]. In the case of artificial ventilation, 30 chest compressions should be performed in situations where professional airway securing surgery has not been performed, and artificial ventilation should be performed twice a second\[5, 6\]. In addition, chest compression is performed for two minutes in patients who have undergone professional airway acquisition, and back valve mask ventilation is performed once every six seconds, but hyperventilation is recommended while squeezing only one-third of the bag\[7\]. Through this ventilation, it is recommended that the optimal ventilation volume is provided 8 to 10 times of division and 6 to 7ml/kg of respiration per time during CPR\[5, 7\].

According to previous studies, if hyperventilation occurs during cardiopulmonary resuscitation, intrathoracic pressure (ITP) increases and may interfere with cardiopulmonary resuscitation\[8, 9\]. The first reason why ITP is not properly carried out properly, and the second reason why ITP increases due to ITP increase due to ITP rise due to ITP rise\[9\]. The third reason is that cerebrovascular contraction occurs through hyperventilation, so there are many reports that blood flow in the brain can decrease due to a decrease in carbon dioxide partial pressure in the blood\[10\]. For these reasons, high-quality cardiopulmonary resuscitation is eventually not provided and may interfere with spontaneous circulation recovery in patients with cardiac arrest. In addition, it does not provide appropriate intracerebral circulation, which adversely affects neurological prognosis. Nevertheless, hyperventilation is frequently occurring during CPR for various reasons by medical providers in hospitals or emergency medical providers outside hospitals\[11\].

Therefore, studies have been conducted to overcome hyperventilation. Some studies have suggested a method of providing accurate artificial respiration speed using metronomes while intratracheal intubation is performed, and studies conducted on mannequins have been conducted to provide ventilation\[12\]. Another recent study has demonstrated that the use of impedance threshold device (ITD) helps improve hemodynamic conditions and short-term survival rates in patients with cardiac arrest\[13–16\]. However, long-term survival rates have failed due to the use of ITD, and it has been reported that these failures increase intravenous pressure and reduce brain perfusion pressure. It was also reported that using ITD could produce epileptic pleural fluid and increase pressure in the left ventricle, resulting in heart failure\[16\]. For this reasons, as real-time ventilation feedback sensors have recently been developed to compensate for the shortcomings of ITD, equipment that feeds back ventilation speed and ventilation volume in an audio manner has been developed and is in use. However, no studies have been conducted on the effect of this device on survival rate and prognosis by preventing hyperventilation and providing an appropriate amount of ventilation in high-quality CPR.

Therefore, this author aims to find out the effect of ventilation feedback devices that provide feedback in real time in the audio method that have recently been commercialized on the survival rate and prognosis of cardiac arrest patients.
2. Materials and Methods

2.1 Study design and setting

The study was conducted as a prospective, single-blind randomized controlled, single-center study. All patients who analysis were 121 among 139 over the age of 19, who were admitted to the ED between 01 July–01 December 2022, and whose written consent could be obtained from them or their legal guardians, were included in the study. The research institute that conducted this study is a regional emergency medical center located in Busan, South Korea, where an average of 1,000 cardiac arrest patients visited the hospital annually. This study was approved by the Institutional Review Board of The Inje university Busan Paik hospital (approval IRB number: 2021-11-063). The requirement for informed consent was waived due to the anonymous nature of the data. This study followed the strengthening the reporting of observational Studies in Epidemiology (STROBE) guidelines.

In order to collect data on patients with pre-hospital cardiac arrest, it was conducted with the cooperation of three emergency medical service(EMS) centers adjacent to the research institution. They paramedics working at three adjacent EMS are rescuers with more than two years of clinical experience and have completed professional cardiac resuscitation training and advanced airway management. Participants were recruited among on-duty basic life support (BLS) and advanced life support (ALS). All participants were experienced in using real-time feedback for chest compressions during OHCA but had no previous exposure to the AccuVent sensor or the ventilation feedback. Participants were required to be trained BLS or ALS providers and perform CPR as a part of their job description. Furthermore, participants were to confirm exposure to at least one OHCA within the last 6 months or attendance at CPR training within the calendar year. Active first aid instructors, physical limitations, and known pregnancy were exclusion criteria. Between 11 July 2022, and 01 December 2022, CA patients were randomized according to the days on which each method would be used. Randomization was conducted using a SAS ver. 9.2 (SAS Institute Inc., Cary, NC, USA). There are a total of two Defibrillators used in the study. One of them was a defibrillator combined with a device for audio ventilation feedback (AVF), and the other used a Non-ventilation feedback (NVF) defibrillator that not combined with a device. Flow chart of study identification and inclusion is shown in Fig. 1. In this study, The CONSORT (Consolidated Standards of Reporting Trials) statement is used (Fig. 1).

2.2. Selection of participants and Data collection

Data were collected from cardiac arrest patients who were transferred to the emergency medical center, a research institute, among those who received specialized cardiac resuscitation performed by paramedics. The subjects included in the study were patients with cardiac arrest outside the hospital aged 19 or older and transferred from three EMSs adjacent to the research institution during 11 July 2022, and 01 December 2022. Among them, patients with endotracheal intubation by paramedic's outside the hospital were selected, if they were physically unable to give consent, members of their immediate family were asked to sign the consent form on their behalf. During this study, a patient under the age of 19, a patient
with cardiac arrest due to trauma, data missing CA, DNR, outcome missing, and a patients failed endotracheal intubation were excluded.

The general characteristics of patients were collected through medical records, and data recorded in the defibrillator’s own database were collected for cardiopulmonary resuscitation-related variables recorded during professional CPR. Variables related to the prognosis of cardiac arrest patients, such as return of spontaneous consistency (ROSC), death, 80 days survival, and cerebral performance category (CPC), were referred to the medical record sheet.

2.3. Sample size calculation.

A total sample size of 139 was calculated using G-Power version 3.1.9.2 (IBM Corp., Dusseldorf, Germany) with an alpha probability of 0.05 and a power of 0.95, and with effect size (0.476). Considering possible dropouts, we decided to include at least 121 patients in this study.

2.4. Outcomes

The primary outcome was comparison of survival rates between groups with AVF and groups with NVF, and the secondary outcomes included the effect on the prognosis of cardiac arrest patients with real-time audio-visual ventilation feedback.

2.5. Data analysis

Categorical variables are presented as frequencies and percentages, while continuous variables are presented as medians and interquartile ranges. After the normality test, parametric (independent t-test or chi-square test) or non-parametric (Mann-Whitney U test) methods were used for comparison. All statistical analyses were performed using SPSS Statistics version 18.0 (SPSS Inc., Chicago, IL, USA). p < 0.05 was considered statistically significant. The main outcomes of this study are to find out the survival rate comparison and factors that affect the survival rate after specialized cardiac resuscitation with AVF and NVF.

To confirm the primary outcome of this study, a chi-square test was performed. If the continuous variable is normally distributed according to the normal distribution, a t-test test was performed and expressed as the mean and standard deviation. If the normal distribution is not followed, rank sum analysis is performed and expressed as intermediate values and quartiles. To confirm the secondary outcome of this study performed more than 30 minutes of spontaneous circulation recovery, 30-hours survival, and survival after performing professional cardiopulmonary resuscitation to verify whether AVF affects the prognosis of cardiac arrest patients. Lastly, The Kaplan–Meier curves, stratified into two groups with AVF devices and a normal manual defibrillator, were used to show the survival period, and the log rank test was used to test the significant difference between AVF group and NVF group. Cox proportional risk regression was used to investigate an independent association between multivariable analytical gender and 80-day mortality. For each study subject, observation continued from the date of discharge to 30 days or until death or censorship. The primary end point was death from all causes.
Data were analyzed using SAS ver. 9.2 (SAS Institute Inc., Cary, NC, USA). If a p-value was less than 0.05, the finding was interpreted as statistically significant.

2.6. Equipment

All device were ZOLL X Series (ZOLL Medical Corporation, Chelmsford, Massachusetts, United States). AccuVent (ZOLL Medical Corporation, Chelmsford, MA) is a disposable differential pressure-based flow sensor that is designed to measure the delivered ventilation rate and tidal volume and provide breath-by-breath feedback to the rescuer (Fig. 2). The sensor is connected between the bag and the mask or endotracheal tube. The sensor is connected to a reusable cable, which is attached to the X Series defibrillator (ZOLL Medical Corporation, Chelmsford, MA, United States).

3. Results

3.1. Baseline characteristics of the study population

Table 1 shows the general characteristics of patients with out-of-hospital cardiac arrest collected. The overall average age of patients with cardiac arrest outside the hospital was 70.36±15.68 and 68 (56.1%) were male patients with cardiac arrest, more than women (56.1% vs 43.9%). Of the total cardiac arrest patients, 13 (10.7%) were performed by witnesses, and 7 (11.1%) and 6 (10.3%) were performed in the AVF-applied patient group. As a result of comparing the cases of ROSC within 30 minutes, there was a significant difference of 35 (55.5%) in the AVF-applied patient group and 26 (44.8%) in the NVF patient group (p=0.031). As a result of comparing the survival rate within 24 hours, there was a significant difference of 31 (49.2%) in the patient group with AVF and 27 (46.5%) in the patient group with NVF (p=0.001). As a result of comparing the survival rate within 80 days between the two groups, there was no significant difference (33.3% vs 22.4, p=0.232)

Table 1. Baseline characteristics of the study population (N=121).
### 3.2. Effect of AVF device on the prognosis of patients with out-of-hospital cardiac arrest.

The results showing the effect of the AVF device on the prognosis of patients with out-of-hospital cardiac arrest are shown in Table 2 below. Patients applying AVF helped increase spontaneous circulatory...
recovery within 30 minutes, and helped survival within 30 hours (0.56 (0.37-1.85), \( p=0.001 \)) and 0.53 (0.31-1.93), \( p=0.03 \)). However, it did not affect the 80-day survival rate, Good Neurologic Outcome (CPC1-2), and Survival to Hospital discharge.

**Table 2.** Logistic regression for outcomes after use AVF

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Adjust OR</th>
<th>OR(95% CI)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROSC within 30 min</td>
<td>0.56</td>
<td>0.37-1.85</td>
<td>0.001</td>
</tr>
<tr>
<td>Survival in 80 days</td>
<td>0.66</td>
<td>0.25-0.87</td>
<td>0.82</td>
</tr>
<tr>
<td>Survival at 30 hours</td>
<td>0.53</td>
<td>0.31-1.93</td>
<td>0.03</td>
</tr>
<tr>
<td>Survival to hospital discharge</td>
<td>0.84</td>
<td>0.39-0.83</td>
<td>0.67</td>
</tr>
<tr>
<td>Good neurologic outcome(CPC1-2)</td>
<td>0.68</td>
<td>0.28-0.91</td>
<td>0.73</td>
</tr>
</tbody>
</table>

OR, odds ratio; CI, confidence interval; CPR, cardiopulmonary resuscitation.

### 3.3. Survival analysis

Overall, 41.8% of cases survived until 80 days. We did not detect a difference in 80 days survival between AVF group (57.3%) and NVF group (42.7%). Figure 3 shows the Kaplan–Meier curve of survivors up to 80 days after CA the log-rank test was not significant (\( P = 0.864 \)). The calculated overall mortality rate was 58.1%. The NVF group mortality was higher in AVF GroupAnd Overall, 50.9% of cases survived until 30hrs. We did detect a significant difference in 30hrs survival between AVF group (91.04%). Figure 2 shows the Kaplan–Meier curve of survivors up to 30hrs after CA the log-rank test was not significant (\( P = 0.0001 \) ) (Figure 3)(Table 3).

**Table 3.** Cox proportional hazard regression for survive f AVF and NVF group

<table>
<thead>
<tr>
<th>Covariate</th>
<th>b</th>
<th>SE</th>
<th>Wald</th>
<th>OR(95% Cl)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVF group</td>
<td>0.2121</td>
<td>0.0822</td>
<td>2.1021</td>
<td>0.7731 - 1.2439</td>
<td>0.0380</td>
</tr>
<tr>
<td>NVF group</td>
<td>0.3563</td>
<td>0.1952</td>
<td>3.3311</td>
<td>0.9740 - 2.0937</td>
<td>0.0675</td>
</tr>
</tbody>
</table>

Harrell's C-index= 0.503, 95%CI(0.400 -0.605), VF; Ventilation feedback, AVF; Aoudio-visual ventilation feedback defibrilator, NVF; Non-ventilation feedback defibrilator, HR; hazard ratio, CI;Confidence interval

And as a result of investigating the effects of AVF device and NVF device on mortality., it can be seen that neither group directly affects the mortality rate(HR: 0.9769(0.4591 -2.2825), p=0.3180 vs HR:
1.0237(0.4381 - 2.1781), p=0.0675)(Table 4).

**Table 4.** Hazard ratios (95% CI) for mortality of AVF and NVF group

<table>
<thead>
<tr>
<th>VF</th>
<th>HR</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVF group</td>
<td>0.9769</td>
<td>0.4591 - 2.2825</td>
<td>0.3180</td>
</tr>
<tr>
<td>NVF group</td>
<td>1.0237</td>
<td>0.4381 - 2.1781</td>
<td>0.0675</td>
</tr>
</tbody>
</table>

VF; Ventilation feedback, AVF; Aoudio-visual ventilation feedback defibrillator, NVF; Non-ventilation feedback defibrillator, HR; hazard ratio, CI; Confidence interval

### 4. Discussion

In this study, the use of audio ventilation feedback devices during professional cardiac resuscitation performed on patients with out-of-hospital cardiac arrest was related to the spontaneous circulation recovery rate within 30 minutes and survival rate within 24 hours of patients with cardiac arrest. And It helps increase the ROSC, however, it was found that it did not affect the 80-day survival rate and good neurological prognosis. Studies that examined the relationship between survival rate and spontaneous recovery rate of ventilation with out-of-hospital cardiac arrest patients previously conducted showed that invasive positive ventilation during cardiopulmonary resuscitation limits lung loss and improves alveolar ventilation rather than ventilation of back valve masks[8, 17]. In addition, as a result of comparing the respiratory effects of 10/min and 20/min per minute using mechanical ventilation during CPR and comparing the spontaneous circulation recovery rate, the spontaneous purification recovery rate was more than 50% even though the gas exchange effect was high[18]. This result showed that the recovery rate of spontaneous circulation increased despite providing more than twice the ventilation compared to the AHA guidline in 2020. Although there is a limitation of research that is insufficient to generalize to water, it is considered sufficient to improve the change in ventilation rate when performing CPR in the future. In fact, in the case of pediatric cardiac arrest patients, the 2020 AHA guidelines recommended increasing it between 20 and 30 bpm, double the existing ventilation rate of 8 to 10 bpm[19]. However, in the case of adults, it has been strongly recommended to prevent hyperventilation in accordance with the guideline recommendations. The reason is that hyperventilation by increasing intrathoracic pressure can reduce venous reflux and impair the hemodynamic efficacy of chest compression and resuscitation[20]. Therefore, it has been found that preventing an increase in intrathoracic pressure during CPR increases the spontaneous circulation recovery rate. In this study, AVF showed that rescuers can receive feedback on ventilation speed and amount of ventilation, thereby preventing an increase in intrathoracic pressure, which increases the voluntary circulation recovery rate compared to the patient group without a feedback device. The reason why the feedback device can provide the correct ventilation speed and amount to the structural person who performs ventilation is provided on the main screen of the defibrillator as a numerical value through the combined sensor, and when the next ventilation is performed after one ventilation, the accurate ventilation rate can be performed. In addition, if the provider performs
hyperventilation, a red alarm is displayed and feedbacks not to perform hyperventilation. Since such feedback can prevent an increase in intrathoracic pressure and a decrease in circulation, it can be interpreted that the spontaneous circulation recovery rate is higher than that of defibrillators without ventilation feedback. And in the current study, it can be seen that the survival rate within 24 hours increased in the patient group using the feedback device. These results prove that the appropriate ventilation power provided to cardiac arrest patients is absolutely helpful in restoring its function by facilitating the oxygenation provided to the organs of cardiac arrest patients. Oxygen is essential for maintaining ATP regeneration and many other energy-consuming processes throughout the body that affect the oxidative phosphorylation and myocardial contraction function of mitochondria. In the event of cardiac arrest, ventilation can be temporarily omitted in the early stages of resuscitation efforts by prioritizing chest compression and defibrillation while utilizing oxygen available in the lungs, blood, and myocardium, but it is clear that spontaneous circulation recovery is impossible in a severe hypoxic environment. Therefore, efforts to secure an appropriate amount of oxygen are essential for resuscitation of cardiac arrest patients. This study has several limitation. First, data were collected using an intubated patients. Use of the Accuvent device is not limited to intubated patients and may be placed in the airway between the bag and the mask or SGA. It is essential that the provider maintains a tight seal on the mask to ensure the tidal volume measured by the device is delivered to the patient. It is, however, possible that the seal may be suboptimal where a facemask or SGA is deployed, an issue requiring further study. Second, it was a study conducted in a single region and a single institution, it is difficult to generalize it as a whole. Third, since it does not reflect the homogeneity of the careers and individual skill skills of paramedic, it is difficult to generalize with the skill results performed by the entire paramedic. In the future, research will be needed to supplement these limitation.

5. Conclusions

AVF device provides accurate ventilation, it helps prevent an increase in intrathoracic pressure by preventing hyperventilation. Therefore, it helps to increase the 30-hour survival rate and the ROSC rate within 30 in patients with out-of-hospital cardiac arrest, but it does not significantly affect the survival rate.

**Abbreviations**

OHCA: Out-of hospital cardiac arrest

CPR: Cardiopulmonary resuscitation

ACLS: Advanced cardio life support

CPC: Cerebral performance category

ROSC: Return of spontaneous consciousness
Declarations

-Ethics Approval and Consent to Participate

This study was approved by and conducted in accordance with the ethical standards of the institutional review board of the Inje University Busan Paik Hospital (IRB number: 2021-11-063). We collected signed informed consent forms from all participants in this study.

- Consent for publication

Not applicable

- Availability of data and materials

generated in this study are available from the corresponding author upon request.

- Conflict of Interest

The authors declare no competing interests.

- Funding

Not applicable

- Authors' contributions

JGJ and EDL designed the study with inputs from YWK, JHK, and YDJ. EDL was responsible for the collection and analysis of OHCA datas with assistance from DSK and YDJ. EDL and YDJ, SYS recruited the patients and performed the data analysis. YWK, JHK, YSY, contributed to the drafting of the manuscript. HK and SYS was transrated this manuscript. All authors discussed the results and implications and commented on the manuscript at all stages. All authors approved the final version of the manuscript. All authors contributed equally to this work.

- Acknowledgements

I would like to thank Jeong SooJin (working AGAPE) for actively supporting the equipment to carry out this study. And I would like to express my gratitude to the ZOLL company for supporting the equipment. Thanks to the equipment you supported, I was able to proceed with the research smoothly.

References


Figures
Figure 1

Flow chart of study for RCT.

OHCA; Out-of hospital cardiac arrest, DNR; Do not resuscitation, AVF; Audio-visual ventilation feedback, NVF; Non ventilation feedback defibrillator.

Figure 2
AccuVent™ flow sensor.

A. Accubent sensor with cable, B. Accubent sensor, C. audio-visual feedback dashboard.

Figure 3

Kaplan–Meier death and survive estimates for AVF group and NVF group in 80 days and 30hrs.

AVF; Aoudio-ventilation feedback defibrilator, NVF; Non-ventilation feedback defibrilator, hr; Hours