

Ventilation Analysis of EM-100, CSI-3000, OXY LIFE II and Bag-Valve Mask in Virtual Reality Ambulance Simulation

Sang-Gyun Roh¹, Jee-Hee Kim²

¹Department of Emergency Medical Services, Sunmoon University, 70, Sunmoon-ro, 221 beon-gil, Tangeong-myeon, Asan-si, Chungcheongnam-do, 31460, Korea; ²Include Department of Emergency Medical Services, Kangwon National University, 346, Hwangjo-gil, Dogye-eup, Samcheok, Gangwon-do, 25949, Korea

ABSTRACT

Background/Objectives: The purpose of the study is to investigate the effective ventilation delivery that affects the rate of resuscitation.

Method/Statistical Analysis: The National Fire Service Academy conducted Virtual Reality (“VR”) based ambulance simulations from April 17, 2018 to April 28, 2018. The mean and standard deviations of mean ventilation and airway pressure were analyzed using descriptive statistics and ANOVA and SPSS software 12.0 (SPSS Ins., Chicago, IL, USA) program.

Findings: When VR-based intubation was performed, the ventilation was 427 ml from Oxylator EM-100, 458 ml from MicroVenT CSI-3000 and 305 ml from OXY-LIFE II. For the airway pressure, Oxylator EM-100 showed 10.623 cmH₂O, MicroVenT CSI-3000 showed 11.291 cmH₂O and OXY-LIFE II showed 6.965 cmH₂O. When tracheal intubation was performed on the VR base, Oxylator EM-100 and MicroVenT CSI-3000 showed adequate ventilation and airway pressure.

Improvements/Applications: This study suggests to use an oxygenator as an efficient ventilation method after intubation in ambulance during transport. Skilled practice and the method of use of rescuer is very important.

Keywords: *Virtual Reality, Oxylator EM-100, MicroVenT CSI-3000, OXY-LIFE II, RespiTrainer® Advance.*

Introduction

In addition to cardiac arrest, it is critical to provide airway maintenance and adequate ventilation for patients with very poor breathing or stopped breathing. Inadequate ventilation in a situation where airway maintenance is difficult and oxygen supply is unavailable is an important determinant of patient survival and normal function recovery and disability^[1]. The most commonly used equipment for artificial ventilation is a

back-valve mask when cardiopulmonary resuscitation (CPR) is performed in a cardiac arrest before arriving hospital, or when secondary respiration is needed due to poor respiration.

Airway maintenance, proper masking, and precise backpressure are required to deliver adequate ventilation volume using a bag-valve mask. Respiration varies depending on the ventilation method of the rescuer and is dependent on the ambulance movement or instability of the ambulance. Internal environment of the ambulance can also affect ventilation. According to recent guidelines, it is recommended that effective artificial ventilation in cardiac arrest should be maintained at a single ventilation of 500 to 600 ml (6 to 7 ml/kg)^[2].

Hyperventilation and artificial respiration of excessive volume interfere with blood flow into the heart due to increased intrinsic pressures, so cardiac output

Corresponding Author:

Jee Hee Kim

Professor,

Department of Emergency Medical Services,
Kangwon National University, Korea

Email: kjh1962@kangwon.ac.kr

decreases even though effective chest compression is performed. In addition, such decrease in cardiac output can reduce the blood flow of the brain and coronary arteries affecting the rate of revival and cause reflux of the gastrointestinal contents to induce reflux and inhalation complications^[3,4]. It is difficult to supply an adequate amount of oxygen in moving ambulance, and since the seat of the rescuer is located on the patient's side, it is difficult to apply the C-E technique when ventilation is performed using a bag-valve mask. In addition, ventilation with a bag-valve mask after intubation with a specialized tube is difficult to maintain a proper amount of one-time respiration due to improper posture of paramedic.

According to Act on 119 Rescue and Emergency Medical Services, the automatic oxygen supply is a must-have device for 119 ambulances, and three models are currently available: MicroVenT® CSI-3000, Oxylator® EM-100 and Oxy-Life® II^[5]. Automatic oxygen supply can assist ventilation either automatically or manually. Automatic oxygen supply is applied when patient's spontaneous breathing is irregular and auxiliary ventilation is needed while manual one can be applied to assist ventilation in patients who require CPR or artificial respiration. The manual oxygen supply is designed to deliver ventilation as long as the button or trigger is pressed or pulled, and there are two types of pressure and volume. The pressure type includes Oxylator EM-100 while volume type includes, MicroVenT CSI-3000 and OXY-LIFE II, and the ventilation and release pressure per hour are different by each product.

The oxygen supply supplies high pressure oxygen as long as the user presses the oxygen supply button or pulls the trigger, and the ventilation delivered to the lungs depends on the time the user presses or pulls. Oxylator, displayed in the existing ambulance vehicles, is based on the US Heart Association guidelines for 2000 and 2005, and is recommended to push or pull the oxygen supply button or trigger for 2 seconds. In the 2010 and 2015 American Heart Association guidelines, the artificial respiration method recommends respiratory assistance with a volume of 500 to 600 ml, which is equivalent to 1 second for adults to prevent over ventilation. However, the manual still introduces old ventilation method before 2005, so the user may cause over ventilation.

Previous studies related to oxygen supply include Comparison of one-time volume in demand valve and pocket mask ventilation^[6], Demand valve ventilation in pneumothorax model^[3], Comparison of bag-valve mask and demand valve ventilation^[4], Comparison of bag-valve mask and demand valve ventilation^[7], Comparison of ventilation and airway pressure using Oxylator EM-100^[8] and Comparison of Oxylator ventilation, etc^[9]. However, such previous studies have been limited to the comparison of oxygen supply with bag-valve mask ventilation in a situation where there is no moving.

This study compared the oxygen supply with ventilation using a bag-valve mask after endotracheal intubation in VR based ambulance. Since previous studies were conducted under fixed conditions, a comparison with VR-based studies is needed. Therefore, the purpose of this study is to provide basic data for efficient use of oxygen mask and bag-valve mask during transferring patient.

Materials and Method

Research Design and Data Collection: This study was a comparative analysis of ventilations of oxygen supply MicroVenT® CSI-3000, Oxylator® EM-100, Oxy-Life® II and back-valve masks with RespiTrainer® Advance in VR simulated ambulances. For this purpose, VR based simulation ambulance in the National Fire Service Academy was used and "Urban outside road scenario" was applied among the developed scenarios. Driving time was 60-80 km/h for 6 minutes. VR based simulation ambulance driving was conducted by the National Fire Service Academy's professor, and the same scenario was used.

Experiments compared the cases using MicroVenT® CSI-3000, Oxylator® EM-100, and Oxy-Life® II with a mask and the cases with a bag-valve mask. Also compared the cases using MicroVenT® CSI-3000, Oxylator® EM -100, Oxy-Life® II and the bag-valve mask after applying endotracheal intubation. The scenarios compared total 60 ventilations for 5 minutes.

For comparison of ventilations, endotracheal intubation was performed by one professor and one emergency first aid technician. Ventilation was performed by pressing and pushing Oxylator's oxygen supply button and trigger for 1 second and then collecting ventilation and airway pressure delivered to the lungs

using RespiTrainer® software (version 1.1, Ingmar, Pittsburgh, USA). The researchers used a stopwatch to practice the oxygen supply button and trigger for 60 seconds, followed by 60 times per each oxygen supply type[Figure 1]. During all ventilations, the investigator performed the test hiding the chest area so that the chest rising of RespiTrainer® Advance could not be seen. It was not easy to press the oxygen supply button for one second in a VR-based situation, although the preliminary experiment had enough practice to not exceed less than 0.9 seconds and more than 1.09 seconds.

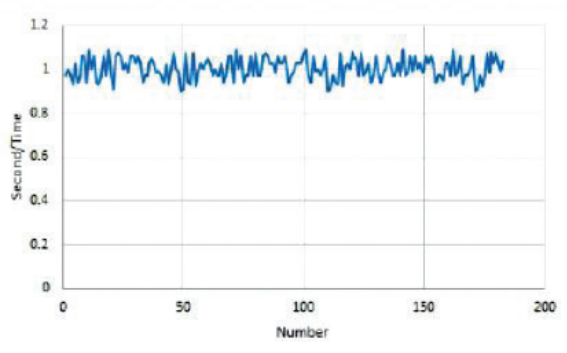


Figure 1: Pre-evaluation of Oxygen supply

Experimental tools

VR based Simulation Ambulance: The VR based ambulance designed to enable the education and training of emergency services in various road environments was developed as a fire research and development (R&D) project. VR based simulation ambulance implemented VR by applying Ambulance Driving Simulation S/W to computer controlled moving platform design[Figure 2]. Six scenarios have been developed to suit the surrounding environment, such as rural, urban and suburban environments, and are designed so that the rescuer can drive while monitoring scenarios set up outside the ambulance.

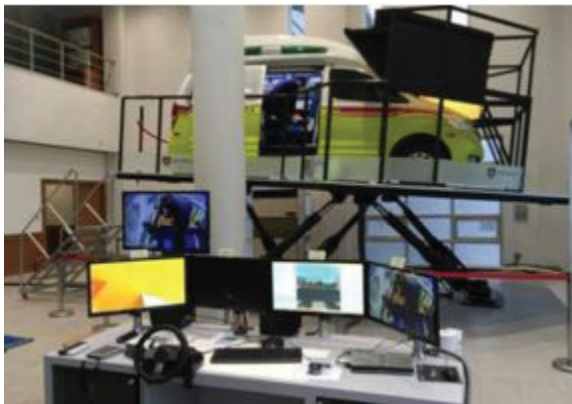


Figure 2: VR-based simulation ambulance

RespiTrainer: RespiTrainer® Advance (version 1.1, Ingmar, Pittsburgh, USA) is the equipment that is optimized for a wide range of special air intubation training and skills, and has realistic materials and anatomical structures. High-performance test lungs (QuickLung®) can achieve realistic lung capacity in adults, and software can be used to verify data such as ventilation and airway pressure. Airway resistance and compliance were set at 5 cmH₂O/L/s and 50ml/cmH₂O, which are the mean values of healthy persons without lung disease[Figure 3].

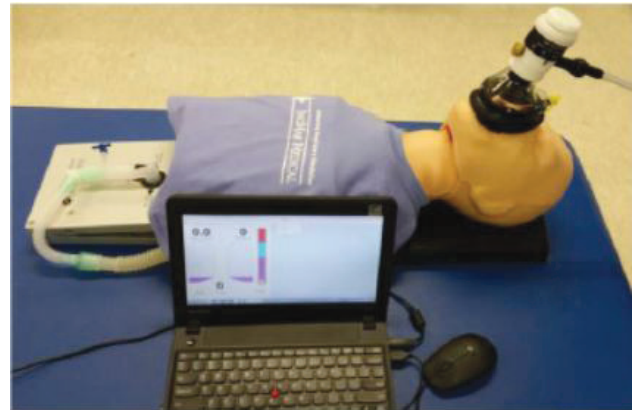


Figure 3: RespiTrainer® Advance

Automatic Oxygen Supply: The Oxylator EM-100 (Roswell, USA) has both automatic and manual pressure delivery methods and provides oxygen as long as the oxygen supply button is pressed while the airway pressure is set to 25-50 cmH₂O. In this experiment, the manual method was used. After connecting the tube of Oxylator EM-100 to the oxygen aspiration system (MEF-22), the supply pressure in the airway was set to 25 cmH₂O as recommended by the manufacturer. CSI-3000 (Chosun Instrument Inc., Korea) delivers compressed oxygen, which has both automatic and manual delivery methods. In passive mode, it can supply oxygen at a flow rate of 40 l/min and supplies oxygen as long as the oxygen supply handle is pulled. In this experiment, the manual method was used and the tube of CSI-3000 was connected to the oxygen aspiration system (MEF-22). OXY-LIFE II (SanCheong, Korea) is a product based on the 2000 guidelines of the American Heart Association. It delivers compressed oxygen in both the automatic and the manual modes and the oxygen is supplied as long as the manual button is depressed. In this experiment, the manual method was used, and the volume of respiration was set at 600 ml, and the tube of OXY-LIFE II was connected to the oxygen aspiration system (MEF-22).

Endotracheal Intubation: The tubes used for endotracheal intubation were Mallinckrodt® I.D. 7.5, and the depth of the intubation was fixed at 22 cm. The cuff was injected with 10 ml of air and fixed to the outside with a Thomas® Tube Holder to prevent loosening or moving.

Bag-valve mask (BVM): BVM was attached to a Laerdal® Silicone Resuscitator with a storage bag and the bag capacity was 1,600 ml.

Data Collection and Analysis

All experiments were conducted within a VR-based simulation ambulance and were conducted at the National Fire Service Academy from April 17, 2018 to April 28, 2018. All data were collected using respiTrainer® software (version 1.1, Ingmar, Pittsburgh, USA) to collect ventilation and airway pressure. The collected data were analyzed using SPSS software 12.0 (SPSS Ins., Chicago, IL, USA). The mean and standard deviation of ventilation and airway pressure were analyzed using descriptive statistics and ANOVA.

Results and Discussion

VR based endotracheal intubation was performed and the results of one-time respiration were analyzed. Back-Valve Mask showed ventilation of 380.750 ± 23.126 ml, with a minimum ventilation of 313 ml and a maximum ventilation of 436 ml. The Oxylator® EM-100 showed an average ventilation of 427.766 ± 21.643 ml, with a minimum ventilation of 380 ml and a maximum ventilation of 490 ml, which required an average of 1.011 seconds to press the oxygen supply button. CSI-3000 showed an average of 458.016 ± 28.978 ml ventilation, 370 ml minimum ventilation and 503 ml maximum ventilation, and it took 1.026 seconds on average to press the oxygen supply button. Oxy-Life® II showed an average ventilation of 305.833 ± 16.508 ml, with a minimum ventilation of 267 ml and a maximum ventilation of 353 ml, and an average of 1.014 seconds was required to press the oxygen supply button [Table 1].

Table 1: Comparison of Delivered Volume

Variables	Mean (ml)	Minimum	Maximum	Standard deviation	F	p	Scheffé
Bag-valve mask (a)	380.750	313.00	436.00	23.126	474.317	.000	a>d, a<bc
Oxylator EM-100 (b)	427.766	380.00	490.00	21.643			B<c, b>ad
MicroVenT CSI-3000 (c)	458.016	370.00	503.00	28.978			c>abd
OXY-LIFE®II (d)	305.822	267.00	353.00	16.508			d<abc

Table 2 shows the results of airway pressure analysis with VR-based endotracheal intubation. The back-valve mask showed an average airway pressure of 14.913 ± 1.151 cmH₂O, with a minimum airway pressure of 12.70 cmH₂O and a maximum airway pressure of 17.40 cmH₂O. The Oxylator® EM-100 showed an average airway pressure of 10.623 ± .438 cmH₂O, with a minimum airway pressure of 9.70 cmH₂O and a maximum airway pressure of 11.90 cmH₂O. CSI-3000 showed an average airway pressure of 11.291 ± 4.90 cmH₂O, with a minimum airway pressure of 10.0 cmH₂O and a maximum airway pressure of 12.20 cmH₂O. Oxy-Life® II showed an average airway pressure of 6.965 ± .340 cmH₂O, with a minimum airway pressure of 6.30 cmH₂O and a maximum airway pressure of 7.70 cmH₂O [Table 2].

Table 2: Comparison of Airway Pressure

Variables	Mean (cmH ₂ O)	Minimum	Maximum	Standard deviation	F	p	Scheffé
Bag-valve mask (a)	14.913	12.70	17.40	1.150	1357.863	.000	a>bcd
Oxylator EM-100 (b)	10.623	9.70	11.90	0.438			B>d, b<ac
MicroVenT CSI-3000 (c)	11.291	10.00	12.20	0.490			c>bd, c<a
OXY-LIFE®II (d)	6.965	6.30	7.70	0.340			d<abc

Effective oxygen delivery is recommended for 1 second at 5-6 ml/kg, but it is not easy to supply oxygen efficiently within a wavering ambulance. There are three kinds of oxygen supplies in the ambulance under the Act on Rescue and Emergency Service: Oxylator EM-100 which is pressure transmission system, MicroVent CSI-3000 which is volume system and OXY-LIFE II. In all three types, oxygen is delivered as long as the oxygen supply button is pressed or the trigger is pulled. Therefore, there is always a risk of over ventilation because the ventilation can be different according to the method used by the rescuer.

A previous study reports that ventilation using Oxylator EM-100, CSI-3000 and OXY-LIFE II after endotracheal intubation was 551 ml for Oxylator EM-100, 527 ml for CSI-3000, 369 ml for OXY-LIFE® II of ventilation^[9]. In the two models, it was identified that 1 minute respiration (500-600 ml) could be delivered while holding the oxygen supply button for 1 second, and the other one showed insufficient ventilation. In this study, ventilations were compared using VR based “Urban outside road scenario”. Ventilations were average 427 ml for Oxylator® EM-100, 458 ml for CSI-3000 and 305 ml for OXY-LIFE II. In comparison with the previous study, the mean ventilation were identified to be lower than the previous studies with Oxylator by 124 ml, CSI-3000 by 69 ml and OXY-LIFE II by 64 ml respectively. In the minimum ventilation, it was identified to show lower than the mean ventilation with Oxylator EM-100 by 135 ml, CSI-3000 by 131ml and OXY-LIFE® II by 74 mL respectively.

On the other hand, the ventilation was 380 ml when using a bag-valve mask after endotracheal intubation. The mean ventilation of the previous studies ranged from 320 to 524 ml, and this study was conducted as a 1/3 bag compression method for delivering one-time volume based on the 2010 guidelines^[10-13]. The reason for this is thought to be the difference depending on the degree of adhesion of the bag-valve mask and the degree of back-squeezing. In order to reduce hyperventilation and high volume and low volume, continuous education and quality control should be performed. On the other hand, in the case of intubation such as endotracheal intubation, manual ventilation using the oxygen supply is relatively easy to use compared with the ventilation with the bag-valve mask, especially, the oxygen could

be easily supplied in the moving space when transferring the patient to the hospital from the accident scene.

Airway pressure above 20-25 cmH₂O can lead to lung injury and reflux and inhalation complications^[14,15]. Ventilation with VR based Oxylator EM-100 showed airway pressure of 10.623 cmH₂O and CSI-3000 of 11.291 cmH₂O. However, OXY-LIFE II showed 6.965 cmH₂O, indicating that ventilation is provided at relatively low pressure. In previous studies, the airway pressure to deliver 496 ml of volume through endotracheal intubation was 11.67 cmH₂O^[8] and the airway pressure to deliver a volume of 537.97 to 488.19 ml was 11.34 to 10.61 cmH₂O^[9]. Therefore, the Oxylator EM-100 (10.623) and CSI-3000 (11.291) shown in this study are considered to have adequate airway pressure.

This study is a comparative analysis of the ventilation and airway pressure of Oxylator EM-100, CSI-3000, and OXY-LIFE II when using manual mode of oxygen supply in VR based firefighting ambulance. On the VR basis, when oxygen was used to provide ventilation with endotracheal intubation, Oxylator EM-100 showed 427 ml, CSI-3000 showed 458 ml and OXY-LIFE II showed 305 ml respectively. Considering the average weight of adults in Korea, Oxylator EM-100 and CSI-3000 showed adequate ventilation, but OXY-LIFE II was found to have low respiratory rate.

Conclusion

In this study, the researcher compared the ventilation delivery of VR based oxygen supply, which is designated as an ambulance essential equipment by the Act on 119 Rescue and Emergency Medical Services and could deduct following conclusion: When endotracheal intubation was performed, the volume of ventilation was 427 ml for Oxylator EM-100, 458 ml for CSI-3000, and 305 ml for OXY-LIFE II. For airway pressure, Oxylator EM-100 showed 10.623 cmH₂O, CSI-3000 showed 11.291 cmH₂O, and OXY-LIFE II showed 6.965 cmH₂O. When endotracheal intubation was performed on VR base, Oxylator EM-100 and CSI-3000 showed mean ventilation and airway pressure.

Ethical Clearance: Not required

Source of Funding: Self

Conflict of Interest: Nil

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