A new portable ventilation system for basic life support

一次救命のための新たな携帯型人工呼吸器の開発

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Mouth-to-mouth resuscitation is believed to be a quick, effective method for providing oxygen to a victim. The International Guidelines of 2000 have recommended reducing the risk of gastric inflation during mouth-to-mouth ventilation by delivering slow breaths at the lowest tidal volume that would still raise the chest visibly with each ventilation. For mouth-to-mouth ventilation in most adults, the tidal volume would be approximately 10 ml/kg (ca. 700–1000 ml). It should be delivered over 2 s. Can however, an appropriate amount be blown in even if there is no special instruction when an untrained citizen suddenly encounters an accident? We investigated the mean tidal volume during mouth-to-mouth resuscitation by untrained citizens, and it was ca. 800 ml, which corresponds to the recommended value of the current guidelines. In the mouth-to-mouth resuscitation, the composition of the expired air that the rescuer administers to the victim was PO_2 and PCO_2 of 115 ± 1 mmHg and 32 ± 1 mmHg when the tidal volume was 500 ml. When the tidal volume was 1 l, PO_2 and PCO_2 were 120 ± 1 mmHg and 29 ± 1 mmHg, respectively (N=10). Moreover, when the ventilation experiment was done to the animal (beagle), the following results were shown (N=7). The amount of ventilation was ca. 20 ml/kg, and 12 breaths per minute. In addition, arterial PaO_2 , $PaCO_2$, and pH were measured. Consequently, after mouth-to-mouth ventilation, PaO_2 decreased to 71 ± 1 mmHg (normal value = 95–100 mmHg), $PaCO_2$ increased to 54 ± 2 mmHg (normal value = 40 mmHg), and the pH became 7.27 ± 0.02 . To improve the respiratory state after mouth-to-mouth ventilation, we developed a new Portable Ventilation System (PVS) to improve ventilation efficiency and to alleviate the risk of infectious disease. By using PVS, the composition of inflow air of the mouth-to-mouth ventilation by rescuers was PO_2 139 ± 2 mmHg and PCO_2 15 ± 1 mmHg (N=10), when the tidal volume was 500 ml and PO_2 and PCO_2 were 131 ± 2 mmHg and 19 ± 1 mmHg, respectively when the tidal volume was 1 l (N=10). This ventilation experiment was performed on animals (beagle). After artificial ventilation with gas made by PVS, changes of arterial PaO_2 , $PaCO_2$ and pH were improved to 84 ± 2 mmHg, 46 ± 1 mmHg, and 7.37 ± 0.01 , respectively (N=7). Consequently, results showed that the ventilation efficiency of the new PVS was higher than that for mouth-to-mouth ventilation.

Keywords : Mouth-to-mouth ventilation; PV System; Blood gas analysis

I. INTRODUCTION

Fifty years since the introduction of modern cardiopulmonary resuscitation (CPR), we have witnessed many advances for respiratory arrest victims. Many studies¹⁻⁴ have shown that mouth-to-mouth resuscitation is better than mouth-to-airway methods of artificial respiration with the chest-pressure arm-lift methods. In the 1960s, it was shown that the above mentioned points are important aspects for resuscitation.⁵⁻⁷

In the resuscitation, the importance of early artificial respiration is clear. When artificial respiration is delayed or when other proper care (CPR, AED, etc.) is not at hand, the so-called "Chain of Survival" is broken. The actions taken during the first few minutes of an emergency are critical to a victim's survival. Resuscitation consists of basic life support (BLS) at the accident site and advanced life support (ALS) in the hospital. Artificial respiration by the bystander is an important part of BLS. The BLS that commences over 4 min after an accident is called Late BLS. The ALS that commences over 12 min after the cardio-respiratory arrest is called Late ALS. Eisenberg et al.⁸ reported that both Late BLS and Late ALS are fatal. In Seattle, U.S.A., the survival rate of patients who were administered BLS by a bystander within 4 min from an accident was 43%. In contrast, the survival rate of patients in late BLS more than 4 min after an accident was 21%. These results emphasize the importance of bystander CPR. However, citizens, even physicians, and nurses are reluctant to perform mouth-to-mouth ventilation.⁹⁻¹⁶ The most commonly stated reason for not performing mouth-to-mouth ventilation is fear of infectious diseases. The perceived risk of disease transmission during CPR has reduced the willingness of some laypersons to initiate mouth-to-mouth ventilation to unknown victims of cardiac arrest. If the rescuer is unwilling or unable to perform mouth-to-mouth ventilation, manual ventilation equipment such as a bag-mask system with valves or a mouth-to-mask can be used, but they are not easy to use for unskilled users.

For artificial respiration, an appropriate removal competence of carbon dioxide from the blood and an ability to add appropriate oxygen to arterial blood are required. Therefore, the discussion about the appropriate tidal volume in artificial respiration has continued for a long time.¹⁷⁻²² A new international guideline was introduced based on previous recommendations.²³⁻²⁹ The 1992 ECC Guidelines³⁰ recommend that adult rescuers breathe

a tidal volume of 800–1200 ml, delivered over 1–2 s. International Guidelines of 2000 recommended that to reduce the risk of gastric inflation during mouth-to-mouth ventilation by delivering slow breaths at the lowest tidal volume that would still raise the chest visibly with each ventilation. For mouth-to-mouth ventilation in most adults, this volume would be approximately 10 ml/kg (ca. 700–1000 ml) and should be delivered over 2 s.

We developed a novel portable ventilation system (PVS) that bystanders can use quickly and effectively, compared to the mouth-to-mouth method in human and animal experiments.

The present PV systems are comprised of the following four parts as shown in Fig. 1: (a) a mask, (b) an intake and exhaust integrated valve, (c) a bellows, and (d) a mouthpiece. The bellows play the role of a "dead space" to provide more fresh-air content than mouth-to-mouth ventilation to patients (see Fig.1-(c)). The integrated valve also contributes to fresh air ventilation. As the bystander inspires air from the mouthpiece, room air is taken into the bellows through the intake portion of the integrated valve (see Fig.2-a). When the bystander expires, mixed air of the expired gas and room air would be provided for patients through the exhaust part of the integrated valve (see Fig.2-b). Expired gas from the patients is discharged separately by the integrated valve (see Fig.2-c). This system allows for efficient and sanitary ventilation.

Fig.1 Portable Ventilation System (PV system)

The present PV system comprises four parts: (a) a mask, (b) an intake and exhaust integrated valve, (c) a bellows, and (d) a mouthpiece.

Fig. 2-a Intake and exhaust integrated valve
First, a bystander inspired air from the mouthpiece; room air will be taken into the bellows through the intake portion of the integrated valve.

Fig. 2-b Intake and exhaust integrated valve
When the bystander expires, mixed air of the expired gas and room air will provide for patients through the exhaust part of the integrated valve.

Fig. 2-c Intake and exhaust integrated valve
Expired gas from the patients was discharged separately through the integrated valve.

II. EXPERIMENTAL METHOD

In practical situation such as disasters, the participation of untrained bystanders in BLS is important. So present experiments enrolled

volunteers who had no experience in emergency resuscitation.

II-A. Investigation of mean tidal volume when using mouth-to-mouth resuscitation or PVS by untrained citizens

This experiment enrolled volunteers (18 males, 11 females) who had no experience in emergency resuscitation. The amount of the expired air that the general citizens blew into the patient was investigated when there was neither knowledge nor instruction concerning the revival. Minimum information (open the airway, tilt the head back, and provide rescue breathing) was given to volunteers. In addition, volunteers were made to perform artificial respiration by mouth-to-mouth breathing. In that case, there was no guidance as to the amount of ventilation. Volunteers were directed to perform artificial respiration 12 times per minute (one breath every 5 s). The amount of the expired air was measured using a flow meter and training aids (Ambu). A similar experiment was done using PVS.

II-B. Comparison of gas composition of expired air between mouth-to-mouth ventilation and the PVS

This study was done to examine gas composition of the expired air when mouth-to-mouth ventilation was done. In addition, a similar experiment was done using PVS. The volunteers consisted of five men and five women. All were healthy adults. PO_2 and the PCO_2 of expired air were compared for mouth-to-mouth breathing and PVS ventilation. The expired air was gathered with mouth-to-mouth resuscitation as recommended in the International Guidelines 2000. However, a gathering method was devised for an impartial sampling shown in Fig.3. Under the procedure shown in Fig. 3, mouth-to-mouth and PVS ventilation were performed alternately. Each amount of expired gas was sampled separately in an air bag for PO_2 and PCO_2 analysis by OSCAR.

Fig. 3 Procedure of gas sampling
Expired air was gathered according to mouth-to-mouth resuscitation recommended in International Guidelines 2000. However, the collection method was devised for an impartial sampling. Under the procedure shown in Fig. 3, mouth-to-mouth and PVS ventilation were performed alternately. Respective expired gases were sampled separately in air bags.

II-C. Comparison of effects on arterial bloodgas between mouth-to-mouth ventilation and PVS in beagle dogs

Incubated and venous anesthetized beagles (females n=7 mean weight = 9.5 kg) controlled by a mechanical ventilator were used for the experiment. Ventilation was controlled using a respirator, and the direction to breathe in 12 times a minute (one breathe every 5 s). The amount of ventilation was approximately 20 ml/kg. Inspired gas was changed in the following order; (1) room air, (2) gas that corresponded to the expired air of the mouth-to-mouth ventilation, and (3) gas that corresponded to the expired air of the PVS. Animals were ventilated continuously for 12 min for each gas and 1 ml of arterial blood was sampled every 3 min. Sampled blood was analyzed quantitatively for PaO₂, PaCO₂, pH, BE, and SO₂ using Portable Clinical Analyzer i-STAT.

III. RESULTS

III-A. Mean tidal volume when using mouth-to-mouth ventilation or PVS by untrained citizens

The volume of expired air that the resuscitation-inexperienced citizens blew into the victim by mouth-to-mouth ventilation was 700–1000 ml (mean 840±150 ml). Similarly, the amount of expired air that the inexperienced citizens for the resuscitation blew in to the victim by PVS was 600–900 ml (mean 740±130 ml) (see Table 1).

Table 1. Comparison of mean tidal volume between Mouth-to-mouth method and the PV system in untrained participants

	Mouth-to-mouth (L)	PV System (L)
Males (N=18)	0.85 ± 0.08	0.77 ± 0.07
Females (N=11)	0.83 ± 0.22	0.70 ± 0.18
Total (N=29)	0.84 ± 0.15	0.74 ± 0.13

III-B. Comparison of gas composition of expired air between mouth-to-mouth ventilation and the PVS

By mouth-to-mouth ventilation, when the tidal volume of the expired gas was 500 ml, PO₂ and PCO₂ were 115±1 mmHg and 32±1 mmHg, respectively (N=10) and when the tidal volume was

1 l, PO₂ and PCO₂ were 120±1 mmHg and 29±1 mmHg, respectively (N=10). Artificial respiration that uses PVS allows the rescuer to send the victim the following composition of gas. When the tidal volume was 500 ml, PO₂ and PCO₂ were 139±2 mmHg and 15±1 mmHg, respectively (N=10) and when the tidal volume was 1 l, PO₂ and PCO₂ were 131±2 mmHg and 19±1 mmHg, respectively (N=10). When the tidal volume was adjusted to 800 ml average tidal volume obtained above, PO₂ and PCO₂ of expired gas with mouth-to-mouth methods were 118±1 mmHg and 30±1 mmHg, respectively and by the PVS, PO₂ and PCO₂ were 134±2 mmHg and 17±1 mmHg, respectively (see Fig.4 and 5).

Fig.4 Relationship between tidal volume and PCO₂ in Mouth-to-mouth method and the PV system

For mouth- to-mouth breathing and the PVS, we examined the relation between the tidal volume and PCO₂ included in rescuers' expired air. The vertical axis shows PCO₂ (mmHg); the horizontal axis shows the tidal volume (l). When the tidal volume is 0.5 l, PCO₂ in mouth-to-mouth breathing and PVS are, respectively, 32±1 mmHg, and 15±1 mmHg (N=10). When the tidal volume is 1.0 l, PCO₂ in mouth-to-mouth breathing and PVS is, respectively, 29±1 mmHg, and 19±1 mmHg (N=10).

Fig.5 Relationship between tidal volume and PO₂ in Mouth-to-mouth method and the PV system

In mouth- to-mouth breathing and the PVS, we examined the relation between the tidal volume and PO₂ included in rescuers' expired air. The vertical axis shows PO₂ (mmHg), and the horizontal axis shows the tidal volume (l). When the tidal volume is 0.5 l, PO₂ in mouth-to-mouth breathing and PVS is respectively 115±1 mmHg, and 139±2 mmHg (N=10). When the tidal volume is 1.0 l, PO₂ in mouth-to-mouth breathing and PVS are, respectively, 120±1 mmHg, and 131±2 mmHg (N=10).

III-C. Comparison of effects on arterial blood gas between mouth-to-mouth ventilation and PVS

In beagles, mouth-to-mouth ventilation

decreased PaO₂ to 71±1 mmHg (normal value = 95–100 mmHg) and increased PaCO₂ to 54±2 mmHg (normal value = 40 mmHg), and the pH became 7.27±0.02. Similarly, after artificial respiration using PVS, changes of PaO₂, PaCO₂, and pH were suppressed as mean 84.0±2 mmHg, 46±1 mmHg, and 7.37±0.01, respectively (N=7) (see Fig.6-8).

Fig.6 Effects of ventilation in each method on arterial blood gas (PaCO₂) (beagle,N=7) (mean±SD)

The vertical axis shows PaCO₂ (mmHg); the horizontal axis shows the time (min). After mouth-to-mouth ventilation, PaCO₂ increased to 54±2 mmHg (normal value = 40 mmHg). Then, after artificial respiration using PVS, changes of PaCO₂ were suppressed: 46±1 mmHg (N=7).

Fig.7 Effects of ventilation in each method on arterial blood gas (PaO₂) (beagle,N=7) (mean±SD)

The vertical axis shows PaO₂ (mmHg); the horizontal axis shows the time (min). After mouth-to-mouth ventilation, PaO₂ decreased to 71±1 mmHg (normal value = 95–100 mmHg). Then, after the artificial respiration using PVS, changes of PaO₂ were suppressed: 84±2 mmHg (N=7).

Fig.8 Effects of ventilation in each method on arterial blood gas (pH) (beagle,N=7) (mean±SD)

The vertical axis shows pH, and the horizontal axis shows the time (min). After mouth-to-mouth ventilation, the pH became 7.27±0.02. Then, after the artificial respiration using PVS, the changes of pH were suppressed 7.37±0.01 (N=7).

IV. DISCUSSION

The need for new methods of CPR is not limited to adults with acute coronary syndrome (ACS) and strokes. Many victims of trauma, drowning, electrocution, suffocation, airway obstruction, drug intoxication, and the like may be saved by prompt CPR, and an automated external defibrillator (AED). Prompt bystander CPR is crucial to all resuscitative efforts.^{31, 32} Victims' lifesaving rate out of the hospital vary widely in reports around the United States, in large metropolitan areas such as Chicago and New York, which have low rates of bystander CPR and longer call-to-shock intervals, of less than 5%.^{33, 34}

For mouth-to-mouth ventilation in most adults, the inflation volume would be ca. 10 ml/kg (ca. 700–1000 ml) and should be delivered over 2 s. However, it was not known how much volume was inspired by citizens doing artificial respiration without using a flow meter. Our data shows that both average tidal volumes to the victim for whom the citizens had used mouth-to-mouth resuscitation or PVS were approximately 800 ml (Table 1) and this is consistent with the recommended value of the current guidelines.

Our new PV system reduced PCO₂ in expired gas by 40% (See Table 2, Figs. 4 and 5) and this is reflected in the animal data of the mean PaCO₂ of blood gas analysis in the PVS, which was smaller by 8 mmHg than that in a mouth-to-mouth equivalent gas condition. Mean PaO₂ of blood gas analysis in the PV system was greater by 13 mmHg than that of the mouth-to-mouth equivalent gas condition (See Table 3, Figs. 6–8). These results show that the unfavorable effect of the mouth-to-mouth ventilation exerted on the living body is unexpectedly large and the PVS can suppress this effect. The PVS has also the advantage of alleviating the risk of infectious disease. In addition to this ventilation efficiency of PVS over mouth-to-mouth ventilation, the PV system with artificial dead space will provide effective ventilation with easy operation for untrained bystanders.

Table 2 Composition of expired gases in respective methods (N=10)

TV(L)	Mouth-to-mouth		PV system	
	PO ₂ (mmHg)	PCO ₂ (mmHg)	PO ₂ (mmHg)	PCO ₂ (mmHg)
0.5	115 ± 1	32 ± 1	139 ± 2	15 ± 1
1.0	120 ± 1	29 ± 1	131 ± 2	19 ± 1
1.5	123 ± 1	27 ± 1	128 ± 1	22 ± 1

Table 3 Effects of ventilation in each method on arterial blood gas (beagle, N=7) (mean±SD)

	Room Air	Mouth-to-mouth	PV system
pH	7.39 ± 0.01	7.27 ± 0.02	7.37 ± 0.01
PaCO ₂ (mmHg)	40 ± 0	54 ± 2	46 ± 1
PaO ₂ (mmHg)	91 ± 3	71 ± 1	84 ± 2

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REFERENCES

- ¹Elam JO, Brown ES, John D. Elder. Artificial Respiration by Mouth-to-Mask Method. The New England Journal of Medicine 1954; 250: 18: 749–54.
- ²Peter Safar, Lourdes A. Escarraga, James O. Elam. A Comparison of The Mouth-to-Mouth and Mouth-to-Airway Methods of Artificial Respiration with The Chest-Pressure Arm-Lift Methods. The New England Journal of Medicine 1958; 258: 14: 671–7.
- ³Elam JO, Greene DG, Brown ES, Clements JA. Oxygen and carbon dioxide exchange and energy cost of expired air resuscitation. JAMA 1958; 167: 328–41.
- ⁴Gordon AS, Frye CW, Gittelson L, Sadove MS, Beattie EJ Jr. Mouth-to-Mouth Versus Manual Artificial Respiration for Children and Adults. JAMA 1958; 167: 3: 320–8.
- ⁵Kouwenhoven W, Jude JR, Knickerbocker GG. Closed-chest cardiac massage. 1960; 173: 1064–67.
- ⁶Safar P, Brown TC, Holtey WJ, Wilder RJ. Ventilation and Circulation with Closed-Chest Cardiac Massage in Man. JAMA 1961; 176: 7: 574–6
- ⁷Harris LC, Kirimli B, Safar P. Ventilation-Cardiac Compression Rates and Ratios in Cardiopulmonary Resuscitation. Anesthesiology 1967; 28: 5: 806–13.

- ⁸Eisenberg MS, Bergner L, Hallstrom A. Cardiac Resuscitation in the Community Importance of Rapid Provision and Implications for Program Planning. JAMA 1979; 241: 18: 1905–7.
- ⁹Ornato JP, Hallagan LF, McMahan SB, Peebles EH, Rostafinski AG. Attitudes of BCLS instructors about mouth-to-mouth resuscitation during the AIDS epidemic. Ann Emerg Med 1990; 19: 151–6.
- ¹⁰Brenner BE, Kauffman J. Reluctance of internists and medical nurses to perform mouth-to-mouth resuscitation. Arch Intern Med 1993; 153: 1763–9.
- ¹¹Locke CJ, Berg RA, Sanders AB, Davis MF, Milander MM, Kern KB, Ewy GA. Bystander cardiopulmonary resuscitation: concerns about mouth-to-mouth. Arch Intern Med 1995; 155: 938–43.
- ¹²Brenner B, Stark B, Kauffman J. The reluctance of house staff to perform mouth-to-mouth resuscitation in the inpatient setting: what are the considerations? Resuscitation 1994; 28: 185–93.
- ¹³Brenner B, Kauffman J, Sachter JJ. Comparison of the reluctance of house staff of metropolitan and suburban hospitals to perform mouth-to-mouth resuscitation. Resuscitation 1996; 32: 5–12.
- ¹⁴Michael AD, Forrester JS. Mouth-to-mouth ventilation: the dying art. Am J Emerg Med 1992; 10: 156–61.
- ¹⁵Bierens JJ, Berden HJ. Basic-CPR and AIDS: are volunteer life-savers prepared for a storm? Resuscitation 1996; 32: 185–91.
- ¹⁶Berkowitz LL. Breaking down the barriers: improving physician buy-in of CPR systems. Health Inform 1997; 14: 73–6.
- ¹⁷Airway and Ventilation Management Working Group of the European Resuscitation Council. Guidelines for the basic management of the airway and ventilation during resuscitation. A statement by the European Resuscitation Council. Resuscitation 1996; 31: 187–200
- ¹⁸Baskett P, Nolan J, Parr M. Tidal volumes which

- are perceived to be adequate for resuscitation. *Resuscitation* 1996; 31: 231–4
- ¹⁹Idris AH. Reassessing the need for ventilation during CPR. *Ann Emerg Med* 1996; 27: 569–75
- ²⁰Becker LB, Berg RA, Pepe PE, Idris AH, Aufderheide TP, Barnes TA, et al. A reappraisal of mouth-to-mouth ventilation during bystander-initiated cardiopulmonary resuscitation. *Resuscitation* 1997; 35: 189–201.
- ²¹Doerges V, Sauer C, Ocker H, Wenzel V, Schmucker P. Smaller tidal volumes during cardiopulmonary resuscitation: comparison of adult and paediatric self-inflatable bags with three different ventilatory devices. *Resuscitation* 1999; 43: 31–7
- ²²Wenzel V, Keller C, Idris AH, Dorges V, Lindner KH, Brimacombe JR. Effects of smaller tidal volumes during basic life support ventilation in patients with respiratory arrest: good ventilation, less risk? *Resuscitation* 1999; 43: 25–9
- ²³Standards for cardiopulmonary resuscitation (CPR) and emergency cardiac care (ECC). *JAMA* 1974; 227: 833–68.
- ²⁴Standards and guidelines for cardiopulmonary resuscitation (CPR) and emergency cardiac care (ECC). *JAMA* 1980; 244: 453–509.
- ²⁵Standards and guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiac Care (ECC). National Academy of Sciences-National Research Council. *JAMA* 1986; 255: 2905–89.
- ²⁶American Heart Association. Guidelines for Cardiopulmonary Resuscitation Emergency Cardiac Care. *JAMA* 1992; 268: 2212–302.
- ²⁷Guidelines for advanced life support: a statement by the Advanced Life Support Working Party of the European Resuscitation Council, 1992. *Resuscitation* 1992; 24: 111–21.
- ²⁸Guidelines for the basic and advanced management of the airway and ventilation during resuscitation. *Resuscitation* 1996; 31: 187–230.
- ²⁹Bossaert L. European Resuscitation Council Guidelines for Resuscitation. Amsterdam, Netherlands: Elsevier; 1998.
- ³⁰Guidelines for cardiopulmonary resuscitation and emergency cardiac care. Emergency Cardiac Care Committee and Subcommittees, American Heart Association. *JAMA* 1992; 268: 2171–295.
- ³¹Larsen MP, Eisenberg MS, Cummins RO, Hallstrom AP. Predicting survival from out-of-hospital cardiac arrest: a graphic model. *Ann Emerg Med* 1993; 22: 1652–8.
- ³²Swor RA, Jackson RE, Cynar M, Sadler E, Basse E, Boji B, Rivera-Rivera EJ, Maher A, Grubb W, Jacobson R, et al. Bystander CPR, ventricular fibrillation, and survival in witnessed, unmonitored out-of-hospital cardiac arrest. *Ann Emerg Med* 1995; 25: 780–4.
- ³³Becker LB, Ostrander MP, Barrett J, Kondos GT. Outcome of CPR in a large metropolitan area – where are the survivors? *Ann Emerg Med* 1991; 20: 355–61.
- ³⁴Lombardi G, Gallagher J, Gennis P. Outcome of out-of-hospital cardiac arrest in New York City: the pre-hospital arrest survival evaluation (PHASE) study. *JAMA* 1994; 272: 1573–4.