—Original—

A Study on Points of Respiratory Assist Devices Using in Pre-Hospital Care Respiratory Assist Devices in Pre-Hospital Care

Kenji Fujimoto, Shinnosuke Kitano, Satoshi Harada, Kenji Narikawa, Kensuke Suzuki, Marina Yamada, Mayumi Nakazawa and Satoo Ogawa

Graduate School of Medical and Health Science, Nippon Sport Science University, Kanagawa, Japan

Background: In Japan, increasing the number of ambulance requests, the case with the use of respiratory assistance devices in prehospital care by paramedics is also increasing[1]. When patient experiences respiratory failure, the first responders frequently select a respiratory assist device (RAD) such as Bag Valve Mask (BVM), Jackson Rees (JR), or BVM with Gas Supply Valve® (BVM+GSV). This is based on both evaluation and experience as there is no study indicating which RAD is the best choice at the pre-hospital emergency site. This study clarified the precautions when using BVM, JR, and BVM+GSV in pre-hospital emergency medical care with healthy volunteers.

Methods: Twenty healthy adults were fitted with a RAD while breathing spontaneously, and changes in vital signs and $ETCO_2$ were observed.

Results: The level of $ETCO_2$ became elevated after each RAD was attached. The value was significantly higher in the JR group than in the others.

Conclusions: The study showed that even in the presence of spontaneous breathing, $ETCO_2$ increased markedly with the application of respiratory assist devices that are used in pre-hospital care for conditions such as hypoxemia and ventilatory disturbance. The increase in $ETCO_2$ was particularly significant in the JR group, suggesting the need for caution when selecting JRs for pre-hospital care. As the number of subjects was only 20 for each RAD, studies with a larger sample size are needed.

(J Nippon Med Sch 2023; 90: 173–178)

Key words: respiratory assist device, respiratory failure emergency medical care, emergency ventilation

Introduction

In Japan, respiratory support devices (RAD) used in emergency situations or in ambulances for patients with respiratory failure in Japanese ambulances are Bag Valve Mask (BVM), Jackson Reese (JR), or BVM with Gas Supply Valve® (BVM+GSV). However, although there are reports within medical regarding the effectiveness and issues associated with the use of these RADs, there are no reports regarding prehospital care. Therefore, we conducted a study using healthy volunteers in order to examine the points to note when using these RADs in pre-hospital relief. The patient is in a state of respiratory failure, the emergency medical team administers oxygen, provides ventilatory support, and transports the patient to the hospital. These situations often require the use of respiratory assist devices (RADs), such as Bag Valve Mask (BVM), Jackson Reese (JR), or BVM with Gas Supply Valve® (BVM+GSV). When providing RAD-based ventilatory assistance, emergency medical teams select a RAD based on their own evaluation and experience because there is limited research to inform them of the best choice of RAD in pre-hospital emergency settings[2].

Therefore, the purpose of this study was to identify reasonable precautions when using BVM, JR, and BVM+GSV for pre-hospital emergency medical care by observing the effects in healthy volunteers.

Correspondence to Kenji Fujimoto, The Graduate School of Health and Sport Science of Nippon Sport Science University, 1221–1 Kamoshida-cho, Aoba-ku, Yokohama, Kanagawa 227–0033, Japan
E-mail: ken6544@gmail.com
https://doi.org/10.1272/jnms.JNMS.2023_90-204
Journal Website (https://www.nms.ac.jp/sh/jnms/)

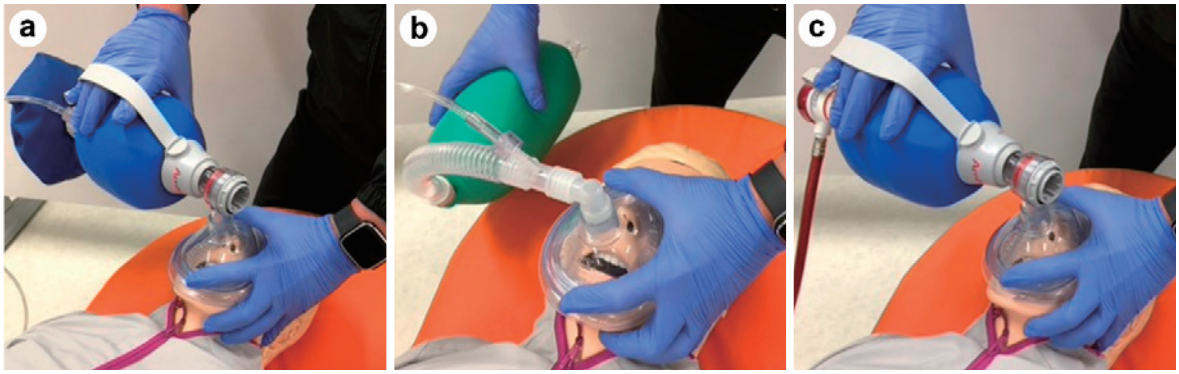

Fig. 1 Three types of respiratory assist devices. a) Bag Valve Mask (BVM) b) Jackson Reese (JR) c) BVM with Gas Supply Valve® (BVM+GSV)

Fig. 2 Stenosis loading model

Materials and Methods

1. Participants

This study recruited 20 healthy male participants with no history of respiratory and cardiovascular disease. The purpose and methods of the study were explained to the participants in advance, and their written consent for participation in this study was obtained. The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki, as reflected in a priori approval by our institution's human research committee (Ethics Committee of Nippon Sport Science University; 021-H175; on December 21, 2021). Prior to testing with RADs, tidal volume (TV) and vital capacity (VC) were measured on a Micro Spirometer® (Spirometer HI-302, NIHON KOHDEN CORPORATION). Blood pressure (BP), pulse rate (PR), and transcutaneous arterial blood oxygen saturation (SpO_2) were also determined for further assessment of respiratory function. Related data collection extended to expiratory terminal carbon dioxide partial pressure ($ETCO_2$), which was methodically assessed and recorded.

2. Procedure

The three types of RADs, namely BVM, JR, and BVM+GSV, were connected to the Koo Face Mask® (face mask, for adults, large, KOOMEDICALJAPAN, Ltd.) (**Fig. 1a～c**). The RAD and face mask were firmly attached with the subject's spontaneous breathing.

The participants were made to lie in the supine position, and the values of PR, respiratory rate (RR), mean blood pressure (MBP), SpO_2, and $ETCO_2$ were noted prior to wearing the RAD, and then through 5 min of wearing, with measurements taken every minute. The minute ventilation volume (MV) was measured 1 min after first donning the RAD. In addition, proper ventilation was ensured using SW-231 SW-L30LPF-01® (air compressor, Fujiwara Sangyo Co.) for the benefit of the participants. The flow rate of the air supplied to the RADs was 10 L/min, and the exhaust valve of the JRs was completely opened to ensure that no pressure was applied to its circuit. The $ETCO_2$ data were displayed and recorded on RESPSENSETMII® (17148050 capnometer, Star Product Limited), whereas data on BP, PR, and SpO_2 were recorded on Lifescope VS® (bedside monitor BSM-3562, NIHON KOHDEN CORPORATION). MV was recorded on a Hello Scale® (manual diagnostic spirometer, IMI Co., Ltd.).

An airway stenosis loading model was simulated because obstructive pulmonary disease is often encountered in pre-hospital emergencies. Thus, a tube for tracheal intubation (5 × 80 mm in diameter) (**Fig. 2**) was connected between the mask and the RAD as respiratory resistance

to reduce 12% of ventilation (**Table 1**). The remaining steps were carried out in the same manner as described above. For minimizing fatigue experienced by the participants from having the equipment attached, the interval between using different RADs was maintained at no less than 15 min.

3. Statistical Tests

The statistical tests performed included the two-way analysis of variance (two-way ANOVA), the non-parametric Friedman test, and post-hoc Bonferroni test (Prism Version 8.4.3, GraphPad). A *p*-value of 0.05 was considered significant. Statistical values are expressed as mean and standard error (SE).

Table 1 Characteristics of participants

Characteristics of subjects		
Age (in years)		22.8±1.1
Weight		67.6±1.9 kg
Height		172±0.1 cm
BMI		23.0±0.6 kg/m^2
Vital capacity		4.8±0.2 L
Respiratory obstruction model		4.2±0.2 L
Minute volume (MV) (Without loading)	BVM	4.8±0.5 L/min
	JR	5.4±0.5 L/min
	BVM+GSV	5.3±0.4 L/min
Minute volume (MV) (With loading)	BVM	4.1±0.4 L/min
	JR	4.7±0.5 L/min
	BVM+GSV	4.2±0.4 L/min

BVM, Bag Valve Mask; BVM+GSV, BVM with Gas Supply Valve®; JR, Jackson Reese

Results

The sample included 20 healthy male participants (age: 22.8 ± 1.1 years, height: 172 ± 0.5 cm, weight: 68.1 ± 1.9 kg, BMI: 23.0 ± 0.6 kg /m^2). The participants had an average VC of 4.8 ± 0.2 L, TV of 1.0 ± 0.1 L, and inspiratory capacity (IC) of 2.9 ± 0.2 L.

There were no significant differences in MV among the three groups, both with and without airway stenosis loading (**Table 1**).

1. Results Without Airway Stenosis Loading (Table 2)

1.1. PR (pulse rate)

There was no significant difference in PR after the participants wore each of the three RADs, nor among the three groups.

1.2. RR (respiration rate)

The RR was decreased by wearing the RADs, which continued from 1 min after donning to 5 min of wearing. However, these changes were not significant. RR values in the participants before wearing the RADs in the BVM, BVM+GSV, and JR groups were 11.9 ± 1.0/min, 12.9 ± 1.1/min, and 13.4 ± 1.0/min, respectively. Moreover, RR values in the participants 5 min after wearing the RADs in the BVM, BVM+GSV, and JR groups were 7.7 ± 0.8/min, 7.7 ± 0.8/min, and 6.8 ± 0.6/min, respectively. No significant after-wearing differences were observed for RR.

1.3. MBP

There was no significant difference in MBP after the participants wore each of the RADs. However, 2 and 3 min after wearing the RAD, MBP was significantly

Table 2 Vital signs and $ETCO_2$ without airway stenosis loading before and after the wearing of respiratory device

		Before	1 min	2 min	3 min	4 min	5 min
PR (/min)	BVM	69.3±2.6	69.3±2.8	69.8±2.7	68.1±2.6	69.6±2.6	70±2.8
	JR	71.4±2.9	70.9±2.9	71.5±2.7	71.7±3.0	72.9±3.2	72.2±3.1
	BVM+GSV	71.0±2.7	69.4±2.8	69.4±2.7	68.5±2.8	69.6±2.7	70.2±2.8
RR (/min)	BVM	11.9±1.0	7.4±0.4	7.2±0.7	7.4±0.6	7.2±0.7	7.7±0.8
	JR	13.4±1.0	7.1±0.6	6.5±0.5	6.1±0.5	6.3±0.5	6.8±0.6
	BVM+GSV	12.9±1.1	8.2±0.7	7.5±0.8	7.6±0.7	7.8±0.7	7.7±0.8
MBP (mmHg)	BVM	83.0±1.9	83.6±1.7	82.5±2.1	82.2±2.1	84.1±1.9	81.1±1.8
	JR	85.3±1.7	85.5±1.8	86.8±1.9 *	85.7±2.2 *	84.9±2.0 *	84.3±1.9 *
	BVM+GSV	82.4±1.9	82.9±1.5	82.2±1.6	82.3±1.7	82.1±1.8	81.3±1.8
SpO_2 (%)	BVM	97.7±0.3	97.6±0.4	97.4±0.4	97.2±0.3	97.1±0.4	97.3±0.3
	JR	98.4±0.3	98.1±0.3	97.5±0.4	97.3±0.4	97.2±0.3	97.4±0.3
	BVM+GSV	98.0±0.3	98.1±0.3	97.9±0.4	97.7±0.4	97.7±0.3	97.7±0.3
$ETCO_2$ (mmHg)	BVM	39.2±0.8	42.7±1.1*	43.6±1.1*	43.5±1.1*	43.3±1.1*	43.7±1.1*
	JR	38.6±0.9	43.7±0.9*	44.7±0.9* *	43.5±0.9* *	45.8±1.1* *	46.0±1.0* *
	BVM+GSV	38.5±0.8	42.7±1.0*	43.0±1.0*	43.0±1.0*	43.0±1.1*	42.9±1.0*

*: Significant difference from before each respiratory assist device P<0.05. BVM, Bag Valve Mask; BVM+GSV, BVM with Gas Supply Valve®; $ETCO_2$, expiratory terminal carbon dioxide partial pressure; JR, Jackson Reese; MBP, mean blood pressure; PR, pulse rate; RR, respiratory rate; SpO_2, percutaneous oxygen saturation

Table 3 Vital signs and $ETCO_2$ with airway stenosis loading before and after the wearing of respiratory device

		Before	1 min	2 min	3 min	4 min	5 min
PR (/min)	BVM	71.2±2.5	67.9±2.6	69.4±2.5	71.4±2.7	70.3±2.8	70.7±2.6
	JR	71.5±2.8	69.7±3.1	69.9±2.9	69.1±2.9	69.9±3.0	70.9±3.0
	BVM+GSV	69.1±2.7	69.0±3.0	70.4±2.9	70.5±2.9	71.2±2.8	70.9±3.1
RR (/min)	BVM	12.9±1.0	7.3±0.6	7.6±0.6	6.9±0.5	6.6±0.5	6.5±0.5
	JR	13.2±0.8	7.1±0.5	7.2±0.6	7.4±0.5	7.3±0.6	7.6±0.7
	BVM+GSV	13.8±1.0	8.5±0.7	7.5±0.5	8.3±0.7	8.2±0.7	7.8±0.7
MBP (mmHg)	BVM	81.9±1.9	82.1±1.6	82.7±1.8	81.7±1.9	81.9±2.2	82.0±2.3
	JR	81.5±2.2	80.6±1.6	81.1±1.0	80.2±1.8	81.5±1.7	81.8±1.6
	BVM+GSV	82.0±1.5	81.6±1.8	82.7±1.9	82.8±1.9	80.8±1.7	81.6±1.9
SpO_2 (%)	BVM	97.9±0.3	97.4±0.3	97.0±0.4	96.9±0.3	96.9±0.3	97.0±0.3
	JR	97.6±0.3	97.6±0.4	97.2±0.4	96.8±0.3	96.9±0.4	96.6±0.4
	BVM+GSV	97.8±0.3	97.5±0.4	96.9±0.4	96.9±0.4	97.0±0.4	97.0±0.4
$ETCO_2$ (mmHg)	BVM	38.4±0.7	43.2±1.0*	43.1±0.9*	43.9±0.9*	43.6±0.9*	44.0±1.0*
	JR	38.8±0.9	43.4±0.9*	44.0±0.9*	44.9±0.9*	47.5±1.8*	46.2±0.8*
	BVM+GSV	38.0±0.7	42.7±0.9*	43.0±1.0*	43.7±1.0*	43.3±1.0*	43.6±1.0*

*: Significant difference from before each respiratory assist device $P<0.05$. BVM, Bag Valve Mask; BVM+GSV, BVM with Gas Supply Valve®; $ETCO_2$, expiratory terminal carbon dioxide partial pressure; JR, Jackson Reese; MBP, mean blood pressure; PR, pulse rate; RR, respiratory rate; SpO_2, percutaneous oxygen saturation

higher among participants in the JR group than in the BVM and BVM+GSV groups. Furthermore, MBP was significantly higher in the JR group than in the BVM+GSV groups 4 min after the participants wore the RAD and significantly higher in the JR group than in the BVM group 5 min after the participants wore the RAD.

1.4. SpO_2

SpO_2 values did not change after the participants wore each of the RADs. There was no significant difference in the SpO_2 values among the three groups either before or after the participants wore each of the RADs.

1.5. $ETCO_2$

$ETCO_2$ values showed a significant increase in all groups 1-5 min after the participants wore the RAD. The participants in the JR group had significantly higher $ETCO_2$ values than those in the BVM+GSV group 2 min after wearing the RAD. Furthermore, $ETCO_2$ was significantly higher in the JR group than in the BVM and BVM +GSV groups 3, 4, and 5 min after the participants wore the RAD.

2. Results with Airway Stenosis Loading (Table 3)

2.1. PR

There was no significant difference in the values of the PR after the participants wore each of the RADs. There was also no significant difference in the PR values among the three groups.

2.2. Respiratory rate

For all RADs, RR decreased from 1 to 5 min. However, the decrease was not significant compared with the RR before the application of airway stenosis load. RR in the BVM group was 12.9 ± 1.0/min before wearing and 6.5 ± 0.5/min 5 min after wearing. In the JR group, it was 13.2 ± 0.8/min before wearing and 7.6 ± 0.7/min 5 min after wearing. In the BVM+GSV group, it was 13.8 ± 1.0/min before wearing and 7.8 ± 0.7/min 5 min after wearing. There was no significant difference in the RR values among the groups after the participants wore the RAD.

The volume of ventilation was reduced by 12% in the airway constriction model.

2.3. MBP

There was no significant difference in MBP among the three groups after the participants wore the RAD. In addition, there was no significant difference in the MBP values among the groups after wearing.

2.4. SpO_2

SpO_2 values did not change after the participants wore each of the RADs. There was no significant difference in SpO_2 values among the three groups before or after the participants wore the RAD.

2.5. $ETCO_2$

The $ETCO_2$ values increased significantly in all groups from 1 to 5 min after the participants wore the RAD. The participants in the JR group had significantly higher $ETCO_2$ values than those in the BVM+GSV group 2 min after wearing the RAD. Furthermore, $ETCO_2$ levels were significantly higher in the JR group than in the BVM and BMV+GSV groups 3, 4, and 5 min after wearing the RADs.

Discussion

In Japan, increasing the number of ambulance requests, the use of respiratory assistance devices in prehospital care by paramedics is slso increasing. For example, the demand for emergency medical care among elderly people is increasing, especially owing to sustained population aging. Elderly people accounted for 62.3% of all ambulance transports and 64.4% of the emergency calls made, owing to sudden illness, in 2020. There are several cases in which elderly people request an ambulance call due to the complications of respiratory failure attributed to worsening cardiac or respiratory disease. In fact, according to the "Current Status of Emergency and Rescue Services," 238,282 and 228,243 patients were transported to emergency hospitals with cardiac or respiratory diseases, respectively, which together, account for 20.5% of all the elderly who called for an ambulance owing to sudden illness[1].

Although many of the protocols for responding to patients are provided by the Japanese Fire and Disaster Management Agency for use at pre-hospital care sites, treatment is selected based on evaluation by the emergency medical team on site. At the emergency site, treatment decisions for patients are based on the severity and urgency standards published in March 2004 by the Emergency Life Saving Technician Association as well as activity standards established by each local fire department[2].

The treatment criteria for respiratory failure indicate a choice of low-flow oxygen, high-flow oxygen, or administration of ventilator support. However, the guidelines do not specify the criteria for the selection of RADs. The selection of RADs for patients with respiratory disorders or respiratory failure owing to respiratory or cardiac disease during pre-hospital care is currently at the discretion of the EMS team[2,3]. In case of suspected respiratory compromise or respiratory failure owing to respiratory or cardiac disease, first responders at the emergency site often select one of the three types of RADs: BVM, JR, or BVM+GSV. There are some reports from medical institutions on the characteristics of these three types of RADs and the points that should be considered when using the devices at the hospital[4–14]. However, there are no reports discussing the merits and demerits of these devices with respect to pre-hospital care[15–17].

In this study, we focused on vital signs and respiratory function when using RADs during pre-hospital care. Our testing showed an increase in $ETCO_2$ after the wearing of each RAD. The mask connected to each RAD has a dead space of approximately 250 mL. In the BVM group, the valve connected to the mask contributes an additional 5 mL, for a total dead-space volume of approximately 255 mL. In the JR group, the circuit (T-piece and snake tube) contributes 100 mL, which along with the mask amounts to 350 mL[18–20]. This dead space in each RAD was thought to be responsible for the significant increase in $ETCO_2$ observed after the wearing of the devices. The increase in $ETCO_2$ was more pronounced in the JR group than that in the other two groups owing to the larger mechanical dead space in the JR device. Furthermore, in the BVM+GSV group, constant positive pressure is exerted in the airway circuit due to the GSV effects on the participant's inspiratory effort. Therefore, it is presumed that the ventilation state is better than that in the JR group. These characteristics were similar after airway stenosis loading.

The present study revealed that $ETCO_2$ significantly increased with the wearing of RADs used for patients with hypoxemia and ventilatory disturbance. The increase in $ETCO_2$ was particularly marked in the JR group, suggesting the need for caution when selecting JR for prehospital care of patients.

This study is the result of wearing RAD attachment and airway stenosis to healthy volunteers, and the study is based on the condition that there is no significant change in vital signs from an ethical point. Under such circumstances, in the absence of airway stenosis, blood pressure increased significantly when $ETCO_2$ increased significantly. On the other hand, in the presence of airway stenosis, there was no significant difference in blood pressure even if $ETCO_2$ increased. It was speculated that the reason for this was that the change in $ETCO_2$ in the latter case was smaller than that in the former case. However, although both variations of these vital signs were statistically significant, the variations were within the normal range.

There are some limitations in the current study. The participants in this study were healthy male volunteers, and the number of the design of the study, it was not possible to use elderly people as subjects, so young healthy subjects were selected. And the number of participants for each RAD was only 20. Therefore, a study with a larger sample size remains warranted to confirm these findings. And our airway stenosis model does not perfectly reflect the actual patient's condition.

In conclusion, this study revealed that the use of these devices increases $ETCO_2$. The increase in $ETCO_2$ was particularly marked in the JR group, suggesting that EMS teams should be careful when using JR for patients with respiratory failure. However, our results must be inter-

preted with caution owing to the limitations described.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of Interest: The Authors declare that there is no conflict of interest.

References

1. Ambulance Service Planning Office of Fire and Disaster Management Agency of Japan. Reiwa 3 nen ban kyukyu kyujo no genjou [Reiwa 3 edition current status of emergency and rescue] [Internet]. Ministry of affairs and communications; 2021. [cited 2022 May 6]. Japanese. Available from: https://www.fdma.go.jp/pressrelease/houdou/items/211224_kyuuki_1.pdf
2. Foundation for Ambulance Service Development. Kyukyuhansou ni okeru jushodo kinkyudo handankijun sakusei iinkai houkokusyo [Report of the committee to develop criteria for judging the severity and urgency of emergency transport] [Internet]. Planning and Research Division of Foundation for Ambulance Service Development; 2004. [cited 2022 May 1]. Japanese. Available from: https://www.mhlw.go.jp/shingi/2009/08/dl/s0825-6c.pdf
3. Yasuda Y, Imai H, Ota S, et al. Kyukyugenba ni okeru jidoushikijinkoukokyuki no shiyou ni kansuru jittaichousa [Survey on the use of automatic ventilators in emergency settings]. Nichirin Kyukyu Ikaishi [J Jpn Soc Emer Med]. 2020;23:36–41. Japanese. doi: 10.11240/jsem.23.36
4. Dörges V, Ocker H, Wenzel V, Sauer C, Schmucker P. Emergency airway management by non-anaesthesia house officers-A comparison of three strategies. Emerg Med J. 2001 Mar;18(2):90–4. doi: 10.1136/emj.18.2.90
5. Brown TC. G. Jackson Rees (Liverpool, England). Paediatr Anaesth. 2012 Feb;22(2):168–9. doi: 10.1111/j.1460-9592.2011.03720.x
6. Fitz-Clarke JR. Effect of tidal volume on gas exchange during rescue ventilation. Respir Physiol Neurobiol. 2020 Feb;273:103335. doi: 10.1016/j.resp.2019.103335
7. Thompson J, Petrie DA, Ackroyd-Stolarz S, Bardua DJ. Out-of-hospital continuous positive airway pressure ventilation versus usual care in acute respiratory failure: A randomized controlled trial. Ann Emerg Med. 2008 Sep;52(3):232–241.e1. doi: 10.1016/j.annemergmed.2008.01.006
8. Schwerin DL, Goldstein S. StatPearls: EMS Prehospital CPAP Devices [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Jan. 2022 Sep 12. Available from: https://www.ncbi.nlm.nih.gov/books/NBK470429
9. Goodacre S, Stevens JW, Pandor A, et al. Prehospital non-invasive ventilation for acute respiratory failure: Systematic review, network meta-analysis, and individual patient data meta-analysis. Acad Emerg Med. 2014 Sep;21(9):960–70. doi: 10.1111/acem.12466
10. Hensel M, Strunden MS, Tank S, Gagelmann N, Wirtz S, Kerner T. Prehospital non-invasive ventilation in acute respiratory failure is justified even if the distance to hospital is short. Am J Emerg Med. 2019 Apr;37(4):651–6. doi: 10.1016/j.ajem.2018.07.001
11. Crossman PF, Bushnell LS, Hedley-Whyte J. Dead space during artificial ventilation: Gas compression and mechanical dead space. J Appl Physiol. 1970 Jan;28(1):94–7. doi: 10.1152/jappl.1970.28.1.94
12. Kawashima K, Furuhashi M, Yamaguchi H, et al. Kinkyusoseihou ni tsuite: Tokuni jinkoukokyuki wo mochiiru houhou [Emergency resuscitation: Especially Artificial Respiration Method]. Iryoukikigaku [Jpn J Med Instrum]. 1962;32(3):177–90. Japanese. doi: 10.4286/ikakikaigakuzassi.32.3_177.
13. Khoury A, Hugonnot S, Cossus J, et al. From mouth-to-mouth to bag-valve-mask ventilation: Evolution and characteristics of actual devices-A review of the literature. Biomed Res Int. 2014 May 27;2014:762053. doi: 10.1155/2014/762053
14. Wayne MA, Delbridge TR, Ornato JP, Swor RA, Blackwell T; Turtle Creek Conference II. Concepts and application of prehospital ventilation. Prehosp Emerg Care. 2001 Jan-Mar;5(1):73–8. doi: 10.1080/10903120190940371
15. Soleimanpour M, Rahmani F, Ala A, et al. Comparison of four techniques on facility of two-hand Bag-valve-mask (BVM) ventilation: E-C, thenar Eminence, thenar Eminence (Dominant hand)-E-C (non-dominant hand) and thenar Eminence (non-dominant hand) - E-C (dominant hand). J Cardiovasc Thorac Res. 2016 Dec 27;8(4):147–51. doi: 10.15171/jcvtr.2016.30
16. Goshi T. Jinkoukokyuki ni masuku wo souchakusi hojokanki wo okonatta 3 syourei [Three cases of ventilator with mask and assisted ventilation]. Purehosupitaru Kea [Prehosp Care]. 2018;31:40–5. Japanese.
17. Nakagoshi H. Tadashii shikizai no tsukaikata inhareta [Correct use of equipment and materials for inhalator]. Purehosupitaru Kea [Prehosp Care]. 2007;20(4):2(1)–2(2). Japanese.
18. Nava S, Navalesi P, Gregoretti C. Interfaces and humidification for noninvasive mechanical ventilation. Respir Care. 2009 Jan;54(1):71–84.
19. Jones HA, Turner SL, Hughes JM. Performance of the large-reservoir oxygen mask (ventimask). Lancet. 1984 Jun 30;1(8392):1427–31. doi: 10.1016/S0140-6736(84)91930-5
20. Clarke AD. Potential dead space in an anaesthetic mask and connectors. Br J Anaesth. 1958;30:176–81. doi: 10.1093/bja/30.4.176

(Received, October 25, 2022)

(Accepted, November 15, 2022)

(J-STAGE Advance Publication, February 21, 2023)