

Original Article

Airway obstruction time and outcomes in patients with foreign body airway obstruction: multicenter observational choking investigation

Yutaka Igarashi,¹ Tatsuya Norii,^{2,3} Kim Sung-Ho,⁴ Shimpei Nagata,⁵ Yudai Yoshino,^{1,6} Takuro Hamaguchi,¹ Riko Nagaosa,¹ Shunichiro Nakao,³ Takashi Tagami,^{1,6} and Shoji Yokobori¹

¹Department of Emergency and Critical Care Medicine, Nippon Medical School, Tokyo, Japan, ²Department of Emergency Medicine, University of New Mexico, Albuquerque, New Mexico, USA, ³Department of Traumatology and Acute Critical Medicine, Osaka University Graduate School of Medicine, Osaka, Japan, ⁴Senshu Trauma and Critical Care Center, Rinku General Medical Center, Osaka, Japan, ⁵Department of Clinical Epidemiology and Health Economics, The University of Tokyo, Tokyo, Japan, and ⁶Department of Emergency and Critical Care Medicine, Nippon Medical School Musashi Kosugi Hospital, Kanagawa, Japan

Aim: Foreign body airway obstruction (FBAO) is a major public health concern worldwide for infants and older adults. This study determines the association between airway obstruction time and neurological outcomes to plan an effective response for patients with FBAO.

Methods: This multicenter retrospective observational study was carried out among patients with life-threatening FBAO in Japan over a period of 4 years. The duration of airway obstruction was calculated from the time of the accident to the time of foreign body removal. The study examined the relationship between airway obstruction time and outcome. The primary outcome was vegetative state or death at hospital discharge.

Results: Among 119 patients, 68 were in the category of vegetative state or death. Logistic regression analysis showed that longer airway obstruction time (adjusted odds ratio 1.04; 95% confidence interval 1.01–1.07) was associated with vegetative state or death. When the cut-off value was set at 10, the sensitivity was 0.88, the specificity 0.47, with the area under the curve 0.69. Using the other cut-off value of 4 min, the negative predictive value was 1.00.

Conclusion: Longer airway obstruction time was associated with vegetative state or death for patients with FBAO. The incidence of vegetative state or death increased when the airway obstruction time exceeded 10 min. Meanwhile, 4 min or less may be set as a target time for foreign body removal in order to prevent vegetative state or death and plan an effective response.

Key words: Airway management, cardiac arrest, foreign body airway obstruction, resuscitation, vegetative state

INTRODUCTION

FOREIGN BODY AIRWAY obstruction (FBAO) is a major public health concern worldwide. It is a life-

threatening condition for individuals of all ages, especially infants and older adults. Foreign body airway obstruction was the third-highest cause of accidental deaths in the United States in 2018 and the second highest cause in Japan in 2019; Japan experienced 8,000 deaths due to FBAO, which was approximately twice as many as in the United States.^{1,2}

Removing the foreign body immediately is crucial to prevent cardiac arrest due to hypoxia. A previous observational study reported better neurological outcomes resulting from bystander support in the removal of the FBAO.³ The guidelines strongly suggest providing first aid through a back blow and abdominal thrust for basic life support.^{4,5} However, no study has thus far investigated the relationship between airway obstruction time and neurological outcomes

Corresponding: Yutaka Igarashi, MD, PhD, Department of Emergency and Critical Care Medicine, Nippon Medical School, 1-1-5 Sendagi, Bunkyo, Tokyo 113-8603, Japan. E-mail: igarashiy@nms.ac.jp

Received 15 Nov, 2021; accepted 18 Feb, 2022

Funding information

This study was supported by funding from the Japanese Association for Acute Medicine and the Foundation for Ambulance Service Development.

for patients with FBAO. This study aimed to determine the relationship between airway obstruction time and outcomes to plan a more effective response in the case of the occurrence of FBAO.

METHODS

Study design

THIS STUDY USED data from a retrospective observational study, the Multicenter Observational Choking Investigation (MOCHI-retro) in Japan, which was created as part of the preparatory work for the ongoing nationwide prospective study.^{6,7} Eight hospitals, two university hospitals, and six general hospitals comparable to level 1 or 2 trauma centers in the United States, participated in this study. Ethics committee approval was obtained at all sites, including at the representative site (Nippon Medical School Hospital, 29-02-901).

Inclusion criteria

In the MOCHI-retro registry, we included all adult patients who were transferred to the hospital from January 1, 2015, to February 28, 2019, who had life-threatening mechanical airway obstruction caused by foreign bodies in the airway. We excluded patients with aspiration of sputum or gastric contents, loss of consciousness before FBAO, neck tumor that caused suffocation, unwitnessed cardiac arrest, or those who drowned. In this study, we excluded patients who did

not record the time completely and were not classified as MOCHI type 1 (upper airway obstruction), to accurately diagnose FBAO and target a more homogenous group.⁸

Data collection

Data were extracted from electronic health records. The duration of airway obstruction was calculated from the time of the accident to the time of foreign body removal. We divided the duration of airway obstruction into four groups: ≤ 5 min, 6–10 min, 11–25 min, and >25 min, by referring to existing studies of drowning time and outcomes.⁹ We also collected data on patients who suffered out-of-hospital cardiac arrest (OHCA).

Outcomes

Cerebral function was measured based on the cerebral performance category (CPC) score.¹⁰ Many older adults who were dependent in their daily life activities, which is equivalent to CPC 3 before the occurrence of FBAO, were included in the previous study.³ Even if these patients recover completely, they continue to remain in CPC 3. Generally, CPC 3, 4, or 5 are considered unfavorable outcomes; however, following the study on cardiac arrest, the primary outcome was defined by vegetative state or death (CPC 4 or 5). In this study, the primary outcome was also defined by vegetative state or death at hospital discharge.¹¹ The secondary outcome was the occurrence of OHCA.

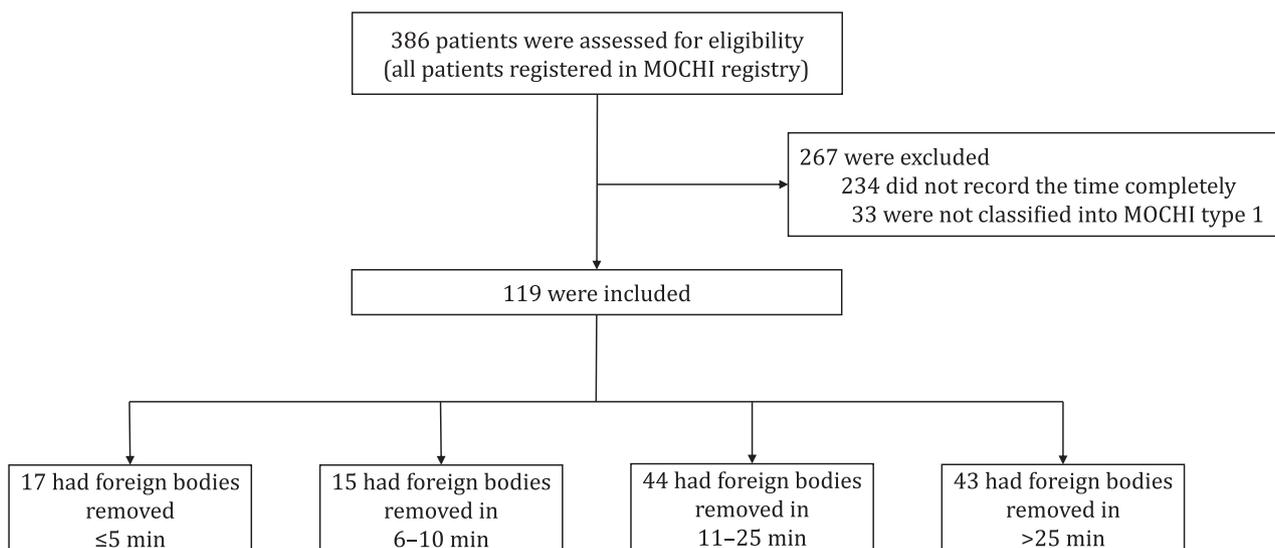


Fig. 1. Flowchart showing recruitment of 119 Japanese patients with foreign body airway obstruction into the Multicenter Observational Choking Investigation (MOCHI) study.

Statistical analysis

Continuous variables were presented as median and interquartile ranges and analyzed using the Mann–Whitney *U*-test. Categorical variables were analyzed using the χ^2 -test or Fisher's exact test as appropriate. *P* values less than 0.05 were considered statistically significant. To adjust for confounding factors, all factors were compared by outcomes.

The logistic regression analysis was performed with variables, and those with *P* value less than 0.1. A receiver operating characteristic (ROC) curve were drawn, and the cut-off value was set by Youden's index, which considers the point where sensitivity and specificity are maximized as its cut-off value. The other target time for foreign object removal from the airway was set at a threshold to achieve the highest negative predictive value to prevent a vegetative state or death.

Table 1. Demographics of 119 Japanese patients with foreign body airway obstruction (FBAO), grouped according to time taken to foreign body removal

	≤5 min (n = 17)	6–10 min (n = 15)	11–25 min (n = 44)	>25 min (n = 43)
Age (years)	81 (73–85)	77 (72–87)	83 (76–86)	80 (73–88)
Sex (male)	9 (53)	8 (53)	22 (50)	20 (47)
Comorbidity				
Cerebral infarction	3 (18)	5 (33)	6 (14)	12 (28)
Dementia	5 (29)	5 (33)	15 (34)	13 (30)
Schizophrenia	0 (0)	2 (13)	2 (5)	2 (5)
Depression	1 (6)	2 (13)	5 (11)	3 (7)
Parkinson's disease	2 (12)	1 (7)	2 (5)	0 (0)
Aspiration	1 (6)	1 (7)	0 (0)	1 (2)
Diabetes	2 (12)	4 (27)	8 (18)	5 (12)
Hypertension	6 (35)	4 (27)	15 (34)	17 (40)
Coronary artery disease	0 (0)	0 (0)	5 (11)	4 (9)
Activity of daily living				
Independent	7 (42)	4 (27)	22 (50)	13 (30)
Needs some assistance	5 (29)	7 (47)	14 (32)	19 (44)
Bedridden	4 (24)	0 (0)	3 (7)	5 (12)
Accident location				
Home	6 (35)	8 (53)	23 (52)	24 (56)
Group home	0 (0)	2 (13)	7 (16)	5 (12)
Nursing home	7 (41)	2 (13)	4 (9)	7 (16)
Restaurant	1 (6)	0 (0)	5 (11)	4 (9)
Obstructed objects				
Rice	0 (0)	1 (7)	5 (11)	10 (23)
Rice cake (mochi)	2 (12)	6 (40)	8 (18)	7 (16)
Bread	3 (18)	3 (20)	8 (18)	3 (7)
Meat	3 (18)	3 (20)	5 (11)	10 (23)
Bystander removal attempt	15 (88)	4 (27)	13 (30)	18 (42)
Bystander removal success	13 (76)	3 (20)	2 (5)	0 (0)
Opening maneuver				
Abdominal thrust	0 (0)	1 (7)	2 (5)	3 (7)
Back blow	7 (41)	2 (13)	7 (16)	6 (14)
Chest thrust/compression	1 (6)	1 (7)	5 (11)	13 (30)
Removal with hands	4 (24)	0 (0)	4 (9)	7 (16)
Magill forceps	0 (0)	6 (40)	11 (25)	12 (28)
Suction	5 (30)	3 (20)	14 (32)	18 (42)
Vacuum cleaner	0 (0)	1 (7)	0 (0)	1 (2)

Data are shown as *n* (%) or median (range). Categories of activities of daily living before FBAO: independent, almost equivalent to cerebral performance category (CPC) 1; needs some assistance, equivalent to CPC 2; and bedridden, equivalent to CPC 3.

Furthermore, in order to compare with hypoxia due to drowning, the group with an airway obstruction time of 5 min or less was considered the reference to which other groups were compared.⁹ We used R version 4.0.4 (The R Foundation for Statistical Computing, Vienna, Austria) for the statistical analysis.

RESULTS

OF THE 386 patients in the MOCHI registry, 119 were included in this study (Fig. 1). The median (interquartile range) age of the patients was 81 (73–86) years. Half of the patients were women. The mean airway obstruction time was 17.0 (10.0–35.8) minutes. For 17 (14%) patients, foreign bodies were removed in 5 min or less, those of 15 (13%) patients in 6–10 min, 44 (37%) patients in 11–25 min, and 43 (36%) patients in more than 25 min (Table 1). There were no missing values in airway obstruction time or outcomes.

One (6%) patient who had foreign bodies removed in 5 min or less was in the vegetative state or death category, whereas 7 (47%), 30 (68%), and 30 (70%) patients had foreign bodies removed in 6–10 min, 11–25 min, and >25 min were in the vegetative state or death category, respectively (Fig. 2). Patients who had foreign bodies removed in 5 min or less had significantly fewer instances of vegetative state

or death than those for whom foreign bodies were removed in 6–10 min (6% vs 47%, $P = 0.008$), 11–25 min (6% vs 69%, $P < 0.001$), or more than 25 min (6% vs 70%, $P < 0.001$).

All variables were compared by outcomes; with airway obstruction time (min), depression, meat as the obstructive object, and back blow as the opening maneuver were the significant variables (Table S1). When logistic regression analysis was undertaken using these variables, airway obstruction time (min), meat, and back blow were significant. Longer airway obstruction time (min) was associated with a vegetative state or death after adjustment (adjusted odds ratio 1.04; 95% confidence interval [CI], 1.01–1.07).

When the cut-off value was set at 10 min from the ROC curve, the sensitivity was 0.88, the specificity 0.47, the positive predictive value 0.69, and the negative predictive value 0.75 with ROC of 0.69 (95% CI, 0.59–0.80) (Fig. 3). Using the cut-off value of 4 min, the negative predictive value was 1.00 (Table S2).

In total, 69 (58%) patients suffered OHCA. Among them, one (6%) had foreign bodies removed in 5 min or less, eight (53%) had them removed in 6–10 min, 31 (70%) had them removed in 11–25 min, and 29 (67%) had them removed in more than 25 min. Additionally, of the 69 patients, 61 (88%) experienced return of spontaneous circulation and 66

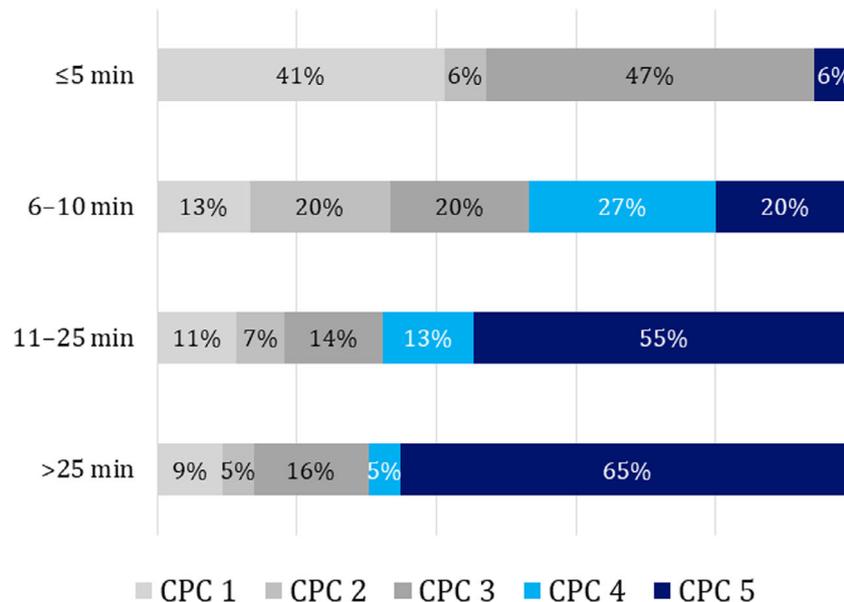


Fig. 2. Relationship between airway obstruction time and neurological outcome (measured by cerebral performance category [CPC]) in 119 Japanese patients with foreign body airway obstruction. CPC 1, good cerebral performance, conscious, alert, able to work and lead a normal life; CPC 2, moderate cerebral disability, conscious, sufficient cerebral function for part-time work in sheltered environment; CPC 3, severe cerebral disability, conscious, dependent on others; CPC 4, coma, vegetative state, not conscious; CPC 5, death, certified brain dead or dead by traditional criteria.⁸

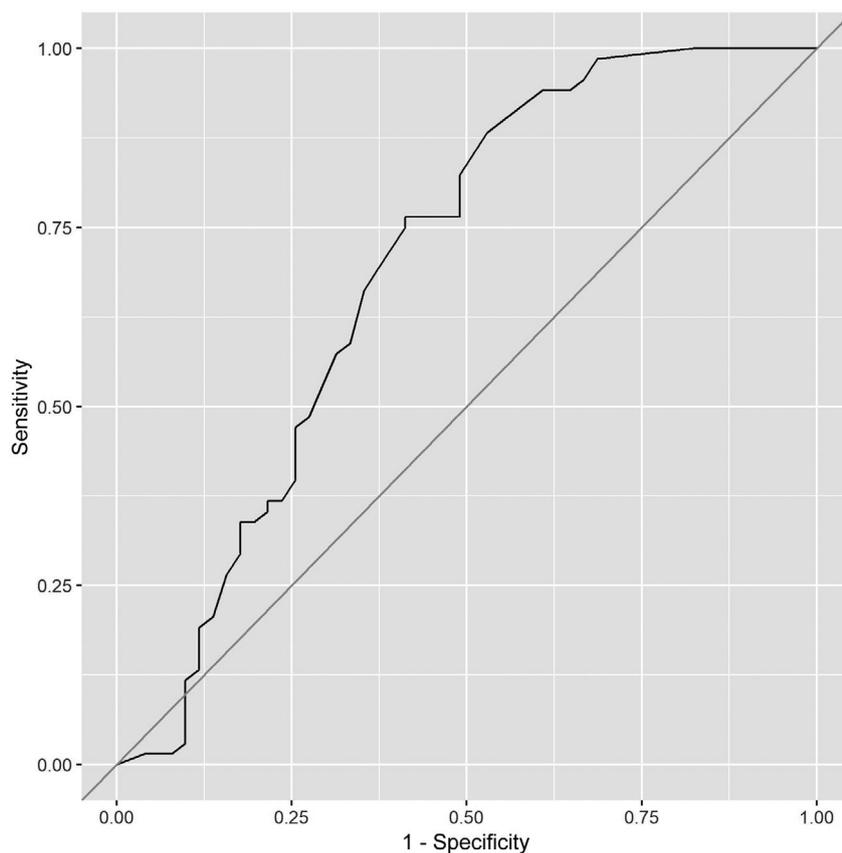


Fig. 3. Receiver operating characteristic curve showing the time to removal of airway obstruction. When the cut-off value was set at 10 min, the sensitivity was 0.88, the specificity 0.47, the positive predictive value 0.69, and the negative predictive value 0.75. Area under curve was 0.69 (95% confidence interval, 0.59–0.80).

(96%) patients died or experienced a vegetative state. Ventilation was carried out at the scene with extraglottic airway devices in 29 patients (42%) and with endotracheal intubation in 23 patients (33%) (Table 2).

DISCUSSION

THIS IS THE first study to reveal the relationship between airway obstruction time and outcomes in patients with FBAO. After adjusting for potential confounding factors, longer airway obstruction time remained significantly associated with vegetative state or death.

To predict vegetative state or death, a cut-off value of 10 min may be acceptable; however, it is not a sufficient target time for foreign body removal to be done in order to prevent vegetative state or death. Four minutes or less may be set as a target time for foreign body removal to plan an effective response because none of the patients in this study who underwent foreign body removal within this

time suffered from a vegetative state or died. In Japan, the average time taken between the emergency call to arrival at the scene is 8.7 min.¹² Therefore, it is unlikely that emergency medical technicians can remove a foreign body within 4 min. Despite the importance of bystander foreign body removal, only 42% of patients had removal attempts undertaken by bystanders in this study. Thus, further awareness of first aid practices is recommended among families living with older adults as well as staff in health-care facilities. Moreover, when rescuers are unfamiliar with administering first aid, oral instruction by dispatchers is important. In the past, verbal guidance of first aid for cardiopulmonary arrest patients has improved survival rates and neurological outcomes.^{13–16} With the widespread use of smartphones, the use of video calls for verbal instruction has improved the quality of cardiopulmonary resuscitation (CPR) with information regarding the appropriate depth of chest compressions and hand positioning being made more accessible.¹⁷

Table 2. Demographics and neurological outcomes of patients who suffered cardiac arrest caused by foreign body airway obstruction (FBAO), grouped according to time taken to foreign body removal

	≤5 min (n = 1)	6–10 min (n = 8)	11–25 min (n = 31)	>25 min (n = 29)
Bystander CPR	0 (0)	3 (38)	17 (55)	15 (52)
Initial rhythm				
Asystole	0 (0)	3 (38)	12 (39)	21 (72)
PEA	0 (0)	4 (50)	16 (52)	6 (21)
VF/pulseless VT	0 (0)	0 (0)	0 (0)	0 (0)
Airway management				
Extraglottic airway device	0 (0)	3 (38)	12 (39)	14 (48)
Endotracheal intubation	0 (0)	3 (38)	14 (45)	6 (21)
Return of spontaneous resuscitation	1 (100)	7 (88)	28 (90)	25 (86)
Neurological outcomes				
CPC 1	0 (0)	0 (0)	0 (0)	0 (0)
CPC 2	0 (0)	1 (12)	0 (0)	0 (0)
CPC 3	0 (0)	0 (0)	2 (7)	0 (0)
CPC 4	0 (0)	4 (50)	6 (19)	2 (7)
CPC 5	1 (100)	3 (38)	23 (74)	27 (93)

Data are shown as *n* (%) or median (range). CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; PEA, pulseless electrical activity; VF, ventricular fibrillation; VT, ventricular tachycardia.

Drowning has a similar pathophysiology as FBAO in terms of hypoxia. In drowning, which also causes hypoxia, a submersion time of 5 min or less leads to a 10% rate of death or severe neurologic impairments. In cases of drowning, the proportion of death or severe neurological impairments is 56% for a submersion time of 6–10 min, 88% for 11–25 min, and almost 100% for more than 25 min.^{18–21} Thus, FBAO is similar to drowning in that the outcomes differ greatly after 6 min. Almost all patients who had drowned for more than 25 min had unfavorable outcomes; however, some patients had favorable outcomes even though foreign body removal took a long time. A possible explanation is that submersion is a condition in which a person's airway is below the surface of the liquid, whereas FBAO involves complete (no air flow) or partial (low air flow) obstruction. Depending on whether the airway obstruction was complete or partial, outcomes may differ even with the same obstruction time. No air flow

and low air flow may change due to the movement of foreign bodies.

Securing airway and ventilation are crucial to preventing hypoxia caused by FBAO. Extraglottic airway devices were used to secure the airway in 42% of patients with OHCA in the field, which is more than the 33% who were intubated. The guidelines state that trained rescuers may consider using extraglottic airway devices during CPR because these have advantages over tracheal intubation in that they are relatively easy to perform and can be used in various positions.⁴ However, as it is not necessary to directly examine the glottis, there is a possibility that a foreign body may be pushed in. Therefore, securing the airway with extraglottic devices is contraindicated when FBAO is suspected.

This study has some limitations. Many cases had missing values and were excluded due to the retrospective nature of the study, and in many cases, the time was not recorded; in addition, the time was recorded using personal interviews, which may have led to errors due to bias. Data on methods and body position for foreign body removal are also important;^{22,23} however, these were not sufficiently collected. A larger prospective study is required, and the planned Japanese MOCHI study should prospectively collect data on patients with FBAO to improve knowledge and understanding of epidemiology and treatment.⁷ Currently, there is some controversy regarding the setting of the outcome. Foreign body airway obstruction is more common among older adults who are already functionally impaired. In many studies of cardiac arrest, neurologically favorable outcomes were defined as CPC 1 or 2. However, only 42% of them performed independent activities of daily living before FBAO, and full recovery did not result in good recovery (CPC 1) or moderate disability (CPC 2). Therefore, CPC 4 or 5 were used as outcomes in this study.

CONCLUSIONS

LONGER AIRWAY OBSTRUCTION time was associated with vegetative state or death for patients with FBAO. The incidence of vegetative state or death increased when the airway obstruction time exceeded 10 min. Four minutes or less could be set as a target time for foreign body removal in order to prevent vegetative state or death and plan an effective response.

DISCLOSURE

APPROVAL OF THE research protocol: Ethics committee approval was obtained at all sites, including the representative site (Nippon Medical School Hospital, 29-02-901).

Informed Consent: Informed consent was waived because of the retrospective nature of the study and because the analysis involved anonymous clinical data. Opt-outs were posted, and patients who did not wish to cooperate in the study were guaranteed the right to noncooperation.

Registry and registration no. of the study/trial: N/A.

Animal studies: N/A.

Conflict of interest: None.

ACKNOWLEDGMENTS

THE AUTHORS THANK the following study hospitals and research personnel for their assistance with this project: Dr. Tatsuho Kobayashi (Aidu Chuo Hospital), Dr. Naoto Yoshida (Ashikaga Red Cross Hospital), Dr. Atsushi Koyama (Iwaki City Medical Center), Dr. Yasuaki Mizushima (Osaka Police Hospital), Dr. Tetsuya Hirota, and Dr. Park Changhwi (Tane General Hospital), Dr. Yozo Kashiwa (Osaka Habikino Medical Center), Professor Takeshi Shimazu (Osaka University Graduate School of Medicine), and all personnel at participating hospitals who contributed toward the study data.

REFERENCES

- National Safety Council. Injury Facts in 2018. [cited 1 Jan 2021]. Available from: <https://injuryfacts.nsc.org/home-and-community/home-and-community-overview/introduction/>.
- Ministry of Health, Labour and Welfare. Current Population Survey in 2019. [cited 24 Dec 2020]. Available from: <https://www.mhlw.go.jp/toukei/saikin/hw/jinkou/geppo/nengai19/dl/gaikyouR1.pdf>.
- Igarashi Y, Yokobori S, Yoshino Y, Masuno T, Miyauchi M, Yokota H. Prehospital removal improves neurological outcomes in elderly patient with foreign body airway obstruction. *Am. J. Emerg. Med.* 2017; 35: 1396–9.
- Panchal AR, Bartos JA, Cabanas JG *et al.* Part 3: adult basic and advanced life support: 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation* 2020; 142 (16_suppl_2): S366–468.
- Olasveengen TM, Mancini ME, Perkins GD *et al.* Adult basic life support: international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. *Resuscitation* 2020; 156: A35–79.
- Norii T, Igarashi Y, Braude D, Sklar DP. Airway foreign body removal by a home vacuum cleaner: Findings of a multi-center registry in Japan. *Resuscitation* 2021; 162: 99–101.
- Norii T, Igarashi Y, Sung-Ho K *et al.* Protocol for a nationwide prospective, observational cohort study of foreign-body airway obstruction in Japan: the MOCHI registry. *BMJ Open* 2020; 10: e039689.
- Igarashi Y, Norii T, Sung-Ho K *et al.* Life-threatening foreign body airway obstruction: Case series and new classification proposal. *Am. J. Emerg. Med.* 2019; 37: 2177–81.
- Szpilman D, Bierens JJ, Handley AJ, Orłowski JP. Drowning. *N. Engl. J. Med.* 2012; 366: 2102–10.
- Cummins RO, Chamberlain DA, Abramson NS *et al.* Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: the Utstein Style. A statement for health professionals from a task force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, and the Australian Resuscitation Council. *Circulation* 1991; 84: 960–75.
- Sandroni C, Cavallaro F, Callaway CW *et al.* Predictors of poor neurological outcome in adult comatose survivors of cardiac arrest: a systematic review and meta-analysis. Part 1: patients not treated with therapeutic hypothermia. *Resuscitation* 2013; 84: 1310–23.
- Fire and Disaster Management Agency. Status of emergency medical services. 2019. [cited 30 Jan 2021]. Available from: <https://www.fdma.go.jp/publication/hakusho/r1/chapter2/section5/47778.html>.
- Rea TD, Eisenberg MS, Culley LL, Becker L. Dispatcher-assisted cardiopulmonary resuscitation and survival in cardiac arrest. *Circulation* 2001; 104: 2513–6.
- Song KJ, Shin SD, Park CB *et al.* Dispatcher-assisted bystander cardiopulmonary resuscitation in a metropolitan city: a before-after population-based study. *Resuscitation* 2014; 85: 34–41.
- Bohm K, Vaillancourt C, Charette ML, Dunford J, Castren M. In patients with out-of-hospital cardiac arrest, does the provision of dispatch cardiopulmonary resuscitation instructions as opposed to no instructions improve outcome: a systematic review of the literature. *Resuscitation* 2011; 82: 1490–5.
- Tanaka Y, Taniguchi J, Wato Y, Yoshida Y, Inaba H. The continuous quality improvement project for telephone-assisted instruction of cardiopulmonary resuscitation increased the incidence of bystander CPR and improved the outcomes of out-of-hospital cardiac arrests. *Resuscitation* 2012; 83: 1235–41.
- Bolle SR, Scholl J, Gilbert M. Can video mobile phones improve CPR quality when used for dispatcher assistance during simulated cardiac arrest? *Acta Anaesthesiol. Scand.* 2009; 53: 116–20.
- Tipton MJ, Golden FS. A proposed decision-making guide for the search, rescue and resuscitation of submersion (head under) victims based on expert opinion. *Resuscitation* 2011; 82: 819–24.
- Szpilman D. Near-drowning and drowning classification: a proposal to stratify mortality based on the analysis of 1,831 cases. *Chest* 1997; 112: 660–5.

- 20 Szpilman D, Soares M. In-water resuscitation--is it worthwhile? *Resuscitation* 2004; 63: 25–31.
- 21 Manolios N, Mackie I. Drowning and near-drowning on Australian beaches patrolled by life-savers: a 10-year study, 1973–1983. *Med. J. Aust.* 1988; 148: 165–7 170–161.
- 22 Luczak A. Head-down self-treatment of choking. *Resuscitation* 2016; 103: e13.
- 23 Luczak A. Effect of body position on relieve of foreign body from the airway. *AIMS Public Health.* 2019; 6: 154–9.

SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1. Comparison of variables between cerebral performance category (CPC) 1–3 and CPC 4–5

Table S2. List of sensitivity, 1 – specificity, positive predictive value, and negative predictive value for each cut-off value