Submitted: 28 November, 2022 Accepted: 24 February, 2023 Published: 08 September, 2023 DOI:10.22514/sv.2023.074

Open Access
Signa Vitae

REVIEW

Emergency airway management with the gum elastic bougie outside of the operating room: a narrative review

Yuko Ono[1,2,*], Kazuaki Shinohara[2], Jiro Shimada[3], Shigeaki Inoue[1], Joji Kotani[1]

[1]Department of Disaster and Emergency Medicine, Graduate School of Medicine, Kobe University, 650-0017 Kobe, Japan
[2]Department of Anesthesiology, Ohta General Hospital Foundation, Ohta Nishinouchi Hospital, 963-8558 Koriyama, Japan
[3]Futaba Medical Center, Fukushima Medical University, 960-1295 Fukushima, Japan

***Correspondence**
windmill@people.kobe-u.ac.jp
(Yuko Ono)

Abstract

The ongoing coronavirus 2019 (COVID-19) pandemic has increased the need for healthcare professionals to perform emergency endotracheal intubation (ETI) in patients with COVID-19-related respiratory failure outside of the operating room. Difficult airways and severe airway-related adverse events occur much more frequently in such settings due to limited time and resources as well as the patient's reduced physiological reserve. The gum elastic bougie (GEB) intubation tube is an inexpensive, simple, and readily transportable aid to intubation, but its effectiveness in emergency airway management has not been comprehensively evaluated in recent years. Here, we performed a literature review and have updated the available evidence on the utility of GEB in emergency airway management. After a systematic MEDLINE search, we identified 36 relevant reports that compared GEB with alternative airway management approaches in a variety of real-world and simulated settings. In most studies, GEB increased the first-pass ETI success rate and decreased the force applied on the tongue and incisors during laryngoscopy. GEB also increased the speed, safety, and reliability of emergency cricothyrotomy. Conflicting results were obtained in studies examining GEB use for ETI during cardiopulmonary resuscitation, and other special circumstances such as selective lung ventilation, the presence of vomitus, and the use of personal protective equipment. These results suggest that GEB use could be expanded beyond difficult airways and rescue after failed ETI attempts, but further studies will be necessary to determine the utility of GEB under special conditions. Because fatal airway-related adverse events can in part be attributed to limited accessibility of proper airway management equipment, devices such as GEB may increase successful outcomes, especially under the overwhelmingly challenging conditions imposed by the COVID-19 pandemic.

Keywords

Gum elastic bougie; Safety redundancy; Airway-related adverse events; Difficult airway management

1. Introduction

The ongoing coronavirus 2019 (COVID-19) pandemic, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has dramatically increased the need for healthcare professionals to perform emergency endotracheal intubation (ETI) in patients with respiratory failure outside of the operating room. Difficult airways and severe airway-related adverse events occur much more frequently in such settings due to a variety of factors, including limited time and resources, noisy and chaotic environments not conducive to successful ETI, and the reduced physiological reserve of the patients. For example, the rate of difficult ETIs ranges from 10.0% to 21.0% in intensive care units (ICUs) [1–5]; from 6.1% to 23.5% in emergency departments (EDs) [3, 6–10], from 6.0% to 17.7% in prehospital settings [11–14], and from 0.5% to 8.5% in planned anesthesia settings [14–19]. Life-threatening ETI-related complications, such as hypoxia, esophageal intubation, and aspiration, are more likely to occur outside of the operating room [20–22]; indeed, the incidence of death and brain damage is about 60-fold higher when major airway events occur in the ED or ICU than in the operative room [20–22].

Fatal airway-related adverse events can in part be attributed to limited access to proper difficult airway management (DAM) equipment resources [21–25]. There is thus an increasing need for such resources to be in place in every ED and ICU, especially in the era of COVID-19. The gum elastic bougie (GEB) tube is a valuable intubation aid that is also inexpensive, simple to use, and easy to transport. Sir

Robert R. Macintosh first described the use of GEB as an adjunct for difficult ETI in 1949 [26], and it continues to be useful for emergency airway management 70 years later. However, the effectiveness of GEB under emergency airway management conditions outside of the operating room has not been comprehensively evaluated. In the present review, we performed a literature search to update and reappraise the utility of GEB in a variety of emergency airway management settings.

2. Materials and methods

The literature search strategy was determined a priori by the survey team, which comprised emergency physicians (YO, SI and JK), an anesthesiologist (KS), and a librarian (MJ, see Acknowledgments). In March 2022, we performed a MEDLINE database search for articles without language or publication date restrictions using the following search terms: tube introducer AND emergency airway management, gum elastic bougie AND emergency airway management, bougie AND emergency airway management, gum elastic bougie AND emergency endotracheal intubation, tube introducer AND emergency endotracheal intubation, and bougie AND emergency endotracheal intubation. PubMed® (https://pubmed.ncbi.nlm.nih.gov/) was used to search the MEDLINE database. We also performed cross-referencing of the articles included in this review. A total of 532 articles were obtained from this screen (Table 1). We then excluded (1) redundant articles; (2) articles other than original research, such as case reports, comments, editorials, and reviews; (3) original articles that lacked a control group or clearly defined outcome measures; and (4) articles that had been retracted after publication.

TABLE 1. Emergency airway management and the gum elastic bougie: MEDLINE search findings.

Number	Search terms	Hit number
#1	gum elastic bougie AND emergency endotracheal intubation	60
#2	tube introducer AND emergency endotracheal intubation	46
#3	bougie AND emergency endotracheal intubation	147
#4	tube introducer AND emergency airway management	48
#5	gum elastic bougie AND emergency airway management	63
#6	bougie AND emergency airway management	168

A total of 498 articles were excluded and 2 articles were added after cross-referencing, resulting in a final selection of 36 reports for inclusion in this review (Fig. 1) [27–62].

The following data were extracted: study design, country, sample number, setting or simulation model, subject number, exposure (intervention) group, control group, primary outcome(s), and main finding(s). The Oxford Centre for Evidence-Based Medicine Level of Evidence was also scored for each study [63]. We referred to the Scale for the Assessment of Narrative Review Articles (SANRA) [64] and Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) Extension for Scoping Reviews checklist [65] when conducting this literature review.

3. Results

Supplementary Table 1 provides a summary of these studies and outcomes. We investigated the role of GEB with respect to the following nine categories: first-pass ETI success; forces on oral structures during laryngoscopy; DAM; combination with videolaryngoscopy; ETI during cardiopulmonary resuscitation (CPR); emergency cricothyrotomy; COVID-19 patients; pediatric patients; and other special circumstances. All of the articles were written in English. We also reviewed the availability of GEB outside of the operating room, such as in ICUs, EDs, and prehospital settings, with a view to the impact on "safety through redundancy".

3.1 First-pass endotracheal intubation success rate with the gum elastic bougie

Emergency ETI-related adverse events include hypoxemia, esophageal intubation, cardiac arrest, regurgitation, aspiration, hypotension, dysrhythmia, bradycardia, mainstem bronchus intubation, dental/lip trauma, and airway trauma [5–10]. These adverse events are most common when multiple laryngoscopies, especially more than three, are performed [6, 7]. Airway manipulations such as endotracheal intubation [66] are aerosol-generating procedures, and multiple attempts may increase the risk of transmission of acute respiratory infection such as SARS-CoV-2. Therefore, airway-opening techniques that are reliable and have the greatest chance of first-pass success should be used not only to reduce the chance of ETI-related adverse events but also to protect healthcare professionals from infection [23, 66].

In two observational studies performed in prehospital settings [27, 28], one RCT in EDs [29] and one observational study in EDs [30], bougie-assisted endotracheal intubation (BAETI) was associated with a significantly higher first-pass emergency ETI success rate than non-BAETI interventions. In contrast, a recent large multicenter RCT involving 1102 critically ill adults undergoing emergency ETI in seven EDs and eight ICUs in the US, there was no significant difference in the first-pass success of intubation by BAETI or endotracheal tube with stylet [31]. Thus, four of these five studies provided evidence in favor of GEB use on the initial attempt at emergency ETI.

3.2 Forces on oral structures during laryngoscopy with the gum elastic bougie

Excess force on upper airway structures during laryngoscopy can increase the activity of the sympathetic nervous system and raise plasma catecholamine levels [67], leading to adverse hemodynamic changes such as hypertension, tachycardia, arrhythmia, and even cardiac arrest [5–10]. Moreover, excess

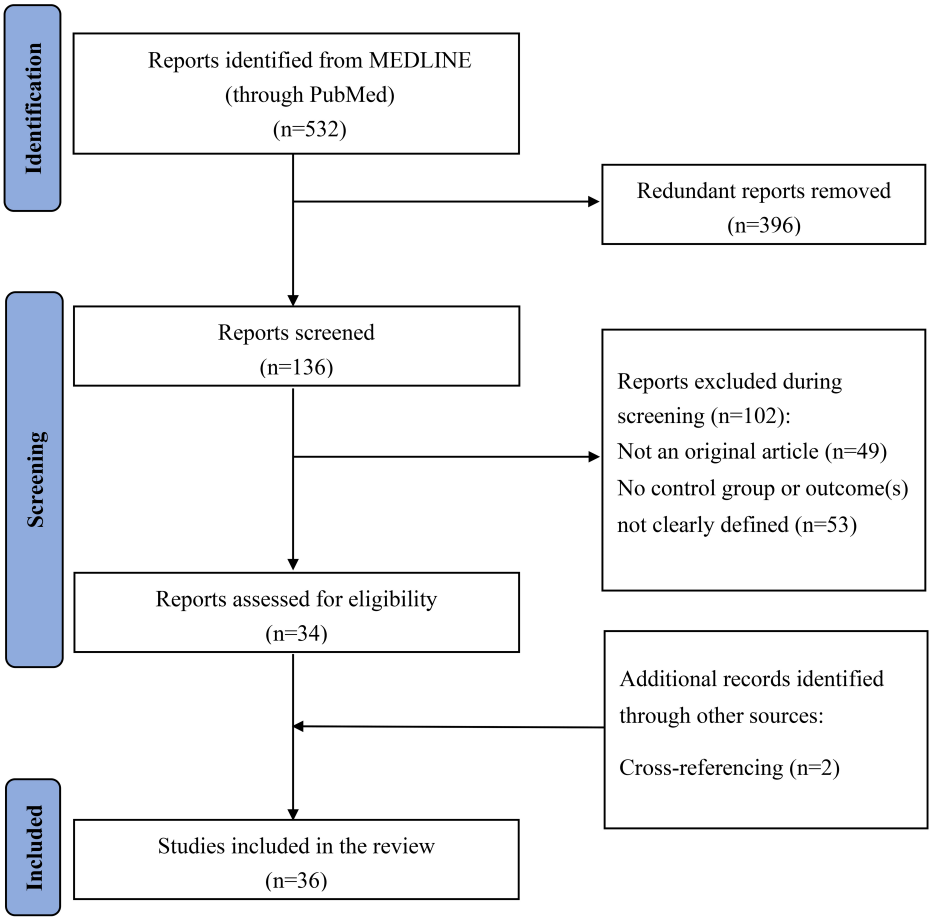

FIGURE 1. Flow diagram for literature review.

force on the maxillary incisors increases the risk of dental injury and upper airway trauma, which is the most common medico-legal claim against laryngoscopists [68]. Therefore, ETI should be performed with as little force on oral structures as necessary to prevent such consequences.

EDs play an important role in teaching airway management skills to novice physicians. In developed countries, approximately 33%–50% of ETI procedures in EDs are performed by junior residents [10, 69, 70], highlighting the need for effective training. Inexperienced laryngoscopists tend to apply more force to the incisors and tongue than do experienced laryngoscopists [71]; thus, senior physicians should employ effective airway adjuncts when supervising ETI performed by novices.

In one simulation study of medical students with normal airways, the maximum forces on tongue and incisors were significantly lower with BAETI compared with endotracheal tube with stylet during both direct and indirect laryngoscopy [32], suggesting a role for GEB beyond DAM in facilitating more gentle ETIs among inexperienced laryngoscopists.

3.3 Difficult airway management and the gum elastic bougie

The usefulness of the GEB as a rescue device after failed ETI attempts is well documented in the anesthesiology literature [11, 72]. However, of the four simulation studies reviewed that modeled DAM in emergency medicine settings [33–36], only one reported a superior ETI success rate with BAETI compared with non-BAETI [35]. Likewise, there was no significant difference in mean time to successful ETI with BAETI compared with endotracheal tube and style in four previous studies with various DAM simulations [33–35, 37]. In fact, two studies reported that BAETI actually significantly increased the time to ETI compared with non-BAETI approaches [33, 34]. In a simulation study examining ETI through supraglottic airway devices, the fiberscope-guided technique was significantly more successful than blind attempts using GEB [38]. Two large observational studies conducted in the US compared first-pass ETI success rates using direct laryngoscopy augmented by laryngeal manipulation, ramped patient positioning, and GEB use with unaided video laryngoscopy [39, 40]. Both studies found a significantly higher success rate with video laryngoscopy compared with the augmented direct laryngoscopy groups [39, 40]. Collectively, these results suggest that video laryngoscopy is superior to GEB as an intubating device.

3.4 Utility of the gum elastic bougie in combination with videolaryngoscopy

The combined use of GEB and videolaryngoscopy may further increase first-pass success. In a single-center RCT that included 757 adults undergoing emergency ETI in the ED, the

use of GEB while performing videolaryngoscopy resulted in a higher overall first-pass success rate compared with videolaryngoscopy performed with a standard endotracheal tube and stylet [29]. The authors of that study claimed that the higher success rate when using GEB might be due to improved visibility. The smaller diameter of the GEB may render it less likely than an endotracheal tube and stylet to obscure the glottis view.

Special attention should be paid to airway management in patients with unstable cervical spine. In a planned anesthesia setting, the use of GEB with videolaryngoscope during ETI significantly reduced movement of the cervical spine compared with the use of videolaryngoscope alone [73]. Therefore, a combination of GEB and videolaryngoscopy may be useful in patients needing cervical spine protection, such as those with multiple injuries.

3.5 Utility of the gum elastic bougie in cardiopulmonary resuscitation

ETI during CPR plays an important role in protecting health care professionals from aerosol exposure, which is particularly pertinent to the current COVID-19 pandemic. Five simulation studies have examined the success rates of ETI with or without GEB during manual or mechanical chest compression [41–45]. Four of the five studies were relatively small and examined ETI success rate as the primary outcome [41–44]; three of those studies reported significantly higher success rates in the BAETI group than in the non-BAETI group [41–43]. Three of the simulation studies [41, 42, 45] also compared the time to ETI completion between the BAETI and non-BAETI groups but conflicting results were reported: one study each reported similar times [41], shorter time in the BAETI group [42], and longer time in the BAETI group [45].

In the real-world clinical setting, CPR and ETI are frequently performed in a moving ambulance. In a simulation study, the mean time to ETI completion was significantly longer in the BAETI group compared with the non-BAETI group in both moving and stationary ambulances [46].

In contrast to the simulation studies, no significant difference in first-pass ETI success between BAETI and non-BAETI groups was detected in a large observational study of 3004 patients undergoing CPR after cardiac arrest in a prehospital setting [47].

Collectively, these results indicate that the utility of GEB in ETI during CPR remains controversial and further studies will be required to settle the issue.

3.6 Emergency cricothyrotomy and the gum elastic bougie

The incidence of emergency surgical airway after failed ETI is reported to be 0.005–0.025% [74] in the operating room, 0.72% [75] during emergency trauma surgery, and 0.26%–0.9% [76–79] outside of the operating room. Ten original studies have been performed to clarify the relative benefits of bougie-assisted emergency surgical cricothyrotomy technique (BACT) and non-BACT in emergency surgical airway. Of the ten, nine were simulations with animal models and one was a high-fidelity normal airway simulation model [48–57]. Eight studies examined time to completion of surgical airway as the primary endpoint [48–55]: the time was found to be significantly shorter in the BACT group in five studies [48–50, 52, 53] and in the non-BACT group in the two studies [54, 55]. In the remaining one study, median time to completion of surgical airway was similar between two groups [51]. One of these studies also examined the surgical airway success rate and found that the BACT group had significantly higher success and a lower rate of iatrogenic posterior tracheal wall injury compared with the non-BACT group [56]. In an anesthetized porcine model [57], BACT was significantly more successful in achieving rescue oxygenation (maintenance of arterial oxygen saturation of >90% at 5 min after the beginning of oxygenation) than the cannula technique using a 14-gauge needle [57].

Taken together, these results show a clear advantage for BACT over non-BACT techniques in emergency cricothyroidotomy with respect to time to completion, success rate, complication rate, and successful rescue oxygenation. Recent consensus guidelines for managing the airway in patients with COVID-19 also recommend BACT as a reliable method of emergency surgical airway [23, 80].

3.7 Emergency airway in patients with COVID-19 and the gum elastic bougie

The incidence of difficult airway may be increased in COVID-19 patients due to physiological issues. For example, COVID-19 patients are often critically ill and are at risk of respiratory and circulatory collapse during emergency ETI [80]. Thus, COVID-19 patients are often considered to be at risk of a physiologically difficult airway [80]. Recent consensus guidelines for managing the airway in patients with COVID-19 refer to the usefulness of GEB [23, 80] based on cumulative evidence in the operating room.

Personal protective equipment (PPE), which comprises surgical face masks, N95 face masks, eye protection, disposable medical gowns, and gloves, have become mandatory for health care professionals during the COVID-19 pandemic [23]. Wearing PPE adds both physiological and psychological burdens on the healthcare professional and may compromise DAM. Hendler *et al.* [81] and Castle *et al.* [82] reported that wearing PPE nearly doubled the time to perform ETI and hampered the laryngoscopic view.

One study evaluated the impact of PPE on emergency ETI parameters, which is of particular interest in the context of the current COVID-19 pandemic. This high-performance simulation study demonstrated that ETI took significantly longer and had a lower success rate in the BAETI group than the non-BAETI group when the practitioners were wearing PPE [58]. Further studies will be required to clarify the usefulness of GEB in airway management in patients with COVID-19.

3.8 Pediatric emergency airway management and the gum elastic bougie

In a simulated difficult airway model in infants, BAETI was associated with a higher success rate and shorter ETI time compared with non-BAETI [59]. Similar results were obtained in an infant Pierre Robin mannequin that mimicked congenital

difficult airway [60]. Likewise, in an infant mannequin receiving chest compression, the use of GEB was associated with a higher success rate and shorter ETI time [42]. Collectively, these results suggest that GEB may also be useful in pediatric emergency airway management.

3.9 Other special circumstances and gum elastic bougie use

Healthcare professionals in EDs sometimes encounter patients who need differential lung ventilation, such as those with severe pulmonary contusion. In one simulation study, the time to successful selective lung ventilation was significantly longer for the BAETI group compared with the non-BAETI group [61]. A study of ETI in simulated normal and vomitus settings showed that the time to ETI success with both direct and indirect laryngoscopy was significantly shortened by GEB use in the vomitus setting but significantly lengthened by GEB use in the normal setting [62].

In summary, the usefulness of GEB when performing emergency ETI under special circumstances such as selective lung ventilation, and vomitus remains unclear and must await further studies.

3.10 Availability of the gum elastic bougie outside of the operating room

Multiple backup options or "safety through redundancy" are routinely required in high-stakes situations where failure or accidents can result in fatalities [83]. In engineering, such redundancy is achieved by duplication of critical system components or functions, usually in the form of a backup or fail-safe mechanism such as multiple engines on aircraft and multi-threaded processing in computing. Safety through redundancy requires rigorous testing under normal conditions [83] and obviously cannot wait to be tested only when major incidents occur. Emergency airway management is another setting where safety redundancy is essential [84], and DAM devices should be used during normal airway management practice, not reserved for use only in patients with difficult airway. In this regard, GEB use should not be limited to aid ETI when laryngoscopic views are poor or after intubation attempts fail. This suggestion is supported by studies by Ångerman *et al.* [28] and Driver *et al.* [29, 30], which demonstrated the benefits of routine GEB use on the success of first-pass intubation in prehospital and ED settings.

The crucial nature of emergency airway management means that physicians should employ laryngoscopy and intubation techniques that maximize the chance of first-pass ETI success [84]. Previous studies found that GEB is available in 21.0%–64.2% of prehospital settings [85–88], 36%–100% of EDs [89–94], and 50.0%–60.7% of ICUs [95–97] in various countries (Fig. 2).

These results suggest that safety redundancy outside of the operating room is, in general, insufficient. Several studies by professional anesthesiology societies [22, 24, 25] have strongly recommended that DAM resources available outside of the operating room should be consistent with those specified for hospital operating rooms. The professional anesthesiology society guidelines [98–100] and recent consensus guidelines for managing the airway in patients with COVID-19 [23, 81] both cite the usefulness of GEB. Because fatal airway-related adverse events can in part be attributed to the limited accessibility of proper DAM equipment resources [21, 22, 24, 25], it is important that every ED and ICU has appropriate DAM resources, including GEB.

3.11 Limitations and strengths

One major limitation of this literature review was that we searched for published articles in a single database (MEDLINE) using a single search engine (PubMed®). Some peer-reviewed articles may therefore have been overlooked. However, we believe that our search strategy was appropriate and clinically relevant because most biomedical researchers use MEDLINE as the first and most reliable source of medical information. It is also unlikely that the results would have substantially differed if other databases (*e.g.*, Embase® and Google Scholar®) had been included. For example, Berry *et al.* [101] found that their MEDLINE search for articles included in systematic reviews of medical imaging successfully identified 94% of the target references. Despite these limitations, to the best of our knowledge, this is the first literature review to evaluate the effectiveness of GEB under emergency airway management conditions outside of the operating room.

4. Conclusions

The COVID-19 pandemic has increased the need for healthcare professionals to perform emergency ETI outside of the operating room. Difficult airways and severe airway-related adverse events occur much more commonly in such settings. The studies reviewed here suggest that, compared with alternative intubation techniques, GEB may increase the first-pass ETI success rate, decrease the force applied to oral structures during laryngoscopy, and aid in gentler ETI, and facilitate safer, faster, and more definitive cricothyrotomy. Moreover, combination GEB and video laryngoscopy may act additively to increase first-pass intubation success and decrease cervical spine movement during laryngoscopy. In high-stake potentially life-saving settings such as emergency airway management, a "safety through redundancy" approach with multiple backup systems is required. Immediate access to and proper implementation of DAM devices, including the GEB, is essential for the patient's safety. As evident from this review, GEB represents an old but still helpful friend in overcoming the vast challenges associated with emergency airway management.

ABBREVIATIONS

BACT, bougie-assisted emergency surgical cricothyrotomy technique; BAETI, bougie-assisted endotracheal intubation; CPR: cardiopulmonary resuscitation; COVID-19, coronavirus 2019; ED, emergency department; DAM, difficult airway management; ETI, endotracheal intubation; GEB, gum elastic bougie; ICU, intensive care units; LOE, level of evidence; PPE, personal protective equipment; RCT, randomized controlled trial; SARS-CoV, severe acute respiratory syndrome coronavirus.

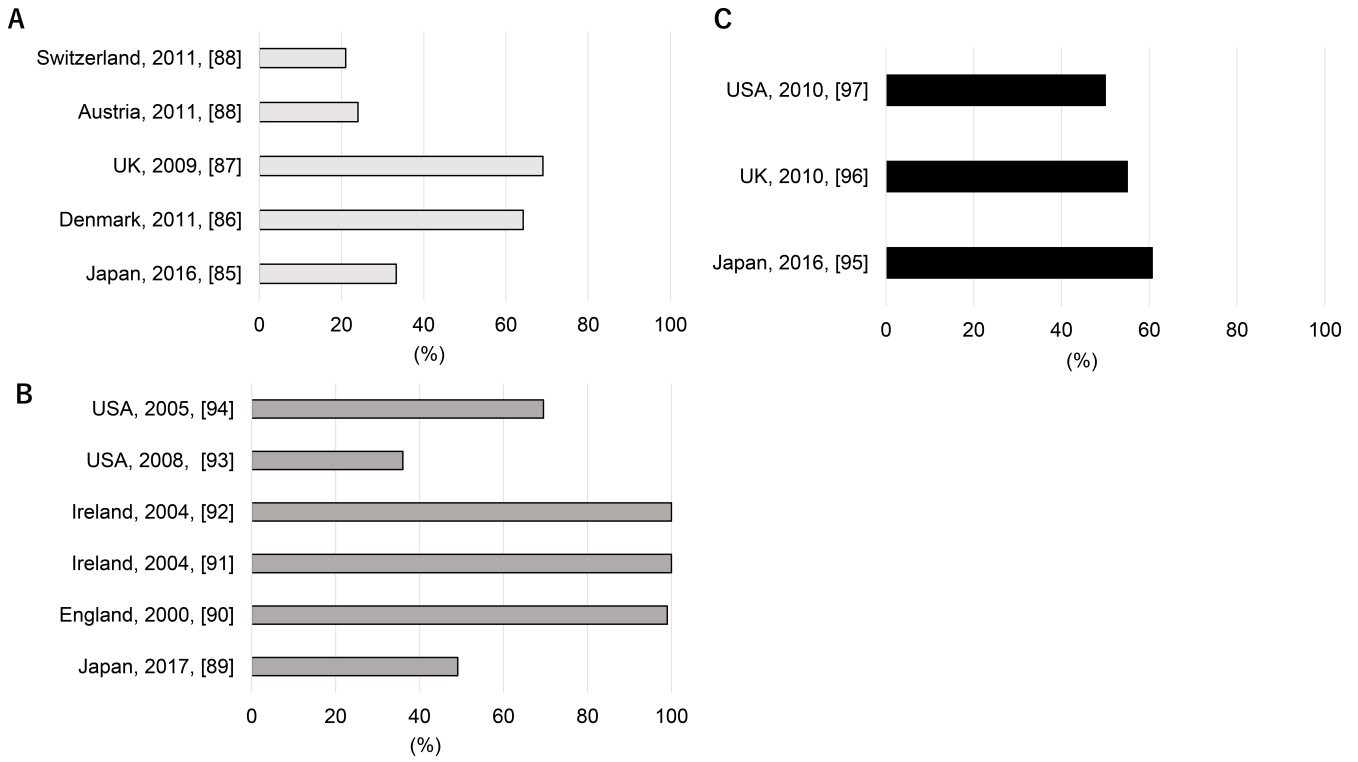

FIGURE 2. Comparison of the availability of gum elastic bougie in (A) prehospital settings, (B) emergency departments, and (C) intensive care units in various countries.

AVAILABILITY OF DATA AND MATERIALS

All relevant data are contained within this article.

AUTHOR CONTRIBUTIONS

YO—conceived the study design, obtained the research funding, drafted the manuscript, and takes primary responsibility for the manuscript. KS and JS—validated the collected literature, critically reviewed the manuscript, and participated in editing. SI and JK—supervised the study and participated in discussing, revising, and editing the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

ACKNOWLEDGMENT

The authors thank Mariko Jyukei (librarian, Library for Medical Sciences, School of Medicine, Kobe University) for advice in the PubMed® search strategy; Nozomi Ono, (Department of Psychiatry, Hoshigaoka Hospital, Koriyama, Japan) for manuscript review, and Anne M. O'Rourke, from Edanz (https://jp.edanz.com/ac) for editing a draft of this manuscript.

FUNDING

This work was partially supported by grants from the Public Trust Foundation of Marumo ER Medicine & Research Institute (2021 grant to YO). The funders had no role in the study design, data collection and analysis, or preparation of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.signavitae.com/mre-signavitae/article/1688467581027926016/attachment/Supplementary%20material.docx.

REFERENCES

[1] Jaber S, Amraoui J, Lefrant JY, Arich C, Cohendy R, Landreau L, *et al*. Clinical practice and risk factors for immediate complications of endotracheal intubation in the intensive care unit: a prospective, multiple-center study. Critical Care Medicine. 2006; 34: 2355–2361.

[2] Heuer JF, Barwing TA, Barwing J, Russo SG, Bleckmann E, Quintel M, *et al*. Incidence of difficult intubation in intensive care patients: analysis of contributing factors. Anaesthesia and Intensive Care. 2012; 40: 120–127.

[3] Martin LD, Mhyre JM, Shanks AM, Tremper KK, Kheterpal S. 3,423 emergency tracheal intubations at a university hospital: airway outcomes and complications. Anesthesiology. 2011; 114: 42–48.

[4] De Jong A, Molinari N, Pouzeratte Y, Verzilli D, Chanques G, Jung B, *et al*. Difficult intubation in obese patients: incidence, risk factors, and

complications in the operating theatre and in intensive care units. British Journal of Anaesthesia. 2015; 114: 297–306.

[5] De Jong A, Molinari N, Terzi N, Mongardon N, Arnal JM, Guitton C, *et al*. Early identification of patients at risk for difficult intubation in the intensive care unit: development and validation of the MACOCHA score in a multicenter cohort study. American Journal of Respiratory and Critical Care Medicine. 2013; 187: 832–839.

[6] Mort TC. Emergency tracheal intubation: complications associated with repeated laryngoscopic attempts. Anesthesia & Analgesia. 2004; 82: 607–613.

[7] Hasegawa K, Shigemitsu K, Hagiwara Y, Chiba T, Watase H, Brown CA 3rd, *et al*. Association between repeated intubation attempts and adverse events in emergency departments: an analysis of a multicenter prospective observational study. Annals of Emergency Medicine. 2012; 60: 749–754.e2.

[8] Reed MJ. Can an airway assessment score predict difficulty at intubation in the emergency department? Emergency Medicine Journal. 2005; 22: 99–102.

[9] Walls RM, Brown CA, Bair AE, Pallin DJ. Emergency airway management: a multi-center report of 8937 emergency department intubations. The Journal of Emergency Medicine. 2011; 41: 347–354.

[10] Brown CA 3rd, Bair AE, Pallin DJ, Walls RM; NEAR III Investigators. Techniques, success, and adverse events of emergency department adult intubations. Annals of Emergency Medicine. 2015; 65: 363–370.e1.

[11] Combes X, Jabre P, Margenet A, Merle JC, Leroux B, Dru M, *et al*. Unanticipated difficult airway management in the prehospital emergency setting. Anesthesiology. 2011; 114: 105–110.

[12] Timmermann A, Eich C, Russo SG, Natge U, Bräuer A, Rosenblatt WH, *et al*. Prehospital airway management: a prospective evaluation of anaesthesia trained emergency physicians. Resuscitation. 2006; 70: 179–185.

[13] Breckwoldt J, Klemstein S, Brunne B, Schnitzer L, Arntz H, Mochmann H. Expertise in prehospital endotracheal intubation by emergency medicine physicians—comparing 'proficient performers' and 'experts'. Resuscitation. 2012; 83: 434–439.

[14] Adnet F, Borron S, Racine S, Clemessy J, Fournier J, Plaisance P, *et al*. The intubation difficulty scale (IDS) anesthesiology. 1997; 87: 1290–1297.

[15] Nørskov AK, Rosenstock CV, Wetterslev J, Astrup G, Afshari A, Lundstrøm LH. Diagnostic accuracy of anaesthesiologists' prediction of difficult airway management in daily clinical practice: a cohort study of 188 064 patients registered in the Danish Anaesthesia Database. Anaesthesia. 2015; 70: 272–281.

[16] Burkle CM, Walsh MT, Harrison BA, Curry TB, Rose SH. Airway management after failure to intubate by direct laryngoscopy: outcomes in a large teaching hospital. Canadian Journal of Anesthesia. 2005; 52: 634–640.

[17] Crosby ET, Cooper RM, Douglas MJ, Doyle DJ, Hung OR, Labrecque P, *et al*. The unanticipated difficult airway with recommendations for management. Canadian Journal of Anaesthesia. 1998; 45: 757–776.

[18] Langeron O, Cuvillon P, Ibanez-Esteve C, Lenfant F, Riou B, Le Manach Y. Prediction of difficult tracheal intubation. Anesthesiology. 2012; 117: 1223–1233.

[19] Lundstrøm L, Møller A, Rosenstock C, Astrup G, Wetterslev J. High body mass index is a weak predictor for difficult and failed tracheal intubation. Anesthesiology. 2009; 110: 266–274.

[20] Peterson G, Domino K, Caplan R, Posner K, Lee L, Cheney F. Management of the difficult airway. Anesthesiology. 2005; 103: 33–39.

[21] Cook TM, Woodall N, Frerk C; Fourth National Audit Project. Major complications of airway management in the UK: results of the fourth national audit project of the royal college of anaesthetists and the difficult airway society. Part 1: anaesthesia. British Journal of Anaesthesia. 2011; 106: 617–631.

[22] Cook TM, Woodall N, Harper J, Benger J. Major complications of airway management in the UK: results of the fourth national audit project of the royal college of anaesthetists and the difficult airway society. Part 2: intensive care and emergency departments. British Journal of Anaesthesia. 2011; 106: 632–642.

[23] Cook TM, El-Boghdadly K, McGuire B, McNarry AF, Patel A, Higgs A. Consensus guidelines for managing the airway in patients with COVID-19: guidelines from the difficult airway society, the association of anaesthetists the intensive care society, the faculty of intensive care medicine and the royal college of anaesthetists. Anaesthesia. 2020; 75: 785–799.

[24] Thomas AN, McGrath BA. Patient safety incidents associated with airway devices in critical care: a review of reports to the UK national patient safety agency. Anaesthesia. 2009; 64: 358–365.

[25] Cook TM, MacDougall-Davis SR. Complications and failure of airway management. British Journal of Anaesthesia. 2012; 109: i68–i85.

[26] Macintosh RR. An aid to oral intubation. The British Medical Journal. 1949; 1: 28.

[27] Latimer AJ, Harrington B, Counts CR, Ruark K, Maynard C, Watase T, *et al*. Routine use of a bougie improves first-attempt intubation success in the out-of-hospital setting. Annals of Emergency Medicine. 2021; 77: 296–304.

[28] Ångerman S, Kirves H, Nurmi J. A before-and-after observational study of a protocol for use of the C-MAC videolaryngoscope with a Frova introducer in pre-hospital rapid sequence intubation. Anaesthesia. 2018; 73: 348–355.

[29] Driver BE, Prekker ME, Klein LR, Reardon RF, Miner JR, Fagerstrom ET, *et al*. Effect of use of a bougie vs endotracheal tube and stylet on first-attempt intubation success among patients with difficult airways undergoing emergency intubation: a randomized clinical trial. JAMA. 2018; 319: 2179–2189.

[30] Driver B, Dodd K, Klein LR, Buckley R, Robinson A, McGill JW, *et al*. The bougie and first-pass success in the emergency department. Annals of Emergency Medicine. 2017; 70: 473–478.e1.

[31] Driver BE, Semler MW, Self WH, Ginde AA, Trent SA, Gandotra S, *et al*. Effect of use of a bougie *vs.* endotracheal tube with stylet on successful intubation on the first attempt among critically ill patients undergoing tracheal intubation: a randomized clinical trial. JAMA. 2021; 326: 2488–2497.

[32] Ono Y, Shinohara K, Shimada J, Inoue S, Kotani J. Lower maximum forces on oral structures when using gum-elastic bougie than when using endotracheal tube and stylet during both direct and indirect laryngoscopy by novices: a crossover study using a high-fidelity simulator. BMC Emergency Medicine. 2020; 20: 34.

[33] Brazil V, Grobler C, Greenslade J, Burke J. Comparison of intubation performance by junior emergency department doctors using gum elastic bougie versus stylet reinforced endotracheal tube insertion techniques. Emergency Medicine Australasia. 2012; 24: 194–200.

[34] Kovacs G, Law JA, McCrossin C, Vu M, Leblanc D, Gao J. A comparison of a fiberoptic stylet and a bougie as adjuncts to direct laryngoscopy in a manikin-simulated difficult airway. Annals of Emergency Medicine. 2007; 50: 676–685.

[35] Messa MJ, Kupas DF, Dunham DL. Comparison of bougie-assisted intubation with traditional endotracheal intubation in a simulated difficult airway. Prehospital Emergency Care. 2011; 15: 30–33.

[36] Phelan MP, Moscati R, D'Aprix T, Miller G. Paramedic use of the endotracheal tube introducer in a difficult airway model. Prehospital Emergency Care. 2003; 7: 244–246.

[37] Nielsen AA, Hope CB, Bair AE. GlideScope videolaryngoscopy in the simulated difficult airway: bougie *vs.* standard stylet. The Western Journal of Emergency Medicine. 2010; 11: 426–431.

[38] Michalek P, Donaldson W, Graham C, Hinds JD. A comparison of the I-gel supraglottic airway as a conduit for tracheal intubation with the intubating laryngeal mask airway: a manikin study. Resuscitation. 2010; 81: 74–77.

[39] Brown CA 3rd, Kaji AH, Fantegrossi A, Carlson JN, April MD, Kilgo RW, *et al*. Video laryngoscopy compared to augmented direct laryngoscopy in adult emergency department tracheal intubations: a national emergency airway registry (NEAR) study. Academic Emergency Medicine. 2020; 27: 100–108.

[40] Kaji AH, Shover C, Lee J, Yee L, Pallin DJ, April MD, *et al*. Video versus direct and augmented direct laryngoscopy in pediatric tracheal intubations. Academic Emergency Medicine. 2020; 27: 394–402.

[41] Komasawa N, Cho T, Mihara R, Minami T. Utility of gum-elastic bougie for tracheal intubation during chest compressions in a manikin: a randomized crossover trial. The American Journal of Emergency Medicine. 2016; 34: 54–56.

[42] Cho T, Komasawa N, Hattori K, Mihara R, Minami T. Gum-elastic bougie efficacy for tracheal intubation during continuous chest compression in infants—a crossover simulation trial. The Journal of Emergency Medicine. 2016; 51: 19–24.

[43] Halhalli HC, Özbek AE, Çelİk E, Yİğİt Y, Yilmaz S, Çardak M. Benefits of using an endotracheal tube introducer as an adjunct to a Macintosh laryngoscope for endotracheal intubation performed by inexperienced doctors during mechanical CPR: a randomized prospective crossover study. World Journal of Emergency Medicine. 2019; 10: 182.

[44] Ozbek AE, Halhalli HC, Yilmaz S, Celik E, Ozerol H, Şancı E. Effects of using an endotracheal tube introducer for intubation during mechanical chest compressions of a manikin: randomized, prospective, crossover study. The Journal of Emergency Medicine. 2020; 59: 56–60.

[45] Tandon N, McCarthy M, Forehand B, Carlson JN. Comparison of intubation modalities in a simulated cardiac arrest with uninterrupted chest compressions. Emergency Medicine Journal. 2014; 31: 799–802.

[46] Karaca O, Bayram B, Oray NC, Acerer A, Sofuoglu Z. Comparison of the airway access skills of prehospital staff in moving and stationary ambulance simulation: a randomized crossover study. Turkish Journal of Emergency Medicine. 2017; 17: 35–41.

[47] Bonnette AJ, Aufderheide TP, Jarvis JL, Lesnick JA, Nichol G, Carlson JN, *et al*. Bougie-assisted endotracheal intubation in the pragmatic airway resuscitation trial. Resuscitation. 2021; 158: 215–219.

[48] Hill C, Reardon R, Joing S, Falvey D, Miner J. Cricothyrotomy technique using gum elastic bougie is faster than standard technique: a study of emergency medicine residents and medical students in an animal lab. Academic Emergency Medicine. 2010; 17: 666–669.

[49] Driver BE, Klein LR, Perlmutter MC, Reardon RF. Emergency cricothyrotomy in morbid obesity: comparing the bougie-guided and traditional techniques in a live animal model. The American Journal of Emergency Medicine. 2021; 50: 582–586.

[50] Chrisman L, King W, Wimble K, Cartwright S, Mohammed KB, Patel B. Surgicric 2: a comparative bench study with two established emergency cricothyroidotomy techniques in a porcine model. British Journal of Anaesthesia. 2016; 117: 236–242.

[51] Yeow C, Greaney L, Foy C, King W, Patel B. Evaluation of a novel cricothyroidotomy introducer in a simulated obese porcine model: a randomised crossover comparison with scalpel cricothyroidotomy. Anaesthesia. 2018; 73: 1235–1243.

[52] Quick JA, MacIntyre AD, Barnes SL. Emergent surgical airway: comparison of the three-step method and conventional cricothyroidotomy utilizing high-fidelity simulation. The Journal of Emergency Medicine. 2014; 46: 304–307.

[53] Chang SS, Tong QJ, Beh ZY, Quek KH, Ang BH. A bench study comparing between scalpel-bougie technique and cannula-to-Melker technique in emergency cricothyroidotomy in a porcine model. Korean Journal of Anesthesiology. 2018; 71: 289–295.

[54] Rees KA, O'Halloran LJ, Wawryk JB, Gotmaker R, Cameron EK, Woonton HDJ. Time to oxygenation for cannula- and scalpel-based techniques for emergency front-of-neck access: a wet lab simulation using an ovine model. Anaesthesia. 2019; 74: 1153–1157.

[55] Heard A, Gordon H, Douglas S, Grainger N, Avis H, Vlaskovsky P, *et al*. Front-of-neck airway rescue with impalpable anatomy during a simulated cannot intubate, cannot oxygenate scenario: scalpel-finger-cannula versus scalpel-finger-bougie in a sheep model. British Journal of Anaesthesia. 2020; 125: 184–191.

[56] Nakstad AR, Bredmose PP, Sandberg M. Comparison of a percutaneous device and the bougie-assisted surgical technique for emergency cricothyrotomy: an experimental study on a porcine model performed by air ambulance anaesthesiologists. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine. 2013; 21: 59.

[57] Umek N, Hodzovic I, Damjanovska M, Cvetko E, Zel J, Seliskar A, *et al*. Rescue oxygenation success by cannula or scalpel-bougie emergency front-of-neck access in an anaesthetised porcine model. PLoS One. 2020; 15: e0232510.

[58] Milk N, Rosman Y, Yavnai N, Cohen B, Ophir N, Eisenkraft A, *et al*. Intubation using the gum-elastic bougie while wearing personal protective equipment. American Journal of Disaster Medicine. 2020; 15: 85–92.

[59] Komasawa N, Hyoda A, Matsunami S, Majima N, Minami T. Utility of a gum-elastic bougie for difficult airway management in infants: a simulation-based crossover analysis. BioMed Research International. 2015; 2015: 1–5.

[60] Matsunami S, Komasawa N, Majima N, Ueno T, Minami T. Evaluation of gum-elastic bougie with direct and indirect laryngoscope for infant difficult airway management: a Pierre Robin simulation model. Journal of Clinical Anesthesia. 2016; 30: 59–60.

[61] Halhallı H, Ozerol H, Şancı E, Karakayalı O, Aydın E. Selective intubation with endotracheal tube introducer in difficult airway: a randomized, prospective, cross-over study. Turkish Journal of Emergency Medicine. 2021; 21: 205.

[62] Ohchi F, Komasawa N, Mihara R, Hattori K, Minami T. Evaluation of gum-elastic bougie combined with direct and indirect laryngoscopes in vomitus setting: a randomized simulation trial. The American Journal of Emergency Medicine. 2017; 35: 584–588.

[63] Centre for Evidence-Based Medicine. Oxford Centre for Evidence-Based Medicine: Levels of Evidence. 2009. Available at: https://www.cebm.ox.ac.uk/resources/levels-of-evidence/oxford-centre-for-evidence-based-medicine-levels-of-evidence-march-2009 (Accessed: 22 March 2023).

[64] Baethge C, Goldbeck-Wood S, Mertens S. SANRA—a scale for the quality assessment of narrative review articles. Research Integrity and Peer Review. 2019; 4: 5.

[65] Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, *et al*. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Annals of Internal Medicine. 2018; 169: 467–473.

[66] Tran K, Cimon K, Severn M, Pessoa-Silva CL, Conly J. Aerosol generating procedures and risk of transmission of acute respiratory infections to healthcare workers: a systematic review. PLoS One. 2012; 7: e35797.

[67] Dashti M, Amini S, Azarfarin R, Totonchi Z, Hatami M. Hemodynamic changes following endotracheal intubation with glidescope(®) videolaryngoscope in patients with untreated hypertension. Research in Cardiovascular Medicine. 2014; 3: e17598.

[68] Warner M, Benenfeld S, Warner M, Schroeder D, Maxson P. Perianesthetic dental injuries. Anesthesiology. 1999; 90: 1302–1305.

[69] Kim C, Kang HG, Lim TH, Choi BY, Shin Y, Choi HJ. What factors affect the success rate of the first attempt at endotracheal intubation in emergency departments? Emergency Medicine Journal. 2013; 30: 888–892.

[70] Goto Y, Goto T, Hagiwara Y, Tsugawa Y, Watase H, Okamoto H, *et al*. Techniques and outcomes of emergency airway management in Japan: an analysis of two multicentre prospective observational studies, 2010–2016. Resuscitation. 2017; 114: 14–20.

[71] Takeuchi S, Shiga T, Koyama Y, Nakanishi T, Honma Y, Morita H, *et al*. Longitudinal acquisition of endotracheal intubation skills in novice physicians. PLoS One. 2017; 12: e0188224.

[72] Combes X, Le Roux B, Suen P, Dumerat M, Motamed C, Sauvat S, *et al*. Unanticipated difficult airway in anesthetized patients. Anesthesiology. 2004; 100: 1146–1150.

[73] Takenaka I, Aoyama K, Iwagaki T, Ishimura H, Takenaka Y, Kadoya T. Approach combining the airway scope and the bougie for minimizing movement of the cervical spine during endotracheal intubation. Anesthesiology. 2009; 110: 1335–1340.

[74] Berkow LC, Greenberg RS, Kan KH, Colantuoni E, Mark LJ, Flint PW, *et al*. Need for emergency surgical airway reduced by a comprehensive difficult airway program. Anesthesia & Analgesia. 2009; 109: 1860–1869.

[75] Ono Y, Yokoyama H, Matsumoto A, Kumada Y, Shinohara K, Tase C. Surgical airways for trauma patients in an emergency surgical setting: 11 years' experience at a teaching hospital in Japan. Journal of Anesthesia. 2013; 27: 832–837.

[76] Sagarin MJ, Barton ED, Chng Y, Walls RM. Airway management by us and canadian emergency medicine residents: a multicenter analysis of more than 6,000 endotracheal intubation attempts. Annals of Emergency Medicine. 2005; 46: 328–336.

[77] Levitan RM, Rosenblatt B, Meiner EM, Reilly PM, Hollander JE. Alternating day emergency medicine and anesthesia resident responsibility for management of the trauma airway. Annals of Emergency Medicine. 2004; 43: 48–53.

[78] Stephens CT, Kahntroff S, Dutton RP. The success of emergency endotracheal intubation in trauma patients: a 10-year experience at a major adult trauma referral center. Anesthesia & Analgesia. 2009; 109: 866–872.

[79] Cobas MA, De la Peña MA, Manning R, Candiotti K, Varon AJ. Prehospital intubations and mortality: a level 1 trauma center perspective. Anesthesia & Analgesia. 2009; 109: 489–493.

[80] Foley LJ, Urdaneta F, Berkow L, Aziz MF, Baker PA, Jagannathan N, *et al*. Difficult airway management in adult coronavirus disease 2019 patients: statement by the society of airway management. Anesthesia & Analgesia. 2021; 133: 876–890.

[81] Hendler I, Nahtomi O, Segal E, Perel A, Wiener M, Meyerovitch J. The effect of full protective gear on intubation performance by hospital medical personnel. Military Medicine. 2000; 165: 272–274.

[82] Castle N, Owen R, Hann M, Clark S, Reeves D, Gurney I. Impact of chemical, biological, radiation, and nuclear personal protective equipment on the performance of low- and high-dexterity airway and vascular access skills. Resuscitation. 2009; 80: 1290–1295.

[83] Ong MS, Coiera E. Safety through redundancy: a case study of in-hospital patient transfers. BMJ Quality & Safety. 2010; 19: e32–e32.

[84] Levitan RM. Patient safety in emergency airway management and rapid sequence intubation: metaphorical lessons from skydiving. Annals of Emergency Medicine. 2003; 42: 81–87.

[85] Ono Y, Shinohara K, Goto A, Yano T, Sato L, Miyazaki H, *et al*. Are prehospital airway management resources compatible with difficult airway algorithms? A nationwide cross-sectional study of helicopter emergency medical services in Japan. Journal of Anesthesia. 2016; 30: 205–214.

[86] Rognås LK, Hansen T. EMS-physicians' self reported airway management training and expertise; a descriptive study from the central region of Denmark. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine. 2011; 19: 10.

[87] Schmid M, Mang H, Ey K, Schüttler J. Prehospital airway management on rescue helicopters in the United Kingdom. Anaesthesia. 2009; 64: 625–631.

[88] SCHMID M, SCHÜTTLER J, EY K, REICHENBACH M, TRIMMEL H, MANG H. Equipment for pre-hospital airway management on helicopter emergency medical system helicopters in central Europe. Acta Anaesthesiologica Scandinavica. 2011; 55: 583–587.

[89] Ono Y, Tanigawa K, Shinohara K, Yano T, Sorimachi K, Inokuchi R, *et al*. Human and equipment resources for difficult airway management, airway education programs, and capnometry use in Japanese emergency departments: a nationwide cross-sectional study. International Journal of Emergency Medicine. 2017; 10: 28.

[90] Morton T, Brady S, Clancy M. Difficult airway equipment in English emergency departments. Anaesthesia. 2000; 55: 485–488.

[91] Walsh K, Cummins F. Difficult airway equipment in departments of emergency medicine in Ireland: results of a national survey. European Journal of Anaesthesiology. 2004; 21: 128–131.

[92] Niazi A, Cummins E, Walsh K. Difficult airway equipment in obstetric units in the republic of Ireland: results of a national survey. European Journal of Anaesthesiology. 2004; 21: 861–863.

[93] Losek JD, Olson LR, Dobson JV, Glaeser PW. Tracheal intubation practice and maintaining skill competency: survey of pediatric emergency department medical directors. Pediatric Emergency Care. 2008; 24: 294–299.

[94] Reeder TJ, Brown CK, Norris DL. Managing the difficult airway: a survey of residency directors and a call for change. The Journal of Emergency Medicine. 2005; 28: 473–478.

[95] Ono Y, Tanigawa K, Shinohara K, Yano T, Sorimachi K, Sato L, *et al*. Difficult airway management resources and capnography use in Japanese intensive care units: a nationwide cross-sectional study. Journal of Anesthesia. 2016; 30: 644–652.

[96] Georgiou AP, Gouldson S, Amphlett AM. The use of capnography and the availability of airway equipment on intensive care units in the UK and the republic of Ireland. Anaesthesia. 2010; 65: 462–467.

[97] Porhomayon J, El-Solh AA, Nader ND. National survey to assess the content and availability of difficult-airway carts in critical-care units in the United States. Journal of Anesthesia. 2010; 24: 811–814.

[98] Japanese Society of Anesthesiologists. JSA airway management guideline 2014: to improve the safety of induction of anesthesia. Journal of Anesthesia. 2014; 28: 482–493.

[99] Apfelbaum JL, Hagberg CA, Connis RT, Abdelmalak BB, Agarkar M, Dutton RP, *et al*. 2022 American society of anesthesiologists practice guidelines for management of the difficult airway. Anesthesiology. 2022; 136: 31–81.

[100] Frerk C, Mitchell VS, McNarry AF, Mendonca C, Bhagrath R, Patel A, *et al*. Difficult airway society 2015 guidelines for management of unanticipated difficult intubation in adults. British Journal of Anaesthesia. 2015; 115: 827–848.

[101] Berry E, Kelly S, Hutton J, Harris KM, Smith MA. Identifying studies for systematic reviews. An example from medical imaging. International Journal of Technology Assessment in Health Care. 2000; 16: 668–672.

How to cite this article: Yuko Ono, Kazuaki Shinohara, Jiro Shimada, Shigeaki Inoue, Joji Kotani. Emergency airway management with the gum elastic bougie outside of the operating room: a narrative review. Signa Vitae. 2023; 19(5): 29-37. doi: 10.22514/sv.2023.074.