ORIGINAL CLINICAL RESEARCH REPORT

CME

Effectiveness of Ventilation via an Endotracheal Tube in Pharynx Versus a Facemask in Patients With Potentially Difficult Airway: A Randomized, Crossover, and Blind Trial

Travis Markham, MD,* Abraham S. AlFarra, MD,† Mubeen Tejani, MD,‡ Daniel J. Tate, MD,§ Jose E. Barrera,‖ Sreelekha Paladugu, MD, DJ,¶ Sepideh Saroukhani, MD, PhD,#** and Yandong Jiang, MD, PhD*

See Article, page 276

BACKGROUND: The difficult airway is frequently encountered across many scenarios. The extreme form is a “cannot intubate and cannot oxygenate” scenario, which lacks a reliable rescue technique. Previous case reports or studies with small sample sizes indicate the feasibility and efficiency of an endotracheal tube in the pharynx (TTIP) to ventilate patients. We hypothesize that ventilation via TTIP is an effective rescue technique for failed mask ventilation.

METHOD: One hundred forty-seven patients with potentially difficult airways were randomly assigned to the sequence (Tube first) of tube first ventilation via TTIP for 1 minute after induction, followed by via mask ventilation for 1 minute or in reverse sequence (Mask first). The ventilation was done with pressure control mode, a peak inspiratory airway pressure of 20 cmH_2O, an inspiratory to expiratory time ratio of 1:2, and a respiratory rate of 10 breaths/min.

RESULTS: A total of 136 patients underwent final analysis. The overall success rate (primary outcome) of ventilation via TTIP and mask, defined as the presence of expired carbon dioxide, was 93.4% (127/136) and 84.6% (115/136), respectively (P = .02). The success rate, 85.7% (6/7), of mask ventilation rescuing a failed TTIP ventilation and 100% (13/13) of TTIP rescuing a failed mask ventilation were comparable (P = .35).

CONCLUSIONS: The success rates of TTIP and mask ventilation are comparable. Ventilation via TTIP could be an alternative rescue technique for managing a difficult airway. (Anesth Analg 2025;140:280–9)

KEY POINTS

- **Question:** Can an endotracheal tube in pharynx (TTIP) ventilation be an effective rescue technique for failed mask ventilation?
- **Findings:** The success rate of TTIP ventilation is comparable with that of facemask ventilation in adult patients with potentially difficult airways.
- **Meaning:** TTIP is a potential alternative for managing difficult airways.

Airway management is critical to ensure adequate ventilation and oxygenation of an apneic patient in the perioperative setting, intensive care unit, emergency room, and during prehospital resuscitation.[1,2] It includes mask ventilation, supraglottic airway (SGA) ventilation, tracheal intubation, and front-of-the-neck access. Difficult airways are frequently encountered across all locations. As defined by the Practice Guidelines of the American Society of Anesthesiologists, a difficult

From the *Department of Anesthesiology, McGovern Medical School, the University of Texas Health Science Center at Houston, Houston, Texas; †Department of Anesthesiology and Pain Management, Cleveland Clinic, Cleveland, Ohio; ‡Department of Anesthesiology and Pain Management, Dallas, Texas; §PGY 1, McGovern Medical School, the University of Texas Health Science Center at Houston, Houston, Texas; ‖McGovern Medical School, the University of Texas Health Science Center at Houston, Houston, Texas; ¶Department of Anesthesia & Critical Care, The University of Chicago, Chicago, Illinois; #Division of Clinical and Translational Sciences, Department of Internal Medicine, McGovern Medical School, The University of Texas Health Science Center at Houston, Houston, Texas; and **Biostatistics/Epidemiology/Research Design (BERD) Component, Center for Clinical and Translational Sciences (CCTS), The University of Texas Health Science Center at Houston, Houston, Texas.

DOI: 10.1213/ANE.0000000000007273

Accepted for publication August 12, 2024.

Conflicts of Interest, Funding: Please see DISCLOSURES at the end of this article.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal’s website (www.anesthesia-analgesia.org).

Clinical Trial Registration: This study was registered at clinicaltrials.gov (NCT05005390) on August 13, 2021, under the name of Dr T. Markham (primary investigator).

Reprints will not be available from the authors.

Address correspondence to Yandong Jiang, MD, PhD, Department of Anesthesiology, The University of Texas Health Science Center at Houston, McGovern Medical School, 6431 Fannin St, Houston, TX 77030. Address e-mail to Yandong.jiang@uth.tmc.edu.

airway is a clinical situation in which anticipated or unanticipated difficulty or failure is experienced by a physician trained in anesthesia care, including but not limited to 1 or more of the following: facemask ventilation, laryngoscopy, ventilation using an SGA, tracheal intubation, extubation, or invasive airway.[3] The extreme condition of a difficult airway is a "cannot intubate and cannot oxygenate (CICO)" scenario, which occurred at an incidence of 0.003%,[4] accounting for 25% to 28% of patient deaths in the perioperative setting.[2] In the emergency department and critical care settings, it accounts for 27% to 50% of patient deaths.[2] In a CICO situation, emergency front-of-the-neck access is recommended as a rescue technique by several major airway management societies[3,5–8] and recent reviews.[9,10] However, a large-scale study indicates that the success rate of emergency front-of-the-neck access when performed by even experienced anesthesiologists in perioperative settings is only 35%.[2] A recent meta-analysis demonstrates the median success rate via needle technique is 50% in the prehospital setting.[11] Commonly used bedside screening tests cannot detect unanticipated difficult airways with acceptable accuracy.[12,13] It remains unknown if the increased availability of video laryngoscopy reduces the rate of CICO. A retrospective study shows that increased utilization of video laryngoscopes does not correlate with a decrease in the need for emergency invasive airway management in perioperative settings.[14] As the currently recommended rescue techniques are suboptimal with a limited success rate, it is imperative that we explore potential alternative and reliable rescue techniques.

The airway obstruction in an unconscious individual most likely occurs in the upper airway[15–17] due to pharyngeal dilator muscle paralysis, soft palate, tongue, and upper glottis blockage. Theoretically, an endotracheal tube in the pharynx (TTIP) can bypass the tongue, soft palate, and epiglottis, potentially overcoming airway obstruction. This technique was first proven effective in a canine study.[18] Several case reports and studies with small sample sizes in humans demonstrate the feasibility, safety, and efficacy of ventilation via TTIP.[19–23] However, a study with sufficient sample size and in a crossover manner that compares its efficiency and safety with those of mask ventilation remains unavailable. In particular, it is unknown if TTIP can be a reliable rescue measure for a failed mask or SGA ventilation. We hypothesize that TTIP is as effective as mask ventilation in unconscious individuals. TTIP and mask ventilation can be mutually effective rescue techniques. We tested this hypothesis on adult patients with a potentially difficult airway under general anesthesia in a randomized and crossover manner.

METHODS

Patient Enrollment

This study was approved by the Institutional Review Board of the University of Taxes, Health Science Center at Houston (Case # HSC-MS-21-0478), with written informed consent obtained before enrollment in all cases and registered at clinicaltrials.gov (NCT05005390) on August 13, 2021, under the name of the primary investigator, Travis Markham. The study occurred in the main operating rooms at Memorial Hermann Hospital in the Texas Medical Center from June 26, 2021, to November 18, 2022. Our primary outcome was the success rates of ventilation using a mask versus TTIP in patients with potentially difficult airways, defined as the presence of at least 1 risk factor of a difficult airway, body mass index (BMI) >30 kg/m^2, and/or Mallampati class III or IV. Success ventilation was defined as CO_2 being observed at least once on capnography within the initial 3 consecutive attempted breaths. Inclusion criteria include >18 years of age and a requirement of general anesthesia with tracheal intubation, with BMI >30 kg/m^2, and/or Mallampati class III or IV. Exclusion criteria include acute and chronic respiratory disorders (including chronic obstructive lung disease (COPD) and asthma), American Society of Anaesthesiologists physical status classification ≥ IV, emergency surgery, induction requiring rapid sequence induction, patients requiring awake intubation, pregnant women, and contraindication for mask ventilation. The process of randomization and blindness was described in the supplementary document (Supplemental Digital Content 1, Detailed Methodology, http://links.lww.com/AA/F126).

Study Protocol

After providing informed consent, the subjects received premedication as usual from the care team, were transported to the operating room, and placed on the operating room table supine with the head in the neutral position on a pillow. The head elevation and ramping were not protocolized but per the preference of the care team. Standard monitors for general anesthesia were applied, including electrocardiography (ECG), noninvasive blood pressure, pulse oximetry, and capnography. Preoxygenation via a medium-sized plastic facemask (Medline Industrial Inc) was performed with a flow rate of 10-L minute^{-1} of 100% oxygen. Once the expired oxygen concentration reached ≥80%, induction of anesthesia started with an intravenous bolus injection of fentanyl (1–2 μg/kg), propofol (1–2 mg/ kg), and rocuronium (0.6 mg/kg). When apnea occurred, ventilation began with one of the 2 techniques, Mask or TTIP, in a randomized crossover manner. The mask ventilation was performed with a 2-hand V-E technique, as shown in Figure 1A, and the detailed description of the application of this

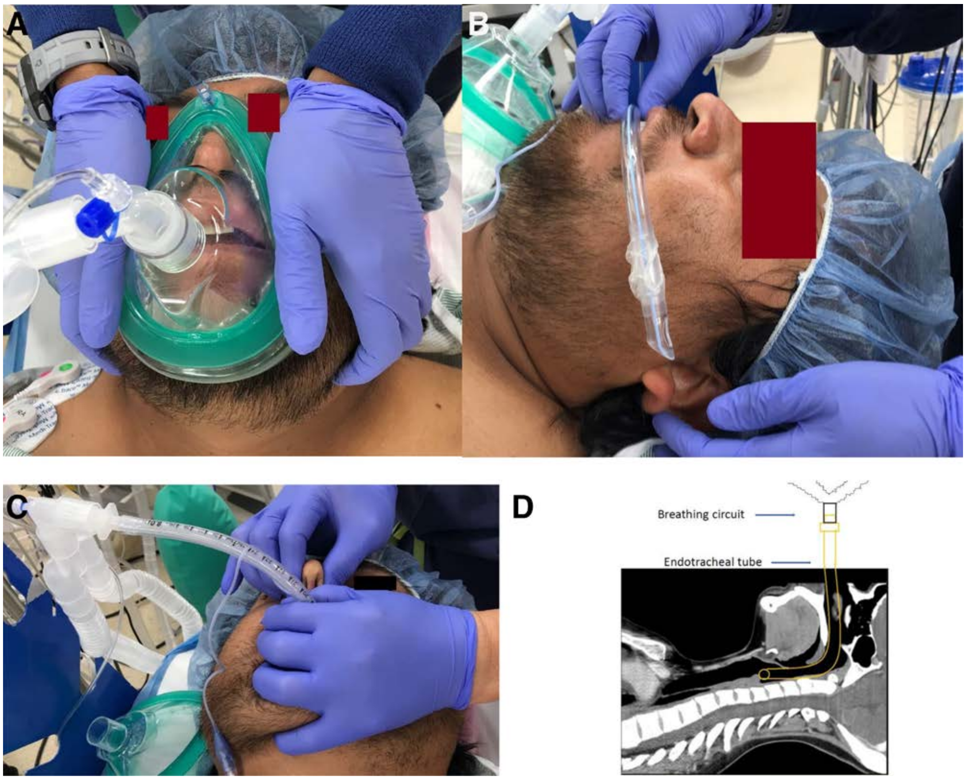

Figure 1. The application of a facemask and endotracheal tube in the pharynx (TTIP) should be done during ventilation. A, Mask ventilation using the V-E technique. B, How to determine the target depth of endotracheal tube in the pharynx. C, Application of endotracheal tube in the pharynx. D, Illustration of an endotracheal tube in the pharynx and upper airway anatomy.

technique is referred to in our previous publication.[24] For TTIP, the care team selected an appropriately sized (7.0 or 8.0mm) endotracheal tube (Parker Medical). The induction started after a brief on-site instruction on determining the target depth of tube insertion, inserting the tube, sealing the tube at the lips, and ventilating the patient. The depth of the endotracheal tube was equal to the curvature length from the ear canal to the upper incisor (Figure 1B). The provider used one hand to scissor the mouth open, and the second hand inserted the endotracheal tube blindly between the tongue and palate. The provider inserted the tube with the tube natural curvature in the alignment of the tongue curvature. If resistance occurred, the provider gently turned the tube clock and counterclocks to ease the insertion. Once the tube reached the target depth, the seal at the lips was achieved with a 2-hand technique, as shown in Figure 1C. The target location of the tip of the distal endotracheal tube is illustrated in Figure 1D. As with mask ventilation, the chin was kept up and the neck in the extended position.

Ventilation by connecting the breathing circuit to either the mask (Figure 1A) or the endotracheal tube (Figure 1C) was achieved with the operating room ventilator (Drager, Model – Apollo).

Sample Size Justification

Our primary outcome was the success rates of ventilation using a mask versus TTIP in patients with potentially difficult airways. A previous study reported a 34.6% failure rate of mask ventilation without nasal or oral airway insertion for morbidly obese patients with potentially difficult mask ventilation.[22] Assuming that our study population was similar to that of the previous study and TTIP will reduce the ventilation failure rate by 50 % (eg, 17.3 % failure for TTIP ventilation), a priori power analysis with type error I (α) < 0.05 and power of 80 % for primary analysis resulted in an estimated total sample size of at least 245 patients for a parallel study design and 132 patients for a crossover study design. Sample size justification was described in the detailed methodology (Supplemental Digital Content 1, Detailed Methodology, http://links.lww.com/AA/F126).

Statistical Analysis

We conducted a descriptive analysis to evaluate the distribution of patients' characteristics and reported frequencies and percentages for categorical variables and mean ± standard deviation (SD) for the continuous variables. To test the primary hypothesis, we performed random effect logistic regression analysis for ventilation success with ventilation technique (group), treatment step (period), and sequence effects included as fixed effects, and patient ID considered a random effect to account for intersubject variability. Specifically, we used a random coefficients model using a G-side random effect with the Variance Components covariance structure.

RESULTS

Demographic Data of the Patients and Training Levels of the Providers

The demographic and clinical characteristics of 147 patients are shown in Table 1. There was no significant difference in any characteristics between the 2 sequences. Eleven patients were excluded from the final analysis. In the tube first sequence, 3 cases were due to equipment failure, and 2 were due to protocol violation. In the mask first sequence, 3 cases were excluded due to protocol violation, 2 cases due to equipment failure, and 1 case was terminated by the care team after induction (Figure 2). One hundred and thirty-six patients, 71 in the Sequence of tube first and 65 in the Sequence of mask first ventilation, completed both Steps 1 and 2 and were included in the final analyses. There was no significant difference in the lowest Spo_2 reading during 2 steps of ventilation between the sequences, Mask first and Tube first ventilation, 98%(97,99) and 98%(97,99). One patient experienced brief hypoxia after trachea intubation during control ventilation, and the pulse oximetry reading returned above 94% in 1 minute. No other adverse event associated with the study was observed. The training levels of the providers who performed the mask and TTIP ventilation were also presented in Table 1. There was no significant difference in the training levels between the 2 sequences.

The Success of Ventilation via TTIP and Mask and Their Rescue Efficiency

The failure and success rates of TTIP and mask ventilation are shown in Table 2. Overall, the success rates of TTIP and mask ventilation were 93.4% (127/136) and 84.6% (115/136), respectively (P = .02). In the sequence of Tube first, 7 (9.9%) out of 71 patients failed Step 1 ventilation with TTIP. Of these 7 patients, 6 (85.7%) were successfully rescued with mask ventilation. In the sequence of mask first, 13 (20.0%) out of 65 patients failed mask ventilation. All 13 patients (100%) were successfully rescued with TTIP ventilation. There was no significant difference between the proportions of successful rescue (P = .35). One of 136 patients (0.7%) failed both a mask and TTIP ventilation. This patient was successfully intubated without an adverse event.

Adequacy of the Seal With Mask and TTIP

The mean of the ventilation parameters in patients who were successfully ventilated with both TTIP and mask are shown in Table 3 by sequences and treatment steps. There was no significant difference in the peak inspiratory airway pressure between the 2 interventions (95% CI): −0.1 (−0.3, 0.2), P = .53).

The Efficiency of Ventilation Assessed With End-Tidal Carbon Dioxide and Oxygen

The mean end-tidal carbon dioxide ($ETCO_2$) obtained from successful ventilation with TTIP was significantly higher than that with mask (34.4 ± 5.5 vs 32.7 ± 6.2 mm Hg, P < .01 in the sequence of Tube first, and 36.4 ± 4.1 vs 33.9 ± 4.1 mm Hg, P < .01 in the sequence of Mask first). The overall comparison after accounting for sequences and treatment steps (mean $ETCO_2$ difference between TTIP and mask (95% CI): 2.1 (1.3, 2.9) mm Hg, (P < .001). Overall, the mean expired oxygen fraction was not significantly different between TTIP (85.1%) and mask ventilation (84.8%) after accounting for sequences and treatment steps (95% CI): 0.3 (−0.6, 1.3), P = .47).

DISCUSSION

This study demonstrated that the success rate of TTIP ventilation is higher than that of the mask ventilation (2-hand V-E technique) without an oral or nasal airway insertion in patients with a potentially difficult airway. Further, TTIP and mask ventilation are mutually effective rescue techniques for each other.

The Efficiency of Ventilation With the 2 Techniques

Our results demonstrate no significant difference in peak inspiratory airway pressure obtained with the mask and TTIP ventilation. We standardized the ventilation settings. Therefore, we could indirectly compare the airway patency obtained via the 2 techniques. In actual practice, providers could choose either method, the bag or pressure mode ventilation. A recent crossover study demonstrated that pressure mode ventilation is superior to classic bag-mask ventilation.[25] Although we did not directly assess for air leaks during ventilation with these 2 techniques, the leak seemed well compensated with pressure mode ventilation since both techniques reached the target peak airway pressure. At the comparable peak inspiratory airway pressure, the expired tidal volume of patients with TTIP was significantly lower than that of mask ventilation (611.1 ± 318.1 mL vs 701.5 ± 352.4 mL, P < .01). The absolute difference is 90.4 mL, favoring mask ventilation. However, a facemask adds significant mechanical dead space from 32% to 42%.[26] We also determined the end-tidal carbon dioxide and oxygen to compare the minute alveolar ventilation of these 2 techniques. Overall, the mean expired oxygen concentration was not significantly different between the 2 ventilation techniques after accounting for the effect of sequences and interventions [mean expired oxygen difference between TTIP and mask ventilation (95% CI) 0.3 (−0.6 to 1.3)%, P = .47)]. Overall comparison of the end-tidal CO_2 [mean $ETCO_2$ difference between TTIP and mask ventilation (95% CI), 2.1 (1.3–2.9) mm Hg, P < .001)] favored mask ventilation. However, the difference in end-tidal carbon dioxide is statistically significant, but the clinical importance of the difference is not profound.

Table 1. Clinical Characteristics of the Patients and Training Levels of the Providers[a]

Variables	Total (N = 147)	Sequence of Tube first (n = 76)	Sequence of Mask first (n = 71)
Age (y, mean ± SD)	46.2 ± 14.0	47.8 ± 14.8	44.4 ± 13.0
Sex			
Male	66 (44.9)	32 (42.1)	34 (47.9)
Female	81 (55.1)	44 (57.9)	37 (52.1)
BMI (kg/m^2, mean ± SD)	36.3 ± 6.7	36.1 ± 7.3	36.6 ± 6.0
< 30	7 (4.8)	4 (5.3)	3 (4.2)
30 ≤BMI <40 (Class 1 and 2 obesity)	109 (74.1)	55 (72.4)	54 (76.1)
≥40 (Class 3 obesity)	31 (21.1)	17 (22.3)	14 (19.7)
ASA physical status			
I	4 (2.7)	2 (2.6)	2 (2.8)
II	66 (44.9)	31 (40.8)	35 (49.3)
III	76 (51.7)	43 (56.6)	33 (46.5)
IV	1 (0.68)	0 (0.0)	1 (1.4)
Mallampati class			
1	41 (27.9)	24 (31.6)	17 (23.9)
2	60 (40.8)	26 (34.2)	34 (47.9)
3	35 (23.8)	19 (25.0)	16 (22.5)
4	11 (7.5)	7 (9.2)	4 (5.6)
Patients with both BMI ≥30 and Mallampati class ≥3	42 (28.6)	23 (30.3)	19 (26.8)
Disqualified and excluded n (%)	11 (7.5)	5 (6.6)	6 (8.45)
Providers' training levels			
Attending anesthesiologists	17 (11.6)	9 (11.8)	8 (11.3)
Anesthesia assistants	36 (24.5)	19 (25.0)	17 (23.9)
Anesthesia residents	94 (63.9)	48 (63.2)	46 (64.8)

Data are reported as frequencies (percentages), otherwise as indicated.

Abbreviations: ASA, American Society of Anesthesiology Classification; BMI, body mass index; SD, standard deviation.

Data are reported as frequencies (percentages), otherwise as indicated.

[a]Providers who performed the mask ventilation and tube in pharynx ventilation. An attending anesthesiologist is an individual who has successfully completed 3 years of training in an ACGME-accredited program and has passed the American Board of Anesthesiology examination. An anesthesia resident is an individual who has undergone a minimum of 3 months of anesthesia training within our program, having administered mask ventilation in over 75 cases. An anesthesia assistant is an individual who has completed the requisite education and training as an Anesthesia Assistant student and has served in our institution as an Anesthesia Assistant for a minimum of 3 months, having performed mask ventilation in over 75 cases.

Our main goal of this study is to determine if TTIP can be a rescue technique for failed mask ventilation. All 13 patients who failed with mask ventilation were successfully rescued with TTIP. The success rate (6/7, or 85.7%) of mask-rescuing failed TTIP ventilation is also high. Only 1 of 136 (0.7%) patients failed both techniques in the very early phase of this study. We believe that our inadequacy in instructing the providers might contribute to the failure of both techniques. Therefore, these 2 techniques are mutually effective in rescuing each other. This study did not aim to prove the superiority of 1 technique over the other. However, we intended to demonstrate that the TTIP technique is a potential rescue technique when other commonly used methods fail.

Working Hypothesis TTIP Rescues Failed Mask Ventilation

The rationale for using TTIP to rescue a failed mask ventilation relies on positive pressure directly applied in the pharynx while avoiding a downward pressure gradient in the upper airway (Figure 3A). The positive pressure can be as high as the peak inspiratory pressure directly applied adjacent to the glottis. The high-pressure functions as a stent to keep the airway open and enables adequate ventilation. We believe that part of the efficacy of this technique results from bypassing the obstructed upper airway. This is because the upper airway is the most common location for obstruction while under general anesthesia.[16,27–29] In addition, positive pressure applied to the pharynx via TTIP creates an upward pressure gradient between the pharynx and the oral cavity. Such an upward pressure gradient would not worsen the upper airway obstruction. However, during classic mask ventilation, a downward pressure gradient exists between the oral cavity and the glottis with or without an oral airway. Such a downward pressure gradient may worsen airway obstruction (Figure 3B). Therefore, TTIP ventilation fundamentally differs from mask ventilation with oral airway insertion. Regardless of the mechanism of failed mask ventilation with or without oral or nasal airway insertion or failed SGA ventilation, adequate positive pressure must not reach the glottis. However, the mechanism of the failed ventilation with TTIP fundamentally differs from that of the other techniques. Therefore, TTIP is potentially a rescue technique for a failed mask or SGA ventilation. Of course, such a notion remains to be tested in the future.

Two potential scenarios that may render TTIP ineffective for ventilation are laryngospasms and major pulmonary aspiration/bronchospasm. Maintaining an adequate sedation level or administering a sufficient dose of a muscle relaxant or both should be adequate in

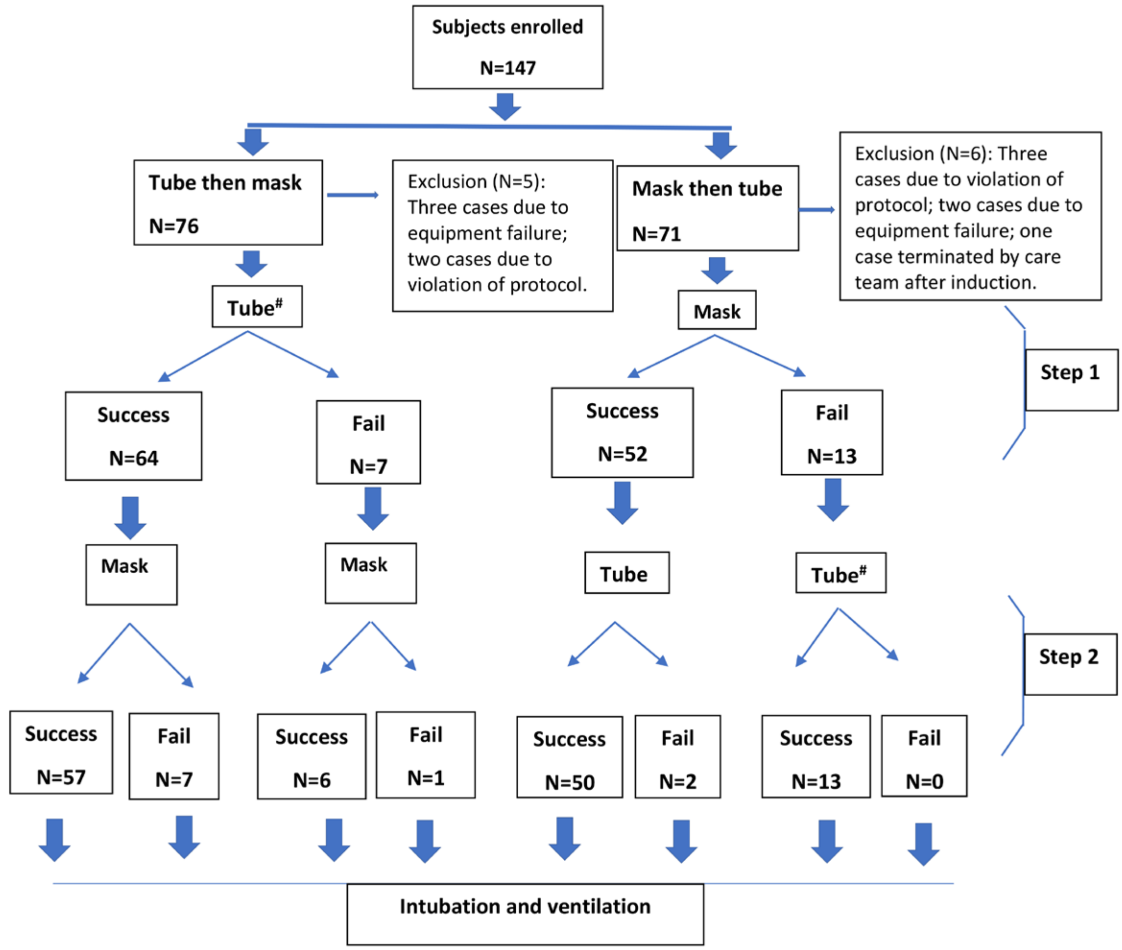

Figure 2. The algorithm of the study procedure. The numbers listed on the chart represent the number of patients. At each step, 10 breaths were the target for each intervention. Successful ventilation was at least one of the first 3 consecutive breaths demonstrating 3-phase end-tidal CO_2 on capnography. Tube# for an endotracheal tube in the pharynx.

overcoming laryngospasm.[30] If major pulmonary aspiration occurs, a standard aspiration protocol should be applied promptly, including tracheal intubation and endotracheal tube suction for the large particulate matter, which might potentially render ventilation ineffective.[31] In such a case, the ventilation via TTIP may be ineffective but should not be inferior to other techniques.

We tested the hypothesis by comparing the effectiveness of TTIP and mask ventilation without oral airway insertion in patients with potentially difficult mask ventilation. While we acknowledge that comparing TTIP and mask ventilation with the insertion of an oral airway would be ideal, as it has been demonstrated to improve success rates of patients with difficult airways, we were unable to perform such a comprehensive study due to resource limitations within our institution. To determine the sample size, we performed a calculation based on the

Table 2. The Failure and Success Rates of Rescue Using a Mask and Endotracheal Tube in the Pharynx Ventilation

												Overall (N = 136)		
		Tube first (n = 71)				Mask first (n = 65)					P^a	success		P^b
Step 1	Tube[c]	Fail (n = 7)		Success (n = 64)		Mask	Fail (n = 13)		Success (n = 52)			Tube[c]	Mask	
Step 2	Mask	Fail	Success (I)	Fail	Success	Tube[c]	Fail	Success (II)	Fail	Success	0.35	127 (93.4%)	115 (84.6%)	0.02
	n (%)	1 (14.3)	6 (85.7)	7 (10.9)	57 (89.1)		0	13 (100)	2 (3.8)	50 (96.1)				

[a]*P*-value that compares the proportion of patients who failed step 1 but were rescued with step 2 between the 2 sequences (column I vs II).
[b]*P*-value for the comparison between endotracheal tube in pharynx and mask based on random effect logistic regression analysis that accounts for both treatment step and sequence.
Tube
[c]for an endotracheal tube in the pharynx.

Table 3. Mean of an Endotracheal Tube in the Pharynx and Mask Ventilation Parameters In Patients Who Were Successfully Ventilated By Both Ventilation Methods

	Tube first (n = 57)			Mask first (n = 50)			Overall TTIP vs mask (n = 107)	
	Step 1:Tube[c]	Step 2: mask	P[a]	Step 1: mask	Step 2:Tube[c]	P[a]	Difference (95% CI)	P[b]
PIP (cmH_2O)	19.7 ± 0.9	20.4 ± 1.3	<0.01	19.4 ± 2.1	19.9 ± 1.3	0.04	−0.1 (−0.3 to 0.2)	0.53
Expired tidal volume (mL)	634 ± 349	727 ± 380	0.046	711 ± 313	599 ± 271	0.03	−102 (−168 to − 36)	<0.01
End-tidal CO_2 (mm Hg)	34.4 ± 5.5	32.7 ± 6.2	<0.01	33.9 ± 4.1	36.4 ± 4.1	<0.01	2.1 (1.3–2.9)	<0.001
FeO_2(%)	82.4 ± 9.7	85.4 ± 9.4	<0.01	81.5 ± 7.6	85.1 ± 5.7	<0.01	0.3 (−0.6 to 1.3)	0.47
FiO_2(%)	91.9 ± 7.8	91.9 ± 8.2	0.96	90.3 ± 7.5	91.3 ± 6.3	0.13	0.5 (−0.2 to 1.2)	0.17

Abbreviations: FeO_2, the fraction of expired oxygen; FiO_2, the fraction of inspired oxygen; PIP, peak inspiratory airway pressure.
[a]*P*-value for within-patient comparison of tube and mask in each sequence.
[b]*P*-value for the comparison between tube and mask based on a linear mixed model that accounts for both treatment step and sequence.
Tube
[c]for an endotracheal tube in the pharynx. Tube first, ventilation via an endotracheal tube in the pharynx first, followed by mask ventilation. Mask first, mask ventilation first, and then via an endotracheal tube in the pharynx.

closest relevant study conducted by Warters et al. In Warters' study,[32] the failure rate of mask ventilation with oral airway insertion was estimated to be 3.4% (3 failures out of 88 cases). Assuming TTIP reduces the failure rate by 50% (resulting in a 1.7% failure rate), which is clinically considered significant, a sample size of 2698 patients (1349 in each group) would be required to test our hypothesis. Such a comprehensive study will hopefully be completed in the future.

TTIP in the Context of Current Guidelines

Current guidelines recommend SGA as a rescue technique if failed mask ventilation and failed intubation occur.[3,5] However, the success rate of SGA rescuing "cannot intubate cannot oxygenate" in the perioperative setting is only 62.8% (95% CI, 52.2%–72.3%).[33] The success rate of SGAs rescuing failed mask ventilation or intubation in the prehospital setting is unknown. One retrospective study demonstrates that the success rate of the first attempted SGA insertion in the prehospital setting was 83% (n = 360).[34] A prospective study showed that the SGAglottic airway insertion success rate in the prehospital setting after 3 attempts was only 64.3%.[35] SGA rescuing failed mask ventilation and intubation in perioperative settings is unlikely to be more effective than TTIP. Therefore, TTIP seems a simple and effective rescue technique for managing a difficult airway. However, its efficiency of rescuing actual "cannot intubate and cannot oxygenate" is unknown. Of note, we do not intend to alter the current standard guidelines. This technique could be used when SGA devices, oral airways, or nasopharyngeal airways are not readily available or fail. We also believe it could serve as a potential bridge measure when the emergency surgical airway is called for or used concurrently with performing surgical airways. Performing TTIP ventilation does

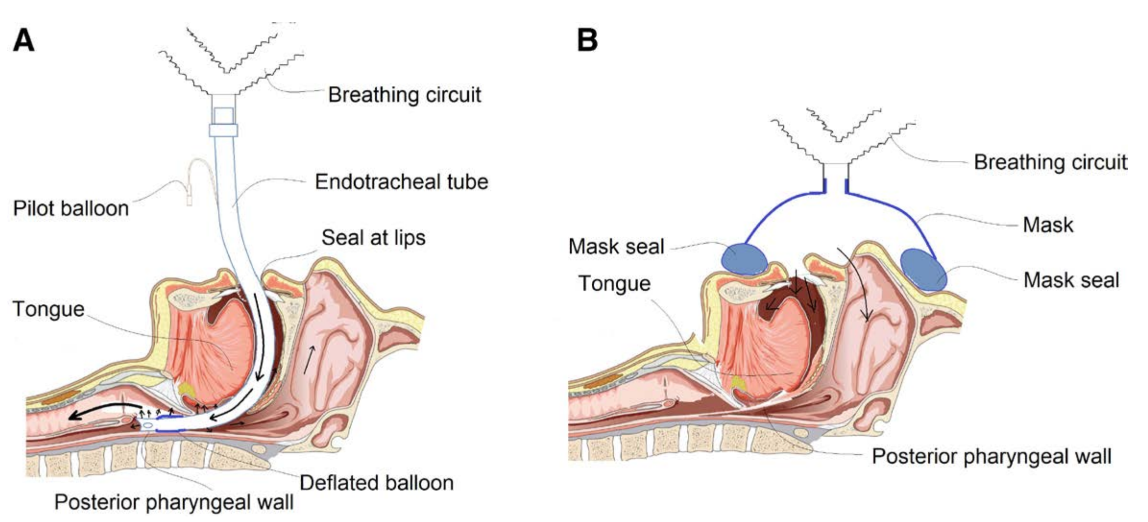

Figure 3. Schematic illustration of the mechanism of the endotracheal tube in the pharynx and mask ventilation. A, For endotracheal tube in the pharynx ventilation, the provider creates a seal at the lip, and inspiratory pressure functions as a stent to create a patent airway. The black arrows indicate the direction of airway flow and pressure gradient. B, For mask ventilation, the seal is at the face, and there is a downward pressure gradient between the oral cavity and the glottis without oral airway insertion. The pressure gradient may worsen airway obstruction. Even with oral airway insertion (not shown), airway obstruction may still occur if the distal opening of the oral airway is not at the glottis level, as the downward pressure gradient is still in effect.

not block the surgical field for emergency tracheostomy or cricothyroidotomy.

The Advantages and Challenges of TTIP Ventilation

TTIP has several advantages. First, inserting the endotracheal tube into the target depth is technically easy without other equipment. Although we did not formally assess the difficulty of applying TTIP, all the operators naïve to this technique could correctly insert the TTIP and ventilate the patients after brief on-site instruction. Second, this technique can be utilized in a patient with limited mouth opening. A patient only needs to have a mouth opening wide enough to allow passage of an endotracheal tube. It is important to emphasize that for an individual with a relatively small oro-pharyngeal cavity, SGA insertion may be impossible. An oral airway may push the tongue downward and worsen airway obstruction. Third, successful ventilation is independent of an adequate mask seal, which is required for mask ventilation. TTIP technique avoids scenarios that make obtaining a mask seal difficult, such as anatomically challenging facial structures like beards, lack of skin turgor, or facial trauma. Finally, it is independent of correct positioning as the tube cuff is not inflated in this technique, contrasting SGAs.

In our practice, we found that keeping the neck extended makes it easier to insert the endotracheal tube with its curvature in alignment with that of the tongue. If the resistance occurs, gently rotating the endotracheal tube clock- and counterclockwise facilitates tube insertion. We also observed that ventilation is most reliable when the neck is extended with the chin up, as is standard fashion with mask ventilation. If the neck flexes, ventilation via this technique can be challenging. If a leak occurs from the nose, a seal can be created by closing the nose and holding the lips around the tube with a single hand. Alternatively, the provider or an assistant can close the nose with 1 hand and seal the lips with the other.

There are several limitations to this study. First, we compared the efficiency of TTIP and mask ventilation without nasal or oral airway insertion. We realize that this is a confounding factor that may cause an overestimation of its efficiency, as an oral or nasal airway is frequently inserted when difficult mask ventilation occurs. A future study should compare the efficiency of TTIP ventilation with mask ventilation with oral or nasal airway insertion. However, it is essential to note that there is a fundamental difference between TTIP and mask with an oral airway insertion, as demonstrated in Figure 3. Second, since most providers were not attending anesthesiologists, the efficiency of ventilation with each technique could be different if providers were attending anesthesiologists. However, the number of mask ventilation the providers practiced was estimated to be at least 75, and they were considered experienced providers as after 27 mask ventilation, the providers archived their acceptable proficiency.[36] Therefore, our observation regarding the providers' training levels is generalizable. Third, the providers were not randomly assigned to the sequences and were not blind to the interventions. Therefore, bias may exist. On the other hand, the success rate of ventilation with TTIP is likely underestimated because all providers were naïve to this technique before this study, and the maximal number of performing TTIP ventilation for a provider was no more than 3. In addition, the nature of the crossover design of this study makes the performance of these techniques comparable. Fourth, based on the previous report, we arbitrarily chose the depth of endotracheal tube insertion for TTIP equal to the curvature length from the ear canal to the upper incisor.[37] Therefore, the depth of endotracheal tube insertion might not be optimal. Nevertheless, with potentially imperfect tube insertion depth, the success rate of ventilation via TTIP and rescuing failed mask ventilation is high. Fifth, we arbitrarily set the inspiratory airway pressure of 20 cm H_2O considering the commonly used pressure of 15–22 cmH_2O.[38] The efficiency of ventilation via TTIP and mask might be suboptimal for adequate ventilation. Sixth, we acknowledge that during tube insertion, the tip of the tube may extend into the upper portion of the esophagus due to the blind nature of the procedure and the estimation of the target depth. This could potentially lead to gastric insufflation. We utilized tubes of size 8.0 or smaller without cuff inflation. Consequently, achieving a seal of the distal portion of the tube in the upper esophagus is unlikely in an adult individual without signs of food impaction, given that the esophageal caliber must exceed 17mm.[39,40] Therefore, the risk of gastric insufflation with TTIP should not exceed that associated with mask ventilation at comparable peak airway pressure. We also appreciate the importance of the recent guidelines for preventing incidental esophageal intubation.[41] However, this guidance has been criticized.[42] Finally, we studied patients with potentially difficult airways and primarily focused on high BMI and/or a high Mallapati classification. The patients enrolled have at least 1 risk factor for a difficult airway. Subgroup analysis was not conducted for additional risk factors such as indenture, beard, and/or chin recession. Therefore, a comprehensive study is warranted to assess the ventilation efficiency of TTIP associated with each commonly observed risk factor. However, a previous study showed that 9 morbidly obese patients who failed mask ventilation after induction were all successfully ventilated via TTIP.[22] This is similar to what we observed in our study.

CONCLUSIONS

Ventilation via TTIP is as effective and safe as mask ventilation without oral or nasal airway insertion. This technique can serve as a reliable rescue method in cases of failed mask ventilation, offering a high success rate. Additionally, it presents a potential bridge technique when an emergency surgical airway is called for or performed simultaneously. Given its promising outcomes, it is warranted to conduct large-scale clinical trials to assess the effectiveness of using TTIP as a rescue technique for failed SGA or mask ventilation with an oral or nasal airway insertion.

ACKNOWLEDGMENTS

We acknowledge the support partially provided by the Department of Anesthesiology and the Biostatistics/Epidemiology/Research Design (BERD) component of the Center for Clinical and Translational Sciences (CCTS), the University of Texas Health Science Center at Houston, for this project that is currently funded through a grant (UL1TR003167), funded by the National Center for Advancing Translational Sciences (NCATS), awarded to the University of Texas Health Science Center at Houston. The content is solely the authors' responsibility and does not necessarily represent the official views of the NCATS. We also thank Dr Jamal Ojeaga and Dr Triana Fernandez for their assistance in enrolling the study patients.

DISCLOSURES

Conflicts of Interest: The University of Texas Health Science Center at Houston, McGovern Medical School, has filed a patent application for an airway device on behalf of Dr Y. Jiang. No other authors declared Conflicts of Interest. **Funding:** This study was supported partially by the Department of Anesthesiology and the Biostatistics/ Epidemiology/ Research Design (BERD) component of the Center for Clinical and Translational Sciences (CCTS), the University of Texas Health Science Center at Houston, and the grant (UL1TR003167), funded by the National Center for Advancing Translational Sciences (NCATS), awarded to the University of Texas Health Science Center at Houston. **This manuscript was handled by:** Narasimhan Jagannathan.

REFERENCES

1. Joffe AM, Aziz MF, Posner KL, Duggan LV, Mincer SL, Domino KB. Management of difficult tracheal intubation: a closed claims analysis. *Anesthesiology*. 2019;131:818–829.
2. Cook TM, Woodall N, Harper J, Benger J; 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 2: intensive care and emergency departments. *Br J Anaesth*. 2011;106:632–642.
3. Apfelbaum JL, Hagberg CA, Connis RT, et al. 2022 American Society of Anesthesiologists Practice Guidelines for Management of the Difficult Airway. *Anesthesiology*. 2022;136:31–81.
4. Tachibana N, Niiyama Y, Yamakage M. Incidence of cannot intubate-cannot ventilate (CICV): results of a 3-year retrospective multicenter clinical study in a network of university hospitals. *J Anesth*. 2015;29:326–330.
5. Frerk C, Mitchell VS, McNarry AF, et al; Difficult Airway Society intubation guidelines working group. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. *Br J Anaesth*. 2015;115:827–848.
6. 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.
7. Japanese Society of Anesthesiologists. JSA airway management guideline 2014: to improve the safety of induction of anesthesia. *J Anesth*. 2014;28:482–493.
8. Kaniyil S, Pavithran P, Rajesh MC, Arun Krishna AK, Venugopal V, Samuel SJ. All India Difficult Airway Association guidelines in practice: a survey. *Indian J Anaesth*. 2021;65:471–478.
9. Edelman DA, Perkins EJ, Brewster DJ. Difficult airway management algorithms: a directed review. *Anaesthesia*. 2019;74:1175–1185.
10. Heidegger T. Management of the difficult airway. *N Engl J Med*. 2021;384:1836–1847.
11. Morton S, Avery P, Kua J, O'Meara M. Success rate of prehospital emergency front-of-neck access (FONA): a systematic review and meta-analysis. *Br J Anaesth*. 2023;130:636–644.
12. Roth D, Pace NL, Lee A, et al. Airway physical examination tests for detection of difficult airway management in apparently normal adult patients. *Cochrane Database Syst Rev*. 2018;5:Cd008874.
13. 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.
14. Fei M, Wanderer JP, Jiang Y, St Jacques PJ. Association between the availability of videolaryngoscopes and the incidence of emergency surgical airway in the perioperative setting of a large academic medical centre: a retrospective observational study. *Br J Anaesth*. 2016;117:824–826.
15. Hillman DR, Platt PR, Eastwood PR. Anesthesia, sleep, and upper airway collapsibility. *Anesthesiol Clin*. 2010;28:443–455.
16. Eastwood PR, Szollosi I, Platt PR, Hillman DR. Collapsibility of the upper airway during anesthesia with isoflurane. *Anesthesiology*. 2002;97:786–793.
17. Isono S, Tanaka A, Nishino T. Dynamic interaction between the tongue and soft palate during obstructive apnea in anesthetized patients with sleep-disordered breathing. *J Appl Physiol*. 2003;95:2257–2264.
18. Hauswald M, Ong G, Hun YB, Tan PS. Use of the endotracheal tube as a pharyngeal airway. *Am J Emerg Med*. 1996;14:48–49.
19. Panadero A, Monedero P, Olavide I, Fernández-Liesa I, Mendieta JM, Macías A. Inflation of the endotracheal tube cuff in the pharynx for ventilation of paralyzed patients with unanticipated difficult airway. *Anesthesiology*. 1999;91:1178–1179.
20. Boyce JR. Poor man's LMA: achieving adequate ventilation with a poor mask seal. *Can J Anaesth*. 2001;48:483–485.
21. Kristensen MS. Tube tip in pharynx (TTIP) ventilation: simple establishment of ventilation in case of failed mask ventilation. *Acta Anaesthesiol Scand*. 2005;49:252–256.
22. Boyce JR, Ness T, Castroman P, Gleysteen JJ. A preliminary study of the optimal anesthesia positioning for the morbidly obese patient. *Obes Surg*. 2003;13:4–9.
23. Lenhardt R, Akca O, Obal D, Businger J, Cooke E. Nasopharyngeal ventilation compared to facemask ventilation: a prospective, randomized, crossover trial in two different elective cohorts. *Cureus*. 2023;15:e39049.

24. Fei M, Blair JL, Rice MJ, et al. Comparison of effectiveness of two commonly used two-handed mask ventilation techniques on unconscious apnoeic obese adults. *Br J Anaesth*. 2017;118:618–624.
25. Fogarty M, Kuck K, Orr J, Sakata D. A comparison of controlled ventilation with a noninvasive ventilator versus traditional mask ventilation. *J Clin Monit Comput*. 2020;34:771–777.
26. Saatci E, Miller DM, Stell IM, Lee KC, Moxham J. Dynamic dead space in face masks used with noninvasive ventilators: a lung model study. *Eur Respir J*. 2004;23:129–135.
27. Mathru M, Esch O, Lang J, et al. Magnetic resonance imaging of the upper airway. Effects of propofol anesthesia and nasal continuous positive airway pressure in humans. *Anesthesiology*. 1996;84:273–279.
28. Isono S, Tanaka A, Tagaito Y, Ishikawa T, Nishino T. Influences of head positions and bite opening on collapsibility of the passive pharynx. *J Appl Physiol*. 2004;97:339–346.
29. Nandi PR, Charlesworth CH, Taylor SJ, Nunn JF, Doré CJ. Effect of general anaesthesia on the pharynx. *Br J Anaesth*. 1991;66:157–162.
30. Gavel G, Walker R. Extubation guidelines: management of laryngospasm. *Anaesthesia*. 2012;67:920–1.
31. Beck-Schimmer B, Bonvini JM, Bonvini JM. Bronchoaspiration: incidence, consequences and management. *Eur J Anaesthesiol*. 2011;28:78–84.
32. Warters RD, Szabo TA, Spinale FG, DeSantis SM, Reves JG. The effect of neuromuscular blockade on mask ventilation. *Anaesthesia*. 2011;66:163–167.
33. Thomsen JLD, Nørskov AK, Rosenstock CV. Supraglottic airway devices in difficult airway management: a retrospective cohort study of 658,104 general anaesthetics registered in the Danish Anaesthesia Database. *Anaesthesia*. 2019;74:151–157.
34. Lee AF, Chien YC, Lee BC, et al. Effect of Placement of a Supraglottic Airway Device vs Endotracheal Intubation on Return of Spontaneous Circulation in Adults With Out-of-Hospital Cardiac Arrest in Taipei, Taiwan: A Cluster Randomized Clinical Trial. *JAMA Netw Open*. 2022;5:e2148871.
35. Murray MJ, Vermeulen MJ, Morrison LJ, Waite T. Evaluation of prehospital insertion of the laryngeal mask airway by primary care paramedics with only classroom mannequin training. *Cjem*. 2002;4:338–343.
36. Komatsu R, Kasuya Y, Yogo H, et al. Learning curves for bag-and-mask ventilation and orotracheal intubation: an application of the cumulative sum method. *Anesthesiology*. 2010;112:1525–1531.
37. Pak HJ, Hong BH, Lee WH. Assessment of airway length of Korean adults and children for otolaryngology and ophthalmic surgery using a fiberoptic bronchoscope. *Korean J Anesthesiol*. 2010;59:249–255.
38. Karalapillai D, Weinberg L, Galtieri J, et al. Current ventilation practice during general anaesthesia: a prospective audit in Melbourne, Australia. *BMC Anesthesiol*. 2014;14:85.
39. Schatzki R. The lower esophageal ring. Long term follow-up of symptomatic and asymptomatic asymptomatic rings. *Am J Roentgenol Radium Ther Nucl Med*. 1963;90:805–810.
40. Nicodème F, Hirano I, Chen J, et al. Esophageal distensibility as a measure of disease severity in patients with eosinophilic esophagitis. *Clin Gastroenterol Hepatol*. 2013;11:1101–1107.e1.
41. Chrimes N, Higgs A, Hagberg CA, et al. Preventing unrecognised oesophageal intubation: a consensus guideline from the Project for Universal Management of Airways and international airway societies. *Anaesthesia*. 2022;77:1395–1415.
42. Qureshi T, Hutton P, Pandit JJ. Sharpening PUMA's teeth: improving guidance for capnography to confirm tracheal intubation in cardiopulmonary resuscitation. *Anaesthesia*. 2023;78:937–942.