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ORIGINAL RESEARCH

Learning curve of fiber-optic orotracheal intubation guided by the nasopharyngeal airway in anesthetized patients

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Abstract

Background: Flexible orotracheal intubation poses a challenge for novice trainees owing to its comparatively low success rate. It is hypothesized that the preplacement of a Nasopharyngeal Airway (NPA) could serve as a guide for the fiber-optic bronchoscope,to enhance the likelihood of successful intubation. **Methods**: Sixteen novice anesthesia trainees were divided into either a guidance group (G group) or a conventional group (C group), with eight trainees in each cohort. Each participant conducted 20 consecutive intubation attempts on anesthetized patients undergoing elective procedures. In the G group, an NPA was prepositioned, and trainees were instructed to locate its tip to guide the flexible fiber-optic bronchoscope towards the glottis during intubation. Conversely, in the C group, trainees performed conventional fiber-optic orotracheal intubation directly following anesthesia induction. The primary outcome assessed was the rate of successful first-attempt intubation, while secondary outcomes included time to glottis exposure, intubation duration, trainee learning curve, and airway-related complications. **Results**: The comparative analysis indicated that novice residents from the G group demonstrated a significantly higher success rate of first-attempt orotracheal intubation using a flexible fiber-optic bronchoscope, reduced times of glottis exposure and intubation, and a steeper learning curve compared to those from the C group ($p < 0.05$). Moreover, no significant differences in airway-related complications were observed between the groups. **Conclusions**: The study suggested that the use of a preplaced NPA device as a guide for advancing the fiber-optic bronchoscope significantly improved success rate and enabled novice residents to achieve proficiency in fiber-optic orotracheal intubation in anesthetized patients with normal airways.

Keywords

Learning curve; Nasopharyngeal airway; Fiberoptic orotracheal intubation; Anaesthetic trainee

1. Introduction

The 2015 Difficult Airway Society (DAS) guidelines update recommends fiber-optic orotracheal intubation through a supraglottic airway device as a secondary option after an unsuccessful initial attempt [1]. Similarly, the 2022 American Society of Anesthesiologists Practice Guidelines suggest fiber-optic orotracheal intubation both for anticipated difficult airways and unexpected challenges [2]. However, research indicates a low 34.1% success rate on the first try for fiber-optic orotracheal intubation in patients without identified difficult airways [3]. Therefore, conducting orotracheal intubation with a flexible fiber-optic bronchoscope demands a deep understanding of anatomy and precise coordination to guide the scope to the glottis visually, and novices may struggle to locate the epiglottis using the mouth approach due to limited visibility. Considering that multiple intubation attempts significantly increase the risk of airway-related complications [4–6], developing additional strategies to facilitate fiber-optic orotracheal intubation is crucial for effective airway management.

The nasopharyngeal airway (NPA), typically a hollow tube made of plastic or soft rubber to minimize the risk of vomiting, is recommended as the preferred airway adjunct for conscious patients due to its ability to maintain airway patency and facilitate oxygenation in challenging situations [7]. The NPA helps maintain airway patency, particularly in challenging oxygenation situations. Its insertion through the nasal cavity is simple, and it can be readily identified under the fiber-optic bronchoscope. Positioned ideally above the glottis [8], the front end of the NPA serves as a practical guide, directing the fiber-optic bronchoscope toward the glottis. Additionally, Cumulative Sum (CUSUM) analysis is widely utilized in learning

curve studies for various clinical skills, including endotracheal intubation, epidural anesthesia and arterial catheterization [9–11]. However, further research is needed to clarify the impact of a preplaced NPA on the success rate and learning curve of novices conducting fiber-optic orotracheal intubation.

The study aims to evaluate the efficacy of a preplaced NPA in improving the success rate and decreasing intubation time during fiber-optic orotracheal intubation in patients without anticipated difficult airways and to determine the number of attempts need to attain proficiency in fiber-optic orotracheal intubation using CUSUM analysis, while also documenting any airway-related complications.

2. Materials and methods

2.1 Patient enrollment

The study was conducted from October 2020 to June 2021 at the First Affiliated Hospital of Wenzhou Medical University. Adult patients of any gender, scheduled for elective non-Ear Nose and Throat (ENT) or non-airway procedures requiring endotracheal intubation for general anesthesia were screened for eligibility. The inclusion criteria comprised (1) ASA physical status I or II, (2) aged between 16 and 70 years, (3) had a body mass index (BMI) between 18 and 25 kg/m^2, (4) an anticipated duration of general anesthesia for 1–3 hours, and (5) no evidence of a predictable difficult airway, as assessed by two attending anesthesiologists using the recommended criteria [12]. Exclusion criteria were medical history of coagulation disorders, presense of nasal tumours, skull base fractures, previous history of airway and cervical surgery, other oral or cervical deformities and pregnancy. Sixteen anesthesiology residents in their first year of training were recruited and randomized into two groups: a guidance group (G group) and a conventional group (C group), using computer-generated numbers. Eligible participants were required to have completed at least 100 intubations using video laryngoscopy, with those having prior experience in fiber-optic orotracheal intubation being excluded. Before the start of the study, all trainees received instruction on selecting the appropriate size of NPA and on using the flexible fiber-optic bronchoscope with an intubation manikin. Additionally, they were provided with a standardized training video detailing the anatomy of the nasopharynx and demonstrating the steps for fiber-optic orotracheal intubation. Then, each trainee performed 20 consecutive fiber-optic orotracheal intubations (defined as attempts 1–20, one case per day, over 20 days), and each intubation procedure was supervised by the same experienced attending anesthesiologist, with relevant intubation data being systematically recorded.

2.2 Anesthesia induction

All patients were required to fast for a minimum of 8 hours before the procedure, with no premedication administered. Following standard monitoring, the patients were pre-oxygenated to achieve an end-tidal oxygen concentration of at least 80% before anesthesia induction, which included intravenous administration of sufentanil (0.3 μg/kg), propofol (2 mg/kg), and rocuronium (0.9 mg/kg). Manual ventilation with 100% oxygen via a mask was provided for 2 minutes preceding endotracheal intubation.

2.3 Insertion of NPA

The appropriate size of the NPA (Wellead, China) was determined by measuring the distance from the philtrum to the ear tragus, which also indicated the depth to which the NPA should be advanced [8]. An anesthetic comprising lidocaine and phenylephrine (1 mL of phenylephrine 1% in 4 mL of lidocaine 2%) was used to anesthetize the nasal mucosa in the right nasal cavity, followed by the application of a water-based lubricant to the NPA tip. Subsequently, the NPA was advanced horizontally into the more patent nostril along the septum, following the natural curvature of the nasopharyngeal cavity floor. In the guidance group (G group), trainees were required to first locate the tip of the blue NPA, which then served as a guide for directing the flexible fiber-optic bronchoscope to the glottis during fiber-optic orotracheal intubation. Conversely, in the conventional group (C group), no NPA was utilized, and trainees performed fiber-optic orotracheal intubation directly after anesthesia induction.

2.4 Intubation and anesthetic management

A flexible fiber-optic bronchoscope (Pentax FB-15X, Montvale, NJ, USA) equipped with a lubricated cuffed endotracheal tube (size: 7 or 7.5) was introduced via a trans-oral approach, and the surface of the tube was lubricated with a water-based lubricant before insertion. To ensure a clear airway and facilitate visualization of the epiglottis during intubation, a jaw thrust was routinely applied, and the force was adjusted as necessary. Adjustments to the position of the patient's head and neck were made to assist the residents in performing the procedure. Once a clear view of the glottis was obtained, the flexible fiber-optic bronchoscope was advanced into the trachea, guiding the endotracheal tube into place.

Sevoflurane administration began after intubation, maintaining the end-tidal sevoflurane concentration between 2–2.5% to ensure adequate anesthesia. Mechanical ventilation settings were adjusted to maintain the end-tidal carbon dioxide concentration within 35–45 mmHg. After completing general anesthesia, the endotracheal tube was removed based on standard criteria for extubation. An investigator, unaware of group allocation, evaluated intubation-related airway complications, such as sore throat, hoarseness, oral mucosal injury and laryngeal edema.

2.5 Outcomes

The primary outcome evaluated was the success rate of first-attempt intubation, defined as the accurate insertion of the endotracheal tube into the trachea on the initial attempt. Confirmation of correct tube placement was based on the observation of five consecutive, normal-appearing end-tidal carbon dioxide waveforms. An attempt was considered unsuccessful if intubation could not be achieved within 150 seconds or if the endotracheal tube was incorrectly positioned. In cases where trainees from either group failed in their intubation attempts, patients were promptly administered additional intravenous

propofol (0.5–1 mg/kg) followed by 2 minutes of manual ventilation with 100% oxygen. Subsequently video laryngoscopy was performed as a rescue procedure to ensure airway patency by the supervising anesthesiologist to ensure airway patency.

Secondary outcomes comprised the time to glottis exposure, intubation time, the learning curve of the resident, and airway-related complications:

(1) Time of glottis exposure: This was measured in seconds from the moment the tip of the flexible fiber-optic bronchoscope passed the patient's teeth to when an adequate view of the glottis was obtained. Failure to visualize the glottis within 120 seconds led to exclusion from the final glottis exposure time analysis.

(2) Time of intubation: Intubation time began when the tip of the fiber-optic bronchoscope passed the patient's teeth and ended once five consecutive end-tidal carbon dioxide waveforms were observed. Patients with unsuccessful first attempts were excluded from the intubation time analysis.

(3) Learning curve of the resident: The learning curves of the residents were determined by recording the number of successful and unsuccessful orotracheal intubations across 20 attempts. Additionally, proficiency in fiber-optic orotracheal intubation was defined as a stable 95% success rate, and the attempts required to achieve this were recorded by an investigator [13, 14].

(4) Airway-related complications: These include sore throat, hoarseness, oral mucosal injury and dysrhythmia, were documented within 24 hours after extubation.

2.6 CUSUM analysis

For this study, an acceptable failure rate for fiber-optic orotracheal intubation was established at 5% (0.05), referencing studies by Schaefer *et al.* [13] and Smith *et al.* [14]. CUSUM analysis was performed to monitor skill acquisition progression, which was defined as:

Sn = Σ (Xn − f0), where Xn = 0 for success and 1 for failure, with n representing the attempt number and f0 = representing the acceptable failure rate [15, 16].

The learning curves for anesthesiology residents from both groups were constructed by plotting the number of attempts (abscissa) against the CUSUM values (ordinate). Polynomial function curves were derived using MATLAB software (version 8.6, The MathWorks, Natick, MA, USA). The point at which the first integral of X after the curve's peak occurs indicates the minimum number of cases required for a trainee to master this skill.

2.7 Sample size calculation

Sample size calculation was based on a precedent study [13], where each trainee underwent 20 attempts at fiber-optic orotracheal intubation to assess the learning curve. As all 16 first-year anesthesiology residents participated in the fiber-optic training course, a total of 160 patients per group was deemed to be necessary.

2.8 Statistical analysis

Data analysis was performed SPSS 20.0 software (SPSS Inc., Armonk, NY, USA). Continuous data following a normal distribution are presented as mean ± standard deviation, with differences between groups assessed using Student's *t*-test. Categorical data are expressed as numbers (%) and analyzed using the chi-squared test for inter-group comparisons. The incidence of trainees from each group exceeding designated intervention thresholds in their CUSUM plots was analyzed using the χ^2 test. Median CUSUM scores at each attempt were compared between groups using the Mann-Whitney U test. A p value < 0.05 was considered statistically significant.

3. Results

3.1 Patients clinical characteristics

Of the 360 participants screened, 320 were enrolled and evenly distributed into the G and C groups, with 160 participants in each. No significant differences were observed between the groups regarding age, body mass index, gender, Mallampati grade, or duration of anesthesia ($p > 0.05$). The demographic and clinical data of the enrolled patients are summarized in Table 1.

3.2 Intubation success rate

In the first 150 seconds, the G group achieved a 93.13% success rate for first-attempt orotracheal intubation using a flexible fiber-optic bronchoscope, compared to 85.63% in the C group with the conventional method ($p < 0.05$, Table 2). In instances where the initial attempt failed, both groups attained a 100% success rate for the second attempt using video laryngoscopy.

3.3 Time of glottis exposure and intubation

In Table 3, it can be observed that the time needed for glottis exposure was notably decreased in the G group compared to the C group ($p < 0.05$). Likewise, the duration of fiber-optic orotracheal intubation was significantly shorter when guided by a preplaced oropharyngeal airway.

3.4 Learning curve

The success rate for tracheal intubation approached 100% after seven attempts with the guidance of the oropharyngeal airway device. In contrast, success using the conventional method remained below 80% before the ninth attempt and only exceeded 90% only after 12 attempts. Fig. 1 illustrates that a minimum of eight attempts was necessary for the G group to master fiber-optic orotracheal intubation, while the C group required 13 attempts (Fig. 2). CUSUM analysis revealed a steeper learning curve in the G group compared to the C group.

3.5 Airway-related complications

The incidence of airway-related complications following intubation was comparable between the two groups, with no significant differences observed in the occurrence of sore throat, hoarseness, oral mucosal injury or laryngeal edema ($p > 0.05$,

TABLE 1. Clinical characteristics of the patients in two groups.

Group	Age (yr)	BMI (kg/m^2)	Gender (M/F)	Mallampati grade (I/II)	Anesthesia duration (min)
C (n = 160)	50 ± 12	22.5 ± 1.8	59/101	82/78	119 ± 15
G (n = 160)	49 ± 11	22.3 ± 1.8	58/102	83/77	123 ± 21

Note: Data are presented as mean ± standard deviation or numbers. BMI: body mass index; M: Male; F: Female.

TABLE 2. Success rate of intubation in two groups.

Group	Successful first-attempt intubation	Successful second-attempt intubation
C	137 (85.63%)	23 (100%)
G	149 (93.13%)	11 (100%)

Note: Data are presented as number (%).

TABLE 3. Intubation data in two groups.

Group	Time of glottis exposure (s)	Time of intubation (s)
C (n = 137)	57.1 ± 13.8	98.0 ± 15.9
G (n = 149)	46.1 ± 18.5	82.2 ± 12.8

Note: Data are presented as mean ± standard deviation.

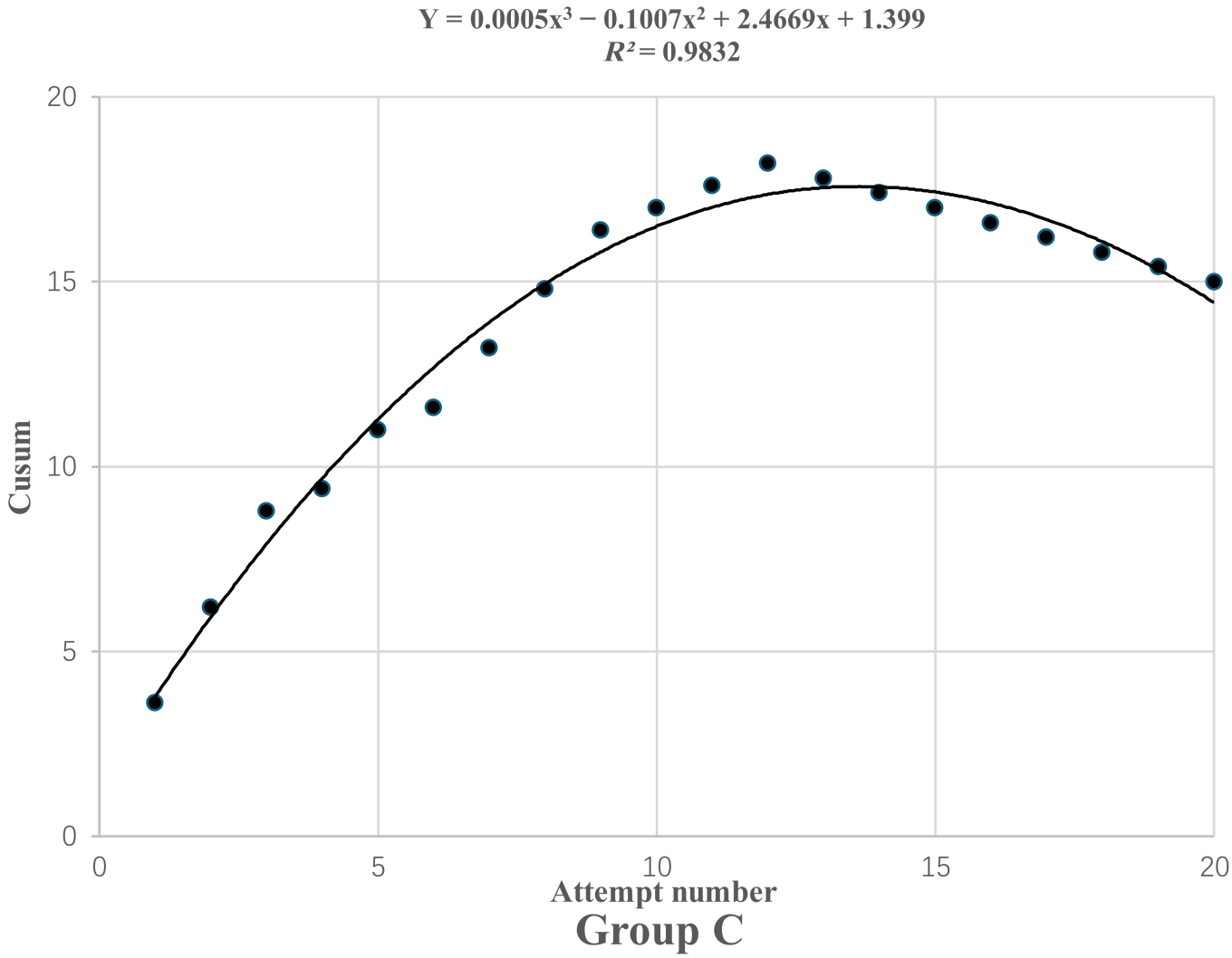

FIGURE 1. The learning curve of Group C.

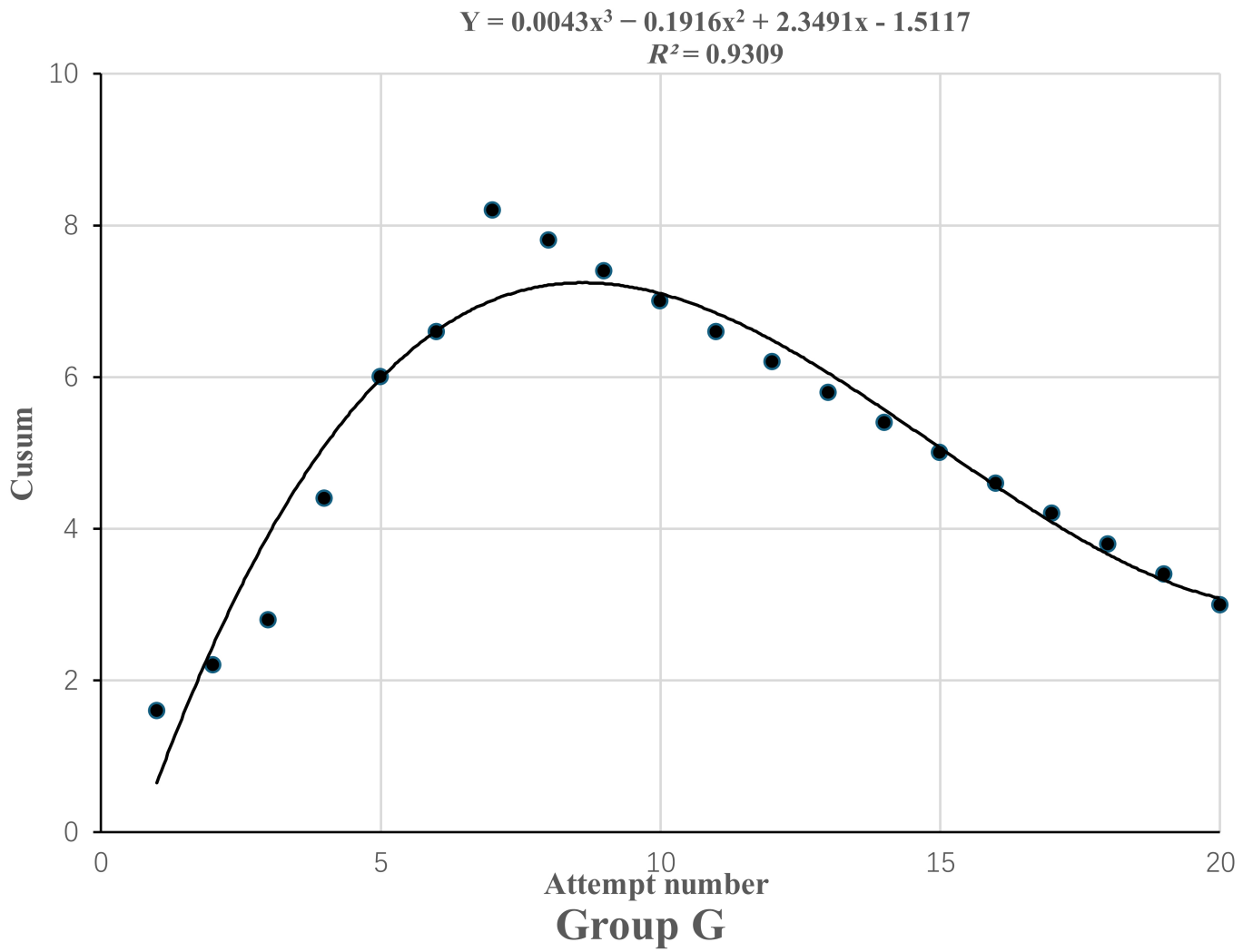

FIGURE 2. The learning curve of Group G.

Table 4).

4. Discussion

The results of this study suggest that employing an NPA device to guide the advancement of a flexible fiber-optic bronchoscope improves the success rate and decreases the time needed for fiber-optic orotracheal intubation among novice anesthesia residents. Moreover, the utilization of an NPA device has been demonstrated to assist novice residents in attaining proficiency in performing fiber-optic orotracheal intubation.

A previous study reported that novice anesthesiologists could achieve competency in fiber-optic orotracheal intubation, define as first-attempt intubation success rates of ≥80%, after 15 procedures following standardized training by experienced anesthesiologists [17]. To improve the success rate of fiber-optic orotracheal intubation, various devices have been designed to facilitate intubation via an oral approach are available. For instance, a case study highlighted the use of a modified Guedel airway to assist fiber-optic orotracheal intubation in unexpectedly difficult airway situations [18]. While orally applied devices and supraglottic airways are useful conduits for tracheal intubation, they are often poorly tolerated by awake patients. In contrast, NPA placement can help maintain oxygenation and ventilation in sedated patients [19, 20]. Although this study focused on anesthetized patients without difficult airways, the findings are expected to inform strategies for awake orotracheal intubation in patients with airway challenges. The use of an NPA to direct fiber-optic orotracheal intubation seems applicable in these clinical scenarios. As shown by our results, preplaced NPA device placement can increase the first-attempt intubation success rate and decrease the time needed for glottis visualization during fiber-optic orotracheal intubation. CUSUM analysis was used to determine the number of intubation attempts required for novices to master the technique of fiber-optic orotracheal intubation. The analysis revealed that the success rate of fiber-optic orotracheal intubation improved with the increasing number of intubations performed by the residents, and novices using this new strategy were able to achieve proficiency more readily after a certain number of intubation attempts.

It has been reported that the jaw-thrust maneuver can effectively clear the airway during fiber-optic intubation by keeping the epiglottis away from the posterior pharyngeal wall and preventing the tongue from obstructing the uvula and soft palate [21]. Additionally, the jaw-thrust technique significantly im-

TABLE 4. Airway-related complications in two groups.

Complications	C group	G group
Sore throat	15 (9.4%)	13 (8.1%)
Hoarseness	9 (5.6%)	10 (6.3%)
Oral mucosal injury	7 (4.3%)	5 (3.1%)
Laryngeal edema	2 (1.3%)	1 (0.6%)

Note: Data are presented as number (%).

proved the success rate of the first intubation attempt and reduced the time required for endotracheal tube advancement during oral fiber-optic intubation by facilitating the tracheal tube's passage over the bronchoscope [3]. The effectiveness of the pre-inserted NPA device in assisting fiber-optic orotracheal intubation may be more noticeable in the absence of the jaw-thrust maneuver, indicating a need for further research. Moreover, the incidence of sore throat, hoarseness, oral mucosal injury, and dysrhythmia among patients undergoing fiber-optic orotracheal intubation with NPA device assistance was comparable to that of the conventional method. This study primarily assessed the success rate of the initial intubation attempt, excluding any subsequent attempts at fiber-optic orotracheal intubation following a failed first attempt, and we hypothesized that permitting multiple intubation attempts could impact the outcomes, potentially increasing the risk of airway-related complications [4–6] due to repeated attempts.

There were several limitations in this study. First, while the use of a pre-inserted NPA device as a guide for the advancement of the fiber-optic bronchoscope in patients with normal airways was found to be beneficial, replicating this study in patients with difficult airways should still be investigated. Fiber-optic orotracheal intubation is a preferred technique for managing challenging airways, making it essential to further determine its efficacy in such cases. Second, the lack of facilities for formal training in this critical area poses a concern. For instance, the absence of adequate difficult airway maneuvers in this study variations among dividual patients should be considered when interpreting the findings. Third, although the placement of the NPA may lead to potential nasal complications, using a lubricated, soft nasopharyngeal airway generally minimizes the risk of severe injuries and is well tolerated by patients. Lastly, the force applied during the jaw-thrust maneuver to aid in visualizing the epiglottis during fiber-optic orotracheal intubation was not objectively measured or standardized, as it was performed by the same investigator throughout the study.

5. Conclusions

The utilization of a nasopharyngeal airway device to guide the advancement of the flexible fiber-optic bronchoscope has been shown to improve the overall success rate of intubation. In addition, it decreased the time required to complete the intubation procedure and helped novice residents master fiber-optic orotracheal intubation in anesthetized patients with normal airways.

AVAILABILITY OF DATA AND MATERIALS

All data included in this study are available upon request by contact with the corresponding author.

AUTHOR CONTRIBUTIONS

SLC and LRW—designed the study, performed the data analysis, and wrote the manuscript. CJN and LLL—aided with study design, data collection, data analysis and review of the data and manuscript. All authors read and approved the submitted manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by Ethics Committee of the First Affiliated Hospital of Wenzhou Medical University (NO. KY2020-053) and registered in the Clinical Trial Registry (29 May 2021; NO. ChiCTR2100046896). All participants or their family caregivers provided an oral and written informed consent in conformity with the ethics approval.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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