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Original Article

The impact of different muscle relaxation depths on the placement of the i-gel laryngeal mask and the analysis of influencing factors on postoperative sore throat: a retrospective study based on general anesthesia in adult patients

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Abstract: Objectives: To investigate the impact of varying neuromuscular blockade (NMB) depths on the success of i-gel laryngeal mask airway (LMA) insertion and to examine determinants of postoperative sore throat (POST) in adult patients under general anesthesia. Methods: This retrospective case-control study included 140 adults who underwent general anesthesia with i-gel LMA from November 2023 to July 2024. Subjects were categorized into four groups based on neuromuscular blockade depth: deep (Group A), moderate (Group B), shallow (Group C), and minimal (Group D), as measured by Train-of-Four ratio. We assessed baseline characteristics, i-gel insertion success rates, complications, and POST severity at multiple intervals after surgery. Factors affecting POST were analyzed using correlation analysis and logistic regression models. Results: Moderate NMB (Group B) demonstrated significantly higher first-attempt i-gel insertion success (91.43%) compared to deep (62.86%), shallow (60.00%), and minimal (60.00%) NMB groups ($P < 0.01$). No significant differences in complication rates were observed among groups. POST severity at 0.5 hours was significantly lower in Group B but equalized across all groups at 6 and 24 hours. Multivariate analysis identified smoking history (OR = 0.258, 95% CI: 0.116-0.574, $P < 0.001$) and blood sputum presence (OR = 0.337, 95% CI: 0.099-1.148, $P = 0.082$) as inversely associated with POST, while higher ASA classification (OR = 0.421, 95% CI: 0.185-0.956, $P = 0.039$) and longer placement time (OR = 0.174, 95% CI: 0.060-0.500, $P = 0.001$) were significant predictors. Conclusion: This study demonstrates that moderate muscle relaxation significantly enhances i-gel LMA insertion success and reduces early POST severity. The identification of protective factors against POST highlights the importance of developing personalized perioperative strategies to improve patient comfort and airway management outcomes.

Keywords: i-gel laryngeal mask airway, neuromuscular blockade, insertion success, postoperative sore throat, general anesthesia, airway management

Introduction

The optimization of airway management during anesthesia remains a critical concern, driving continuous evaluation of alternative airway devices and techniques [1, 2]. The i-gel laryngeal mask airway (LMA), a relatively recent innovation, has gained popularity due to its unique non-inflatable anatomical design that facilitates insertion, provides effective sealing, and potentially reduces pharyngeal morbidity [3, 4]. However, successful placement and performance of the i-gel LMA depend on multiple factors, with neuromuscular blockade (NMB) depth during anesthesia being particularly influential [5]. This study aims to elucidate how varying degrees of neuromuscular relaxation affect i-gel LMA insertion success and to identify factors contributing to postoperative sore throat (POST), a common complication associated with airway management.

Effective airway management is fundamental to anesthetic practice, often determining both the safety and efficiency of surgical procedures under general anesthesia [6]. The i-gel LMA has

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emerged as a preferred option due to its simplified insertion without requiring cuff inflation and its potential for minimizing airway leakage [7, 8]. Nevertheless, successful airway device placement is significantly influenced by the degree of muscle relaxation induced by neuromuscular blocking agents [9]. Appropriate muscle relaxation facilitates the reduction of laryngeal and pharyngeal reflexes, enabling smoother insertion and improved stability of the airway device [10, 11]. Despite this understanding, the optimal depth of NMB remains an area of active investigation, wherein excessive relaxation may suppress necessary airway reflexes, while inadequate relaxation could maintain residual muscle tone that complicates insertion [12].

POST represents a distressing side effect following general anesthesia with multifactorial etiology. Contributing factors include mechanical trauma during airway manipulation, mucosal drying, and chemical irritation [13, 14]. A comprehensive understanding of these causative factors during and after airway device insertion is essential for developing effective strategies to minimize POST occurrence [15]. Although various perioperative factors have been associated with POST, limited research has specifically evaluated the influence of NMB depth on its incidence.

In summary, this study investigates the impact of NMB depth on successful i-gel laryngeal mask placement during general anesthesia and explores factors associated with the development of POST.

Materials and methods

Case selection

This retrospective case-control study included 140 adult patients who underwent general anesthesia at our hospital from November 2023 to July 2024, with the i-gel laryngeal mask as their airway management device. Patients underwent various elective surgeries, including orthopedic procedures (32.1%), general surgery (28.6%), gynecological procedures (21.4%), and urological surgeries (17.9%), with no significant differences in distribution among the four study groups ($P > 0.05$). Train-of-Four (TOF) monitoring was employed as a standard monitoring tool for all general anesthesia procedures in our hospital, particularly for procedures requiring muscle relaxation, to ensure appropriate assessment of neuromuscular function.

Initially, 312 patients were screened for eligibility. After applying inclusion and exclusion criteria, 186 patients remained eligible. To achieve balanced groups, we employed stratified random sampling based on age, gender, and American Society of Anesthesiologists (ASA) classification, resulting in 140 patients equally distributed into four groups (35 patients per group).

Patients were categorized into four groups based on the Train-of-Four ratio. The deep NMB group (Group A, n = 35) included patients with a TOF count (TOFc) of 0, indicating the disappearance of the first twitch (T1). The moderate NMB group (Group B, n = 35) comprised patients with a TOFc of 1 to 3, signifying the disappearance of the second (T2), third (T3), or fourth twitch (T4). The shallow NMB group (Group C, n = 35) included patients with a TOFc of 4 and TOF ratio (TOFr) ≤ 0.4, while the minimal NMB group (Group D, n = 35) consisted of patients with a TOFr between 0.4 and 0.9. We collected demographic and clinical information from the electronic medical records, including first-attempt insertion success rates and postoperative complications. Based on the severity of sore throat 24 hours after surgery, patients were classified into either a sore throat group (n = 50) or a non-sore throat group (n = 90).

This study received approval from the Institutional Review Board and Ethics Committee of Tongling Municipal Hospital (approval number: AH-TL-002). The requirement for informed consent was waived by the Ethics Committee because the study utilized only de-identified patient data, presenting no risk to patient care. This waiver complied with regulatory and ethical guidelines for retrospective research studies.

Inclusion and exclusion criteria

Inclusion criteria for the study were: 1) patients aged between 12 and 85 years; 2) ASA physical status classification I to III [16]; 3) suitability for surgery using the i-gel laryngeal mask as an airway device; and 4) scheduled general anesthesia for procedures expected to be completed within three hours.

Exclusion criteria included: 1) pre-existing chronic pharyngitis, sore throat, or gastroesophageal reflux disease; 2) obesity with a body mass index (BMI) exceeding 30 kg/m^2; 3) history of upper gastrointestinal, head, or neck surgeries, oropharyngeal deformities, limited cervical spine mobility, or an interincisor gap less than three finger breadths; 4) significantly loose teeth; and 5) upper limb deficiencies, myasthenia gravis, or peripheral neuropathy.

Treatment approach

Surgical methodology: Selection of Laryngeal Mask Size and Anesthesia Method: The appropriate i-gel laryngeal mask size was determined using the formula: body weight (kg)/20 + 1 (± 0.5), calculated based on the patient's weight and body habitus. All patients underwent standard preoperative preparation. Upon entering the operating room, an intravenous line was established, and standard monitoring (electrocardiogram, non-invasive blood pressure, pulse oximetry) was initiated. The neuromuscular monitoring device was attached to the arm with sufficient operational space, depending on the surgical site. Before anesthesia induction, patients underwent oral assessment for loose teeth, gum bleeding, chronic sore throat, or other pharyngeal discomfort symptoms.

General anesthesia was induced with midazolam (0.04 mg/kg; "Liyuexi", Xuzhou Third Pharmaceutical Factory, Enhua Pharmaceutical Group, Jiangsu Province), sufentanil (0.3 μg/kg; IDT Biologika GmbH, Germany), and etomidate (3 mg/kg; Jiangsu Hengrui Medicine Co., Ltd., Lianyungang, Jiangsu Province). To establish the appropriate muscle relaxation for the study, atracurium besylate (0.1 mg/kg; Aiteisi, Shenzhen, Guangdong Province) was administered at a dose equivalent to ED95. The muscle relaxant was administered intravenously after preoxygenation, with concurrent activation of the neuromuscular monitoring device [17].

Insertion method and technique for the laryngeal mask: Prior to inserting the i-gel laryngeal mask, a thin layer of dyclonine hydrochloride mucilage was applied evenly to the anterior and posterior surfaces of the mask. To minimize operator variability and standardize the procedure across all subjects, all i-gel insertions were performed by the primary author using a standardized head-supported chin lift technique [18]. This standardized approach was consistently applied to ensure procedural uniformity and eliminate potential bias from different operators' skill levels or technical approaches. The procedure involved gently supporting the patient's occiput with the right hand while lifting the chin with both hands to achieve the optimal sniffing position. After opening the mouth, the mask was held in the right hand with its opening directed toward the chin [19]. It was then advanced along the midline, following the contour of the hard palate, soft palate, and posterior pharyngeal wall to properly position the i-gel laryngeal mask [20].

First-attempt insertion success rate

The success of i-gel laryngeal mask insertion was evaluated using two primary criteria [21]. First, ventilation function was assessed by: (1) observing regular chest and abdominal movements; (2) auscultating for normal and symmetrical lung breath sounds; (3) confirming that mechanical ventilation airway pressure remained within normal range with an appropriate end-tidal carbon dioxide (EtCO2) waveform; (4) verifying the absence of air leakage sounds; and (5) maintaining normal blood oxygen saturation levels. The second criterion involved testing the seal pressure by manually adjusting the adjustable pressure limiting (APL) valve to 30 cmH_2O. Adequate seal pressure was confirmed if leakage occurred only after reaching this pressure threshold. This assessment was required to be completed within 5 seconds.

If the first insertion attempt failed, a second attempt was performed immediately. If the second attempt also failed, the procedure was converted to endotracheal intubation without delay. Upon successful i-gel insertion, the anesthesia machine was set to volume-controlled ventilation with a tidal volume of 6-8 mL/kg and a respiratory rate of 12-14 breaths per minute, with adjustments made based on EtCO2 levels [22].

Insertion time

The insertion time was measured from the moment the leading edge of the mask entered the oral cavity until complete insertion was achieved. In cases requiring multiple attempts, the mask was removed from the oral cavity, repositioned, and reinserted, with the insertion

time recalculated for each attempt. We also recorded the incidence of pharyngeal injury, gastric distension, coughing, breath-holding, and laryngospasm observed after mask removal [23, 24].

Assessment of POST

Voice recordings were obtained before anesthesia induction (0 hour) and at 6 and 24 hours post-surgery. Patients were assessed for POST severity at 0.5, 6, and 24 hours after surgery. The intensity of POST was measured using a four-point scale: 0 (no sore throat); 1 (sore throat noted only when prompted); 2 (sore throat eliciting spontaneous complaint); and 3 (severe sore throat leading to refusal to swallow). POST was considered present when the score exceeded 1 [25].

Data cleaning and management

Before analysis, we implemented a standardized data cleaning process to identify and correct inconsistencies, errors, and missing values. This process involved thorough dataset review, removal of duplicate entries, correction of data input errors, and addressing missing data.

Missing values were imputed using the K-Nearest Neighbors (KNN) method with the Impyute library in Python 3.6.0. The process began with basic mean imputation to create a complete dataset, which was then used to construct a KDTree. This KDTree facilitated computation of nearest neighbors, and the weighted average of these K nearest points provided the values for imputation.

Missing data was limited to less than 5% to minimize potential selection bias. Sensitivity analysis was conducted by calculating outcomes for cases lost to follow-up under both worst-case and best-case scenarios. When conclusions showed no significant differences between these scenarios, we determined that missing data had minimal impact on the results, supporting the reliability of our findings. The final results incorporate these imputed values.

Statistical analysis

Data analysis was performed using SPSS 29.0 statistical software (SPSS Inc., Chicago, IL, USA). For categorical data comparisons, we employed chi-square tests when the sample size was ≥ 40 and the theoretical frequency (T) was ≥ 5. When the sample size was ≥ 40 but the theoretical frequency fell between 1 and 5 ($1 \leq T < 5$), we applied a corrected chi-square formula using Yates' continuity correction. For small sample sizes or sparse data, we used Fisher's exact test to ensure accurate probability calculations.

For continuous variables, we first assessed normality using the Shapiro-Wilk test. For normally distributed data, we used independent samples t-tests for two-group comparisons and one-way analysis of variance (ANOVA) for multiple-group comparisons, presenting results as mean ± standard deviation ($x \pm s$). For non-normally distributed data, we used the Wilcoxon rank-sum test for two-group comparisons and the Kruskal-Wallis test for multiple-group comparisons, presenting results as median (25th percentile, 75th percentile).

For multiple comparisons, we adjusted *P*-values using the Bonferroni correction method to control the family-wise error rate. This method divided the standard significance level ($\alpha = 0.05$) by the number of comparisons performed. A *P*-value less than the adjusted threshold was considered statistically significant.

For correlation analyses, we calculated Pearson correlation coefficients (r) for continuous variables and Spearman rank correlation coefficients (rho) for categorical or non-normally distributed variables. Correlation strength was interpreted as follows: negligible (0.00-0.10), weak (0.10-0.39), moderate (0.40-0.69), strong (0.70-0.89), or very strong (0.90-1.00).

For regression analyses, we first performed univariate logistic regression to examine individual variable relationships with outcomes. Variables with $P < 0.20$ in univariate analysis were considered for inclusion in the multivariate model. We then conducted multivariate logistic regression using a backward stepwise approach based on likelihood ratio tests, eliminating variables with $P > 0.10$. Model fit was assessed using the Hosmer-Lemeshow goodness-of-fit test and explained variance (Nagelkerke R^2). Results were reported as odds ratios (OR) with 95% confidence intervals (CI).

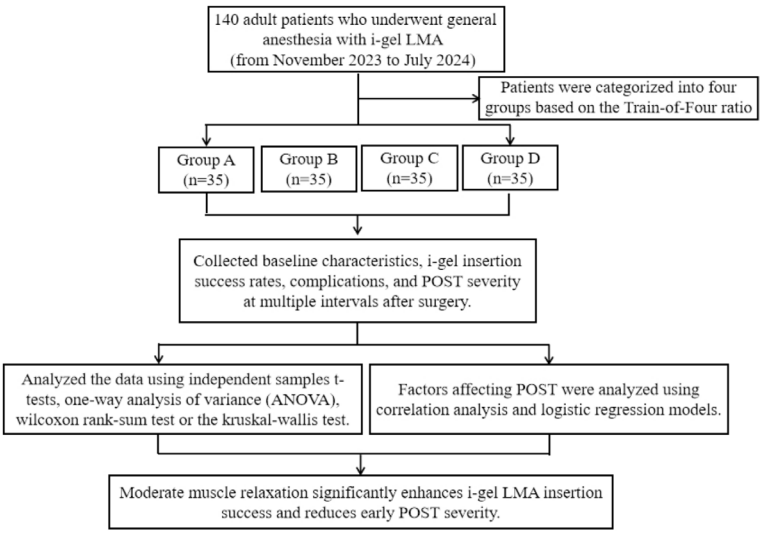

Figure 1. Flowchart of a study on 140 i-gel LMA general anesthesia patients.

Results

The impact of different muscle relaxation depths on the placement of the i-gel laryngeal mask

Baseline characteristics: The patient selection and grouping process is detailed in the study flowchart (**Figure 1**). In this retrospective study of 140 adult patients distributed equally across four groups, baseline characteristics - including gender, age, BMI, smoking and drinking history, hypertension, diabetes, employment status, marital status, ASA classification, and incidence of blood sputum - showed no statistically significant differences (**Table 1**). The only significant difference observed was in surgery duration between Group A and Group C (P = 0.017), with Group C having shorter surgical times. The absence of other significant differences in baseline characteristics suggests that observed outcomes are unlikely to be confounded by these factors, thereby isolating muscle relaxation depth as the primary variable influencing the study results.

One-time implantation success rates: When evaluating the impact of different muscle relaxation depths on i-gel laryngeal mask placement success, Group B (moderate NMB) demonstrated a significantly higher first-attempt success rate of 91.43% compared to Group A (62.86%, P = 0.004), Group C (60.00%, P = 0.002), and Group D (60.00%, P = 0.002) (**Table 2**). No significant differences in first-attempt success rates were observed among Groups A, C, and D (P = 0.806 for both A/C and A/D, and P = 1.000 for C/D). These findings suggest that moderate muscle relaxation substantially enhances first-attempt i-gel laryngeal mask placement success compared to other relaxation depths.

Complications: Pharyngeal injury occurred in 8.57% of patients in Groups A, C, and D, and in 5.71% of patients in Group B, with no significant differences among groups (P = 1.000 for all comparisons) (**Table 3**). Gastric distension was observed in 2.86% of patients in Groups A and D, with no cases in the other groups (P = 1.000 for all comparisons). Cough was the most frequent complication, occurring in 28.57% of Group A, 20.00% of Group B, 25.71% of Group C, and 22.86% of Group D patients, but these differences were not statistically significant (P > 0.403 for all comparisons). Isolated cases of apnea and laryngospasm were reported, but without statistically significant differences among groups (P = 1.000 for all comparisons). These results indicate that muscle relaxation depth did not significantly affect complication rates.

POST grade: Analysis of POST intensity revealed that at 0.5 hours post-operation, Group B had a significantly different distribution of POST grades compared to Groups A, C, and D (P = 0.005 for A/B, P = 0.034 for B/C, and P = 0.010 for B/D) (**Table 4**). Specifically, Group B showed a higher proportion of patients with grade 1 POST and none with grades 2 or 3, indicating lower severity at this time point. At 6 and 24 hours post-operation, no statistically significant differences in POST grade distributions were observed among the groups (P > 0.05). These data suggest that while Group B initially experienced less severe POST shortly after surgery, POST intensity equalized across all groups by 6 and 24 hours.

Influencing factors of POST

Baseline characteristics: The sore throat group had a significantly higher prevalence of smoking history (60.00% vs 34.44%, P = 0.003) and blood sputum (18.00% vs 6.67%, P = 0.038) (**Table 5**). Regarding ASA classification, the

Table 1. Baseline characteristics of participants

Parameters	Group A (n = 35)	Group B (n = 35)	Group C (n = 35)	Group D (n = 35)	*p* (A/B)	*p* (A/C)	*p* (A/D)	*p* (B/C)	*p* (B/D)	*p* (C/D)
Gender (Male)	20 (57.14%)	19 (54.29%)	21 (60%)	22 (62.86%)	0.810	0.808	0.626	0.629	0.467	0.806
Age ($\bar{x}$ ± s, years)	44.24 ± 16.44	44.81 ± 15.06	46.36 ± 16.41	46.92 ± 15.97	0.881	0.591	0.491	0.682	0.572	0.885
BMI ($\bar{x}$ ± s, kg/m^2)	24.91 ± 2.44	25.15 ± 2.79	24.39 ± 2.77	24.95 ± 3.06	0.705	0.408	0.945	0.254	0.772	0.422
Smoking history [n (%)]	15 (42.86%)	17 (48.57%)	16 (45.71%)	13 (37.14%)	0.631	0.81	0.626	0.811	0.334	0.467
Drinking history [n (%)]	16 (45.71%)	16 (45.71%)	19 (54.29%)	14 (40.00%)	1.000	0.473	0.629	0.473	0.629	0.231
Hypertension [n (%)]	5 (14.29%)	7 (20.00%)	7 (20.00%)	6 (17.14%)	0.526	0.526	0.743	1.000	0.759	0.759
Diabetes [n (%)]	10 (28.57%)	7 (20.00%)	8 (22.86%)	6 (17.14%)	0.403	0.584	0.255	0.771	0.759	0.550
Employment [n (%)]	33 (94.29%)	31 (88.57%)	35 (100.00%)	33 (94.29%)	0.669	0.473	1.000	0.122	0.669	0.473
Marital Status [n/(%)]					0.673	0.356	0.898	1.000	1.000	0.614
Married	31 (88.57%)	33 (94.29%)	34 (97.14%)	32 (91.43%)						
Single	1 (2.86%)	0 (0.00%)	0 (0.00%)	1 (2.86%)						
Divorced	3 (8.57%)	2 (5.71%)	1 (2.86%)	2 (5.71%)						
Duration of surgery (min)	91.36 ± 2.37	90.58 ± 3.01	89.84 ± 2.77	90.96 ± 2.83	0.230	0.017	0.529	0.358	0.586	0.135
Blood sputum [n (%)]	4 (11.43%)	3 (8.57%)	5 (14.29%)	3 (8.57%)	1.000	1.000	1.000	0.707	1.000	0.707
ASA classification [n (%)]					0.844	0.966	0.838	0.894	0.536	0.791
ASA classification I	2 (5.71%)	3 (8.57%)	2 (5.71%)	1 (2.86%)						
ASA classification II	23 (65.71%)	21 (60.00%)	22 (62.86%)	24 (68.57%)						
ASA classification III	10 (28.57%)	11 (31.43%)	11 (31.43%)	10 (28.57%)						

Note: BMI = body mass index; ASA = American Society of Anesthesiologists.

Table 2. Comparison of one-time implantation success rates among the four groups

Parameters	Group A (n = 35)	Group B (n = 35)	Group C (n = 35)	Group D (n = 35)	*p* (A/B)	*p* (A/C)	*p* (A/D)	*p* (B/C)	*p* (B/D)	*p* (C/D)
Success rate of one-time implantation [n (%)]	22 (62.86%)	32 (91.43%)	21 (60.00%)	21 (60.00%)	0.004	0.806	0.806	0.002	0.002	1.000

Table 3. Incidence of complications among the groups

Parameters	Group A (n = 35)	Group B (n = 35)	Group C (n = 35)	Group D (n = 35)	*p* (A/B)	*p* (A/C)	*p* (A/D)	*p* (B/C)	*p* (B/D)	*p* (C/D)
Pharyngeal Injury	3 (8.57%)	2 (5.71%)	3 (8.57%)	3 (8.57%)	1.000	1.000	1.000	1.000	1.000	1.000
Gastric Distension	1 (2.86%)	0 (0.00%)	0 (0.00%)	1 (2.86%)	1.000	1.000	1.000	1.000	1.000	1.000
Cough	10 (28.57%)	7 (20.00%)	9 (25.71%)	8 (22.86%)	0.403	0.788	0.584	0.569	0.771	0.780
Apnea	1 (2.86%)	0 (0.00%)	1 (2.86%)	0 (0.00%)	1.000	1.000	1.000	1.000	1.000	1.000
Laryngospasm	0 (0.00%)	1 (2.86%)	1 (2.86%)	0 (0.00%)	1.000	1.000	1.000	1.000	1.000	1.000

Table 4. Distribution of POST grades among the groups

Parameters	Group A (n = 35)	Group B (n = 35)	Group C (n = 35)	Group D (n = 35)	*p* (A/B)	*p* (A/C)	*p* (A/D)	*p* (B/C)	*p* (B/D)	*p* (C/D)
The intensity of POST grade: 0:1:2:3										
0.5 h	13 (37.14%)/13 (37.14%)/9 (25.71%)/0 (0.00%)	15 (42.86%)/20 (57.14%)/0 (0.00%)/0 (0.00%)	14 (40.00%)/15 (42.86%)/6 (17.14%)/0 (0.00%)	13 (37.14%)/14 (40.00%)/8 (22.86%)/0 (0.00%)	0.005	0.677	0.953	0.034	0.010	0.836
6 h	18 (51.43%)/10 (28.57%)/7 (20.00%)/0 (0.00%)	18 (51.43%)/14 (40.00%)/3 (8.57%)/0 (0.00%)	22 (62.86%)/11 (31.43%)/2 (5.71%)/0 (0.00%)	21 (60%)/10 (28.57%)/4 (11.43%)/0 (0.00%)	0.322	0.199	0.592	0.619	0.594	0.692
24 h	18 (51.43%)/4 (11.43%)/10 (28.57%)/3 (8.57%)	15 (42.86%)/9 (25.71%)/9 (25.71%)/2 (5.71%)	19 (54.29%)/5 (14.29%)/7 (20.00%)/4 (11.43%)	13 (37.14%)/7 (20.00%)/12 (34.29%)/3 (8.57%)	0.485	0.847	0.614	0.470	0.796	0.405

Note: POST = Postoperative sore throat.

Table 5. Baseline characteristics of participants

Parameters	Sore Throat Group (n = 50)	Non-sore Throat Group (n = 90)	t/χ^2	*p*
Gender (Male)	32 (64.00%)	50 (55.56%)	0.945	0.331
Age (years)	44.17 ± 6.17	43.26 ± 5.91	0.851	0.397
BMI (kg/m^2)	24.36 ± 2.77	24.77 ± 2.81	0.816	0.416
Smoking history [n (%)]	30 (60.00%)	31 (34.44%)	8.538	0.003
Drinking history [n (%)]	23 (46.00%)	42 (46.67%)	0.006	0.940
Hypertension [n (%)]	10 (20.00%)	15 (16.67%)	0.243	0.622
Diabetes [n (%)]	11 (22.00%)	20 (22.22%)	0.001	0.976
Employment [n (%)]	48 (96.00%)	84 (93.33%)	0.074	0.786
Marital Status [n/(%)]			0.001	0.976
Married	46 (92.00%)	84 (93.33%)		
Single	1 (2.00%)	1 (1.11%)		
Divorced	3 (6.00%)	5 (5.56%)		
Duration of surgery (min)	89.77 ± 2.14	90.26 ± 2.59	1.132	0.260
Blood sputum [n (%)]	9 (18.00%)	6 (6.67%)	4.316	0.038
ASA classification [n (%)]			8.731	0.013
ASA classification I	3 (6%)	6 (6.67%)		
ASA classification II	29 (58%)	71 (78.89%)		
ASA classification III	18 (36%)	13 (14.44%)		

Note: BMI = body mass index; ASA = American Society of Anesthesiologists.

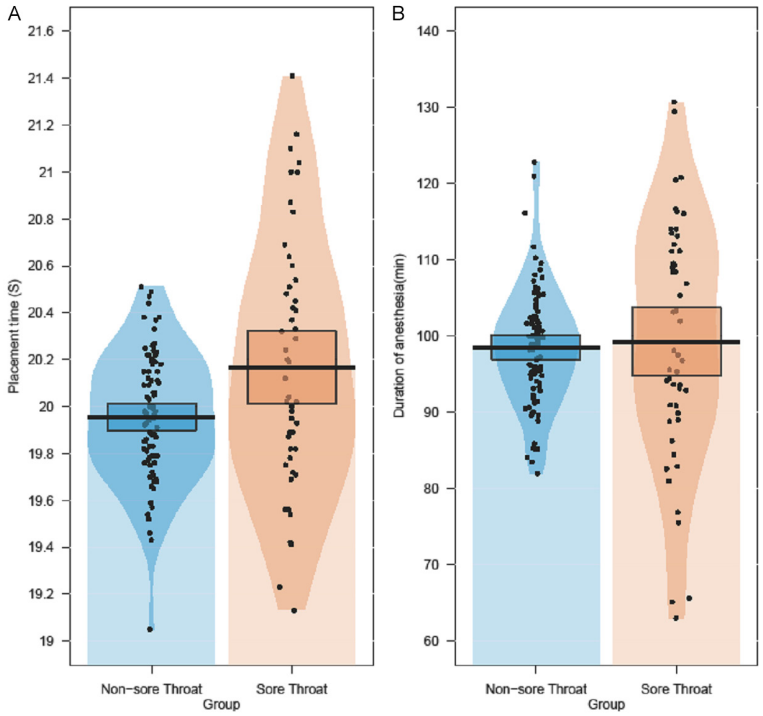

Figure 2. Comparison of placement and anesthesia duration between patient groups. A. Comparison of placement time between sore throat and non-sore throat groups; B. Comparison of anesthesia duration between sore throat and non-sore throat groups.

Table 6. Correlation analysis between muscle relaxation depth and POST

Parameters	rho	P
Smoking history [n (%)]	-0.247	0.003
Blood sputum [n (%)]	-0.176	0.038
ASA classification [n (%)]	-0.217	0.010
Placement time (S)	-0.235	0.005

Note: ASA = American Society of Anesthesiologists; POST = Postoperative sore throat.

sore throat group had a higher proportion of patients classified as ASA III (36% vs 14.44%) and a lower proportion classified as ASA II (58% vs 78.89%). Other baseline parameters, including gender, age, BMI, drinking history, hypertension, diabetes, employment status, marital status, and surgery duration, showed no significant differences between groups (P > 0.05). These findings suggest that smoking history, blood sputum presence, and ASA classification may significantly influence POST occurrence.

Placement and anesthesia duration: The sore throat group had a significantly longer placement time (20.17 ± 0.54 seconds) compared to the non-sore throat group (19.96 ± 0.27 seconds; P = 0.012) (**Figure 2**). However, no significant difference was observed in anesthesia duration between the two groups, with the sore throat group averaging 99.27 ± 15.77 minutes and the non-sore throat group 98.54 ± 7.68 minutes (P = 0.758). These results suggest that longer placement time may be associated with POST development, while anesthesia duration appears to have no significant impact.

Correlation analysis: Correlation analysis between muscle relaxation depth and POST revealed several significant associations (**Table 6**). Negative correlations were observed between muscle relaxation depth and smoking history (rho = -0.247, P = 0.003), blood sputum (rho = -0.176, P = 0.038), and placement time (rho = -0.235, P = 0.005). This suggests that deeper muscle relaxation is associated with lower incidences of these factors. Similarly, a negative correlation was found with ASA classification (rho = -0.217, P = 0.010), indicating that patients with lower ASA classifications might receive shallower muscle relaxation. These correlations suggest that both patient characteristics and clinical practices regarding muscle relaxation depth during surgery could influence POST occurrence.

Univariate logistic regression analysis: Univariate logistic regression analysis identified significant associations between several factors and POST likelihood (**Table 7**). Smoking history was inversely associated with POST, with an odds ratio (OR) of 0.350 (95% CI: 0.169-0.709, P = 0.004), suggesting smokers were less likely to experience sore throat with deeper muscle relaxation. Similarly, blood sputum presence was associated with decreased POST likelihood (OR = 0.325, 95% CI: 0.103-0.963, P = 0.045). A significant negative association was observed with ASA classification, where lower classifications increased POST odds (OR = 0.416, 95% CI: 0.199-0.834, P = 0.016). Placement time showed a strong

Table 7. Univariate logistic regression analysis of muscle relaxation depth and POST

Parameters	Coefficient	Std Error	Wald	P	OR	95% CI
Smoking history [n (%)]	-1.049	0.364	2.881	0.004	0.350	0.169-0.709
Blood sputum [n (%)]	-1.123	0.560	2.003	0.045	0.325	0.103-0.963
ASA classification [n (%)]	-0.878	0.363	2.417	0.016	0.416	0.199-0.834
Placement time (S)	-1.386	0.482	2.877	0.004	0.25	0.092-0.621

Note: OR = odds ratio; CI = confidence interval; ASA = American Society of Anesthesiologists.

Table 8. Multivariate logistic regression analysis of muscle relaxation depth and POST

Parameters	Coefficient	Std Error	WaldStat	P	OR	OR CI Lower	OR CI Upper
Smoking history [n (%)]	-1.356	0.408	-3.320	< 0.001	0.258	0.116	0.574
Blood sputum [n (%)]	-1.087	0.625	-1.739	0.082	0.337	0.099	1.148
ASA classification [n (%)]	-0.866	0.419	-2.068	0.039	0.421	0.185	0.956
Placement time (S)	-1.751	0.540	-3.245	0.001	0.174	0.060	0.500

Note: OR = odds ratio; CI = confidence interval; ASA = American Society of Anesthesiologists.

inverse relationship, with longer times significantly reducing POST probability (OR = 0.25, 95% CI: 0.092-0.621, P = 0.004). These findings highlight key factors that may influence POST through their interaction with muscle relaxation depth during i-gel mask placement.

Multivariate logistic regression analysis: Multivariate logistic regression analysis identified several significant predictors of POST related to muscle relaxation depth (**Table 8**). Smoking history was inversely associated with POST, with an odds ratio (OR) of 0.258 (95% CI: 0.116-0.574, P < 0.001), indicating that smokers have a reduced likelihood of experiencing sore throat. Similarly, blood sputum presence was associated with lower POST likelihood (OR = 0.337, 95% CI: 0.099-0.148, P = 0.082). A significant negative association was found with ASA classification, where patients with lower classifications had increased odds of developing POST (OR = 0.421, 95% CI: 0.185-0.956, P = 0.039). Placement time was a strong negative predictor, with longer insertion times significantly reducing POST risk (OR = 0.174, 95% CI: 0.060-0.500, P = 0.001). These results underscore the importance of various preoperative and perioperative factors in mitigating POST risk, particularly in relation to muscle relaxation depth during anesthesia.

Discussion

In this retrospective study, we investigated how varying depths of neuromuscular blockade affect i-gel laryngeal mask placement success and explored factors associated with POST incidence in adult patients under general anesthesia.

The success of i-gel laryngeal mask insertion was significantly influenced by NMB depth, with Group B (moderate NMB) demonstrating superior first-attempt success compared to both deeper and shallower blockade groups. This finding aligns with our understanding of laryngeal mask placement dynamics, where appropriate muscle relaxation facilitates optimal head and neck positioning and reduces insertion resistance. Interestingly, the reduced success rate in the deep NMB group (Group A) might be attributed to excessive relaxation potentially suppressing necessary airway reflexes required for proper mask placement and sealing. Conversely, inadequate relaxation in the shallower groups (Groups C and D) likely maintained residual muscle tone, creating resistance during insertion and compromising seal integrity, as evidenced by the consistent success rates across these groups.

Our POST analysis revealed intriguing correlations with several variables. Notably, smoking history and blood sputum presence were inversely associated with POST incidence. While seemingly counterintuitive - as these factors are generally considered predisposing for throat irritation - this observation may indicate that habitual smokers or patients prone to blood sputum may have developed adaptive mucosal changes or altered pain perception thresholds, potentially diminishing POST sever-

ity perception. Alternatively, chronic irritation in smokers may desensitize pain reception pathways to additional surgical irritation.

The absence of significant differences in POST severity across groups at later postoperative time points, despite initial disparities, adds nuance to these observations. This temporal pattern suggests an evolution of symptomatology where initial inflammation or irritation diminishes as mucosal healing progresses. Additionally, factors such as alcohol consumption and comorbidities like hypertension and diabetes showed no significant associations with POST, suggesting their influence on airway reactivity during anesthesia may involve more complex mechanisms than direct cause-effect relationships, or their impact may manifest under different clinical or pharmacological conditions.

Regarding muscle relaxation depth and its interaction with patient-specific factors, our study provides several insights. The distribution of ASA classifications suggests differential sensitivity to muscle relaxants, where higher ASA grades likely correlate with varied pharmacodynamic responses. This operates through complex physiological interactions, where higher ASA grades may indicate underlying systemic disorders affecting drug metabolism or hemodynamics, contributing to variable muscle blockade intensities. These findings suggest that personalizing muscle relaxation protocols based on ASA classification could optimize airway management and enhance patient safety.

Furthermore, the correlation between longer placement time and reduced POST risk introduces a procedural aspect related to technical skill and thoroughness. Extended insertion times may reflect a more meticulous, patient-centered technique that minimizes abrupt movements, thereby reducing trauma to laryngeal structures. This highlights the critical importance of operator skill and procedural attentiveness in influencing POST outcomes.

Our multivariate analysis provided robust examination of complex interdependencies between variables [26]. For instance, our models identified smoking history as an independent factor inversely associated with POST likelihood, confirming that potential confounding effects from other examined variables are relatively minor. The significance of ASA classification in these models further emphasizes the importance of integrating preoperative assessment with anesthetic planning to mitigate adverse respiratory outcomes.

While our study conducted comprehensive analyses and yielded valuable insights, it must be interpreted within its limitations. Its retrospective design imposes inherent constraints regarding data precision and the ability to establish causality versus association. Moreover, despite careful adjustment for potential confounders, unrecognized bias or interaction effects may influence our interpretations. Additionally, our study population was restricted to patients undergoing surgeries shorter than three hours, potentially limiting generalizability to longer procedures where factors influencing POST may differ.

Conclusion

This study enhances our understanding of the complex relationship between muscle relaxation depth, i-gel laryngeal mask placement success, and POST incidence. Our findings demonstrate the importance of tailored neuromuscular blockade strategies to improve airway management efficacy and reduce patient discomfort. The evidence supports further research to develop individualized anesthetic protocols that integrate patient characteristics, perioperative practices, and operator skills. Such efforts are essential to optimize clinical outcomes, enhance surgical safety, and improve patient-centered care.

Disclosure of conflict of interest

None.

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