Am J Transl Res 2026;18(7):5664-5676
www.ajtr.org /ISSN:1943-8141/AJTR0172734

Original Article

Evaluation of airway stress response and respiratory complications in adults undergoing general anesthesia with sevoflurane plus mivacurium chloride and positive pressure ventilation via laryngeal mask

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Received March 18, 2026; Accepted May 29, 2026; Epub July 15, 2026; Published July 30, 2026

Abstract: Objective: This research aimed to evaluate the effect of sevoflurane combined with mivacurium chloride (MC) and positive pressure ventilation by a laryngeal mask airway in adult patients undergoing general anesthesia. Methods: This retrospective study included 88 adult patients who underwent surgery under general anesthesia induced with sevoflurane, MC, and fentanyl. Based on the anesthesia method documented in medical records, patients were divided into an endotracheal general anesthesia (EGA) group (n=44) and a laryngeal mask airway general anesthesia (LMAGA) group (n=44). Results: The LMAGA group had lower heart rate, mean arterial pressure, end-tidal carbon dioxide, and cortisol levels than the EGA group ($P < 0.05$). Time to loss of eyelash reflex, extubation time, and awakening time were significantly shortened in the LMAGA group ($P < 0.05$). In the LMAGA group, postoperative time to first ambulation and first oral intake was significantly less than that in the EGA group ($P < 0.05$). Bispectral index values and Narcotrend index at the defined time points T2 and T5 were significantly higher in the EGA group ($P < 0.05$). The LMAGA group had a lower complication rate than the EGA group ($P < 0.05$) and exhibited better postoperative cognitive status ($P < 0.05$). Conclusion: Sevoflurane combined with MC provides a better anesthetic effect and a favorable safety profile.

Keywords: General anesthesia, sevoflurane, mivacurium chloride, laryngeal mask, tracheal intubation

Introduction

Selecting the appropriate combination of anesthetic drugs and techniques is crucial for reducing the stress response in adults during surgery and postoperative respiratory complications. With the advancement of medical technology and the field of anesthesiology, how to further improve the safety and efficacy of anesthesia has become an important topic in the realm of anesthesia today. Sevoflurane, as a volatile anesthetic, has gained widespread application in anesthesia due to its rapid onset, low irritation, and ease of adjusting the depth of anesthesia [1]. Mivacurium chloride (MC), because of its rapid onset and relatively short duration of action, has become an indispensable drug for assisting in airway management and performing surgical procedures [2]. Sevoflurane combined with MC is used for the induction of general anesthesia in adults. Theoretically, this combination allows for a fast and smooth induction of general anesthesia, which facilitates optimal airway management and provides favorable conditions for surgery [3]. However, in actual clinical use, especially when a laryngeal mask is used for positive pressure ventilation, how to systematically evaluate the influence of this combination of anesthetics on the stress response in adults and the risk of respiratory complications needs to be further studied in depth. Although the laryngeal mask is commonly used in anesthesia due to its simplicity and minimal trauma, attention should also be paid to the safety of positive pressure ventilation with a laryngeal mask, as well as respiratory complications such as hoarseness, sore throat, and laryngospasm [4]. The stress response is a normal physiologic reaction during general

https://doi.org/10.62347/TGWE9679

anesthesia, but an exaggerated stress response may lead to adverse outcomes, including enhanced cardiovascular responses, metabolic disturbances, and immunosuppression, which can affect postoperative recovery and prognosis [5].

In this study, the effectiveness and safety of tracheal intubation and laryngeal mask airway positive pressure ventilation in the induction of anesthesia with sevoflurane combined with MC in adults were compared to provide a reference for improving the effect of general anesthesia in adults, and reducing postoperative adverse reactions.

Materials and methods

General information

A total of 88 adults undergoing elective surgery in the Tianjin Second People's Hospital from January 2022 to January 2025 were recruited. Inclusion criteria: (1) patients receiving sevoflurane inhalation for induction of anesthesia with MC and fentanyl; (2) patients whose American Society of Anesthesiologists (ASA) grades were I-II. Exclusion criteria: (1) patients with liver and renal insufficiency; (2) use of medications that affect coagulation function, platelet function, or fibrinolytic system function within two weeks before operation; (3) patients with a history of allergy to drugs used in the study; (4) patients with contraindications to general anesthesia; (5) patients with a recent history of upper respiratory tract infection. The sample size of this retrospective study was determined by the available clinical data that met the inclusion criteria. 88 patients were ultimately included in the final analysis. To ensure the statistical reliability of our findings, a power analysis was performed using G*Power software (version 3.1.9.7). Based on the observed effect size of hemodynamic fluctuations and a significance level of $\alpha=0.05$, the calculated statistical power ($1-\beta$) of this study was 0.85, indicating that the sample size was sufficient to detect significant differences between the groups. This retrospective cohort study included 88 consecutive patients who underwent surgery with induction using sevoflurane combined with muscle relaxants and fentanyl at our hospital between January 2022 and January 2025. Based on the actual airway management method documented in previous anesthesia records, the patients were divided into an endotracheal general anesthesia (EGA) group and a laryngeal mask airway general anesthesia (LMAGA) group, with 44 patients in each group. This study was approved by the Ethics Committee of Tianjin Second People's Hospital.

Methodology of anesthesia

Adults in the two groups were fasted for 12 h before surgery and forbidden to drink for 4 h before surgery. After entering the operating room, they were intravenously injected with compound sodium chloride (State Food and Drug Administration [SFDA] approval number H33021931, Zhejiang MaoYuan Pharmaceutical Co., Ltd.), and after the opening of the intravenous channel, they were instilled with 5% glucose and sodium chloride injection (specifications: 30 mg: 10 g, SFDA approval number H340222839, Guangdong Escher Pharmaceutical Co., Ltd.). All patients then received sevoflurane (specifications: 120 mL, SFDA approval number H20070172, Shanghai HengRui Pharmaceutical Co., Ltd.) for inhalation induction. Meanwhile, fentanyl citrate (specification: 10 mL: 0.5 mg, SFDA approval number H20003-688, Yichang Renfu Pharmaceutical Co., Ltd.) and MC (registration number H20100454, GlaxoSmithKline Manufacturing S.p.A.) were combined for induction anesthesia. Sevoflurane was administered using the tidal volume method. The evaporator was adjusted to 8.0%, and the supply flow of fresh oxygen was set to 6.0 L/min. After the circuit was prefilled, the output port was connected to the mask, and the mask was tightly secured to the nose and mouth of the adult before spontaneous breathing. After the adult consciousness disappeared, the evaporator was adjusted to 3.0%, and the oxygen supply flow was adjusted to 2.0 L/min. An intravenous route was established, and 2.0 μg/kg fentanyl citrate and 200.0 μg/kg MC were intravenously administered within 1 min. The patient was ventilated under pressure for 3 min using a mask.

Based on the above operations, the adults in the EGA group were intubated, and the adults in the LMAGA group were ventilated with a laryngeal mask airway. They were connected to the anesthesia ventilator circuit, and 1.5-2.0% sevoflurane was administered to maintain anesthesia. The end-tidal carbon dioxide ($PETCO_2$) level was monitored, and the value needed to be maintained within the range of 40-43 mmHg. When the $PETCO_2$ value exceeded 45 mmHg, respiratory assistance was required. Anesthetics were stopped 5 min before the end of surgery, and the oxygen supply was adjusted to 6.0 L/min. When the adult recovered to spontaneous breathing, spontaneous limb activity, swallowing reflex, and circulatory function, and body temperature returned to normal, they were extubated and given mask oxygen.

Observation indices

Before anesthesia induction (T0), immediately after anesthesia induction (T1), 1 minute after intubation/laryngeal mask airway insertion (T2), during tracheal intubation/laryngeal mask airway insertion (T3), 3 minutes after intubation/laryngeal mask airway insertion (T4), and at the end of surgery (T5), heart rate (HR), mean arterial pressure (MAP), oxygen saturation (SpO_2), and $PETCO_2$ were monitored using an electrocardiogram monitor (Beijing Healthme Medical Ltd., PM-9000+). At each of these time points, the skin around the intravenous site was swabbed with an antiseptic, allowed to air dry, and a sterile syringe or blood collection tube was attached to the intravenous connector. Then, 2.0 milliliters of blood were collected. The blood was then placed onto a glucose test strip, and the blood glucose level was recorded. The remaining venous blood was centrifuged at 3,000 r/min for 10 minutes. The supernatant was carefully removed, and its cortisol content was determined by radioimmunoassay. The time to loss of eyelash reflex, extubation time, recovery time, time to first ambulation, time to first oral intake, Bispectral index (BIS) of electroencephalogram values, Narcotrend index, and respiratory complications (hoarseness, sore throat, laryngospasm, cough during emergence, regurgitation, and respiratory depression) were recorded. The number of patients with agitation, night terrors, and sleep disorders in the two groups was counted. Cognitive function was evaluated using the Montreal Cognitive Assessment (MoCA) [6] at preoperative and 3 days postoperatively, with total scores ranging from 0 to 30. Higher scores indicate better cognitive function in the patients.

Statistical analysis

Statistical analysis was performed using SPSS 29.0 (IBM, USA). Categorical data were presented as frequencies (percentages), and comparisons between groups were conducted using the chi-square test. Continuous data were first tested for normality using the Shapiro-Wilk test and for homogeneity of variance. Baseline data that followed a normal distribution and had homogeneous variances were expressed as mean ± standard deviation (SD), and comparisons between groups were performed using the independent samples t-test; otherwise, nonparametric tests were used. For repeated measures data at multiple time points, including HR, MAP, and $PETCO_2$, a repeated-measures analysis of variance was used to evaluate the effects of group, time, and their interaction. Before the repeated-measures analysis, Mauchly's test of sphericity was applied to assess whether the data met the sphericity assumption; if not, the Greenhouse-Geisser method was used to correct the degrees of freedom. If the interaction between group and time was significant ($P < 0.05$), Bonferroni correction was further applied for *post hoc* pairwise comparisons to adjust for multiple testing. All statistical tests were two-tailed, and a P-value < 0.05 was considered significant.

Results

Comparison of baseline data between the two groups

Table 1 presents a comparison of baseline data between the two groups. In the EGA group, there were 25 males and 19 females, with ages ranging from 21 to 48 years (mean ± SD: 34.71 ± 11.53 years) and body weights ranging from 49 to 71 kg (mean ± SD: 64.65 ± 12.13 kg). Among them, 26 patients were classified as ASA grade I, and 18 as ASA grade II. The operative time ranged from 60 to 120 minutes, with a mean ± SD of 83.19 ± 5.60 minutes. In the LMAGA group, there were 23 males and 21 females, with ages ranging from 21 to 48 years (mean ± SD: 34.59 ± 11.67 years), body weights ranging from 40 to 70 kg (mean ± SD: 65.02 ± 12.64 kg), and ASA grade I in 25 patients and ASA grade II in 19 patients. The operative time ranged from 60 to 120 minutes, with a mean ± SD of 84.36 ± 5.73 minutes. No significant differences were observed in the baseline characteristics or operative time between the two groups ($P > 0.05$), indicating comparability.

Table 1. General characteristics of the study groups

Indicator	EGA group (n=44)	LMAGA group (n=44)	χ^2/t value	P
Gender (Cases, %)			1.52	0.275
Male	25 (56.82)	23 (52.27)		
Female	19 (43.18)	21 (47.73)		
Age (Years)	34.71 ± 11.53	34.59 ± 11.67	0.65	0.619
Body weights (kg)	64.65 ± 12.13	65.02 ± 12.64	1.15	0.367
ASA (Cases, %)			1.03	0.753
I	26 (59.09)	25 (56.82)		
II	18 (40.91)	19 (43.18)		
Operation time (min)	83.19 ± 5.60	84.36 ± 5.73	0.58	0.592

Note: EGA: endotracheal general anesthesia; LMAGA: laryngeal mask general anesthesia; ASA: American Society of Anesthesiologists. Data are presented as mean ± standard deviation or n (%).

Table 2. Changes in intubation stress response indicators in the two groups of adults

Indicator	EGA group (n=44)	LMAGA group (n=44)	t	P
HR (beats/min)				
T0	106.12 ± 10.31	107.02 ± 10.53	-0.32	0.753
T1	83.23 ± 9.82	81.14 ± 9.52	0.78	0.438
T2	112.34 ± 11.12	96.42 ± 10.75	3.86	< 0.001
T3	108.11 ± 10.64	91.25 ± 10.32	4.23	< 0.001
T4	92.03 ± 9.93	87.12 ± 9.61	1.59	0.115
T5	93.14 ± 10.21	88.30 ± 9.83	1.74	0.085
MAP (mmHg)				
T0	70.21 ± 6.12	70.02 ± 6.31	0.11	0.912
T1	59.10 ± 5.84	58.34 ± 5.62	0.52	0.611
T2	73.40 ± 6.52	61.23 ± 6.03	5.13	< 0.001
T3	69.02 ± 6.23	60.12 ± 5.92	5.56	< 0.001
T4	62.12 ± 5.91	59.02 ± 5.72	1.86	0.068
T5	61.32 ± 5.80	58.21 ± 5.63	2.11	0.038

Note: HR: heart rate; MAP: mean arterial pressure; EGA: endotracheal general anesthesia; LMAGA: laryngeal mask general anesthesia; T0: before anesthesia induction; T1: immediately after anesthesia induction; T2: 1 minute after endotracheal intubation/laryngeal mask airway insertion; T3: during endotracheal intubation/laryngeal mask airway insertion; T4: 3 minutes after endotracheal intubation/laryngeal mask airway insertion; T5: at the end of surgery. Data are presented as mean ± standard deviation.

Comparison of intubation stress response in adults

The changes of HR and MAP levels in the EGA group and LMAGA group at each time point were observed. The results are shown in **Table 2**. At T1, the levels of HR and MAP decreased in both groups. At T2, the levels of HR and MAP were increased in both groups. Then, at time points T0, T1, and T4, there were no significant differences in HR and MAP levels between the two groups ($P > 0.05$). However, at time point T5, although the difference in HR between the groups was not significant ($P > 0.05$), the MAP level in the LMAGA group was significantly lower than that of the EGA group ($P < 0.05$). Moreover, the HR and MAP levels in the LMAGA group at T2 and T3 were markedly reduced compared with those in the EGA group ($P < 0.05$).

Comparison of hemodynamic levels in adults

Peripheral SpO_2, arterial partial pressure of carbon dioxide, and $PETCO_2$ at different perioperative time points were compared between the two groups (**Table 3**). No significant differences were observed in these values between the two groups at baseline (T0), indicating good comparability ($P > 0.05$). At each time point after airway instrumentation (T1-T4), SpO_2 levels were generally higher in the LMAGA group than in the EGA group, with a significant difference noted at T3 ($P < 0.05$), suggesting that the laryngeal mask airway may be more favorable for maintaining oxygenation stability. Regarding arterial partial pressure of carbon dioxide, levels in the EGA group increased continuously from T1 to T4, whereas those of the LMAGA group remained relatively stable, with significant differences at all time points from T1 to T4 ($P < 0.05$). This suggests that tracheal intubation may lead to reduced ventilatory efficiency or increased dead space ventilation. $PETCO_2$ levels were significantly higher in the EGA group than in the LMAGA group during T2-T4 ($P < 0.05$). By T5, both groups returned to baseline levels, with no significant difference between the groups ($P > 0.05$).

Table 3. Changes in hemodynamic indices in two groups of adults

Indicator	EGA group (n=44)	LMAGA group (n=44)	*t*	*P*
Blood oxygen saturation (%)				
T0	97.21 ± 1.82	97.42 ± 1.12	0.08	0.935
T1	98.10 ± 1.33	98.32 ± 1.73	1.34	0.197
T2	98.43 ± 0.62	99.14 ± 1.51	1.74	0.081
T3	98.22 ± 0.85	99.60 ± 1.62	2.18	0.044
T4	98.74 ± 1.41	99.12 ± 0.83	1.14	0.152
T5	98.12 ± 1.92	99.01 ± 1.52	0.81	0.286
Partial pressure of carbon dioxide (mmHg)				
T0	41.02 ± 4.21	41.15 ± 4.31	-0.08	0.943
T1	46.03 ± 4.52	43.02 ± 4.12	2.02	0.047
T2	47.12 ± 4.73	42.21 ± 4.03	3.26	0.002
T3	46.02 ± 4.62	41.30 ± 4.21	3.19	0.002
T4	43.23 ± 4.43	40.10 ± 4.02	2.45	0.017
T5	41.02 ± 4.12	40.01 ± 3.93	1.18	0.243
End-expiratory carbon dioxide (mmHg)				
T0	44.32 ± 5.92	44.13 ± 6.12	0.17	0.873
T1	50.01 ± 5.35	47.02 ± 5.43	0.86	0.398
T2	50.04 ± 5.51	44.01 ± 5.22	3.79	< 0.001
T3	48.05 ± 5.23	43.05 ± 5.16	3.17	0.002
T4	45.02 ± 5.04	42.01 ± 4.92	2.12	0.038
T5	43.03 ± 4.82	42.02 ± 4.72	0.00	1.000

Note: EGA: endotracheal general anesthesia; LMAGA: laryngeal mask general anesthesia; T0: before anesthesia induction; T1: immediately after anesthesia induction; T2: 1 minute after endotracheal intubation/laryngeal mask airway insertion; T3: during endotracheal intubation/laryngeal mask airway insertion; T4: 3 minutes after endotracheal intubation/laryngeal mask airway insertion; T5: at the end of surgery. Data are presented as mean ± standard deviation.

Comparison of blood glucose and cortisol levels in adults

The changes in blood glucose and cortisol concentrations in the EGA group and LMAGA group at each time point were observed. The results are shown in **Table 4**. There were no significant differences in blood glucose levels between the two groups at any time point (T0-T5) ($P > 0.05$). Cortisol concentrations in the LMAGA group were significantly lower than those of the EGA group at time points T2, T3, T4, and T5 ($P < 0.05$).

Comparison of anesthesia and awakening in adults

The differences in time to loss of eyelash reflex, extubation time, and awakening time between the EGA group and the LMAGA group were observed, and the results are shown in **Figure 1**. The time to loss of eyelash reflex, extubation time, and awakening time in the LMAGA group were notably shorter than those of the EGA group ($P < 0.05$). **Figure 2** illustrates the differences in anesthesia and emergence indicators, including time to loss of eyelash reflex, extubation time, and awakening time, between the EGA group and the LMAGA group across different subgroups (stratified by age, operative duration, and body weight). The results showed that regardless of grouping by age (< 35 years vs ≥ 35 years), operative duration (< 90 min vs ≥ 90 min), or body weight (< 50 kg vs ≥ 50 kg), the LMAGA group had significantly shorter durations for all three indicators compared to the EGA group ($P < 0.05$).

Time to first ambulation and first oral intake in the two groups

Figure 3 presents a comparison of the time to first ambulation and first oral intake postoperatively between the two groups. **Figure 3A** illustrates the time to first ambulation. The LMAGA group had a shorter time to first ambulation than the EGA group ($P < 0.05$). **Figure 3B** displays the time to first oral intake, which was sig-

Table 4. Changes in blood glucose and cortisol levels in the two groups of adults

Indicator	EGA group (n=44)	LMAGA group (n=44)	*t*	*P*
Blood glucose (mmol/L)				
T0	5.30 ± 0.81	5.30 ± 0.80	0.00	1.000
T1	5.50 ± 0.82	5.20 ± 0.79	1.37	0.175
T2	5.60 ± 0.83	5.50 ± 0.81	0.51	0.612
T3	5.30 ± 0.81	5.60 ± 0.82	-0.94	0.351
T4	5.10 ± 0.79	5.30 ± 0.80	-0.87	0.387
T5	5.40 ± 0.82	5.25 ± 0.79	0.73	0.475
Cortisol concentration (nmol/L)				
T0	172.13 ± 9.32	171.82 ± 9.61	0.15	0.882
T1	401.21 ± 10.51	382.43 ± 9.83	2.57	0.075
T2	512.32 ± 11.24	486.13 ± 10.44	6.18	< 0.001
T3	620.14 ± 11.82	590.24 ± 10.61	6.90	< 0.001
T4	529.03 ± 12.35	486.22 ± 10.15	7.22	< 0.001
T5	433.15 ± 12.73	399.78 ± 11.16	5.87	< 0.001

Note: EGA: endotracheal general anesthesia; LMAGA: laryngeal mask airway general anesthesia; T0: before anesthesia induction; T1: immediately after anesthesia induction; T2: 1 minute after endotracheal intubation/laryngeal mask airway insertion; T5: at the end of surgery. Data are presented as mean ± standard deviation.

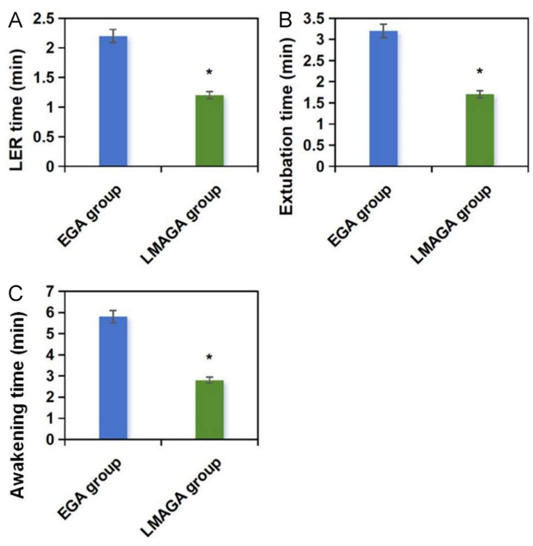

Figure 1. Differences in anesthesia and awakening indicators between the two groups. EGA: endotracheal general anesthesia; LMAGA: laryngeal mask airway general anesthesia; LER: Loss of eyelash reflex. A. LER time; B. Extubation time; C. Awakening time; **P* < 0.05 vs EGA group.

nificantly earlier in the LMAGA group than in the EGA group (*P* < 0.05).

BIS and Narcotrend index at different time points in the two groups of patients

Table 5 illustrates the changes in the BIS and Narcotrend index at different time points (T0-T5) in the two groups of patients. Both groups were in an awake state at T0, with BIS and Narcotrend values close to 100. Following anesthesia induction, the values in both groups decreased to a range between 38 and 49 (T1-T4). The BIS and Narcotrend indices in the EGA group were significantly higher than those in the LMAGA group at T2 and T5 (*P* < 0.05).

Comparison of respiratory complications in adults

The differences in the rates of respiratory complications between the EGA group and the LMAGA group were observed, and the results are shown in **Table 6**. The total respiratory complication rate was 34.09% (15/44) in the EGA group and significantly lower at 6.82% (3/44) in the LMAGA group (*P* < 0.05).

Comparison of MoCA cognitive function dimension scores before and after surgery between the two groups

Table 7 presents the comparison of MoCA dimension scores between the two groups before and after surgery, including language ability, orientation, abstract thinking, calculation ability, and memory. There were no significant differences between the two groups in any indicator before surgery (*P* > 0.05), indicating baseline balance. Postoperatively, the LMAGA group had significantly higher scores than the EGA group in the cognitive domains of lan-

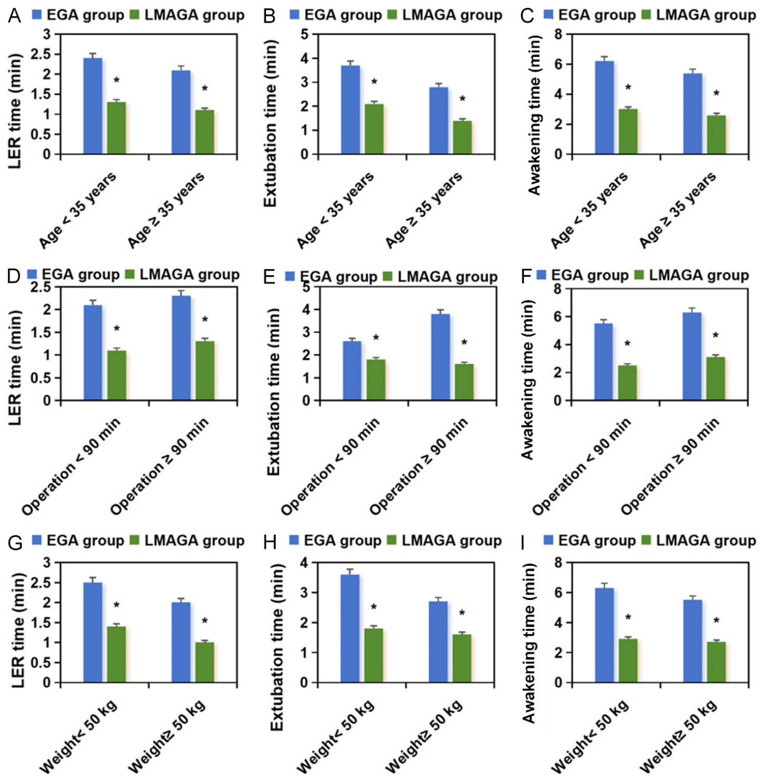

Figure 2. Subgroup differences in anesthesia and recovery indicators between the two groups. EGA: endotracheal general anesthesia; LMAGA: laryngeal mask airway general anesthesia; LER: Loss of eyelash reflex. A. LER time in different age groups; B. Extubation time in different age groups; C. Awakening time in different age groups; D. LER time in different surgical durations; E. Extubation time in different surgical durations; F. Awakening time in different surgical durations; G. LER time in different body weight groups; H. Extubation time in different body weight groups; I. Awakening time in different body weight groups; *$P < 0.05$ vs EGA group.

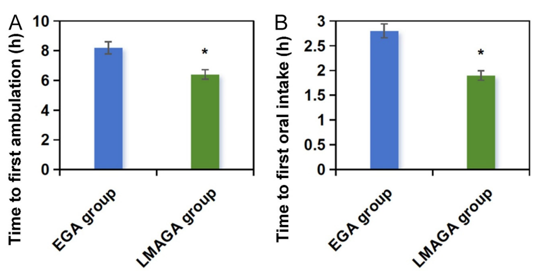

Figure 3. Time to first ambulation and first oral intake in the two groups of patients. EGA: endotracheal general anesthesia; LMAGA: laryngeal mask airway general anesthesia. A. Time to first ambulation; B. Time to first oral intake. *$P < 0.05$ vs EGA group.

guage, orientation, abstract thinking, calculation, and memory assessment ($P < 0.05$). The postoperative scores of both groups decreased significantly compared to their preoperative scores ($P < 0.05$), and the decrease in the LMAGA group was smaller than that of the EGA group ($P < 0.05$).

Comparison of medium- to long-term postoperative sleep-related complications between the two groups

Figure 4 shows the comparison between the EGA group and the LMAGA group in terms of the number of cases of three adverse sleep-related complications during the medium- to long-term postoperative period: restlessness, night terrors, and sleep disorders. The number of cases in the LMAGA group was significantly lower than that of the EGA group across all three indicators ($P < 0.05$).

Discussion

In this study, the effects of positive pressure ventilation by laryngeal mask airway and endotracheal intubation were compared in patients undergoing short-duration general anesthesia induced with sevoflurane combined with mivacurium and fentanyl. More stable hemodynamic values (HR, MAP) and ventilatory variables ($PETCO_2$) were observed in the LMAGA group immediately and within 1 minute after laryngeal mask airway placement. Serum cortisol levels, as a marker of perioperative stress, were significantly lower in the LMAGA group than in the EGA group. Recovery indicators such as the time to loss of eyelash reflex, extubating time, and awakening time were all shortened. Postoperatively, earlier ambulation and oral intake were initiated in the LMAGA group. Lower BIS and Narcotrend index values at T2 and T5 indicated that anesthesia was more stable. The overall incidence of respiratory complications was 6.82% in the LMAGA group, compared to 34.09% in the EGA group. The LMAGA group showed a significantly lower incidence of agitation, night terrors, and sleep disorders compared to the EGA group, and exhibited significantly better postoperative cognitive

Table 5. BIS and Narcotrend indices at different time points in the two groups of patients

Indicator	EGA group (n=44)	LMAGA group (n=44)	*t*	*P*
BIS				
T0	96.21 ± 5.12	95.82 ± 5.04	0.32	0.757
T1	42.50 ± 5.36	40.35 ± 5.21	1.58	0.118
T2	48.72 ± 5.58	41.43 ± 5.48	4.13	< 0.001
T3	43.66 ± 5.42	43.86 ± 5.32	-0.07	0.945
T4	39.13 ± 5.26	37.82 ± 5.17	0.75	0.461
T5	52.32 ± 5.60	45.65 ± 5.53	3.45	0.001
Narcotrend index				
T0	96.23 ± 5.23	95.82 ± 5.14	0.24	0.818
T1	41.56 ± 5.45	40.92 ± 5.32	0.46	0.654
T2	47.32 ± 5.61	42.12 ± 5.56	3.98	< 0.001
T3	44.81 ± 5.53	41.55 ± 5.40	2.14	0.056
T4	40.24 ± 5.31	39.81 ± 5.22	0.26	0.803
T5	52.42 ± 5.72	43.03 ± 5.63	3.29	0.001

Note: BIS: bispectral index; EGA: endotracheal general anesthesia; LMAGA: laryngeal mask airway general anesthesia; T0: before anesthesia induction; T1: immediately after anesthesia induction; T2: 1 minute after endotracheal intubation/laryngeal mask airway insertion; T5: at the end of surgery. Data are presented as mean ± standard deviation.

Table 6. Incidence of respiratory related complications in the two groups

Indicator	EGA group (n=44)	LMAGA group (n=44)	X^2	*P*
Hoarseness n (%)	4 (9.09)	2 (4.55)	0.36	0.551
Sore throat n (%)	5 (11.36)	1 (2.27)	3.86	0.049
Laryngospasm n (%)	2 (4.55)	0 (0.00)	2.05	0.153
Cough n (%)	2 (4.55)	0 (0.00)	2.05	0.153
Regurgitation n (%)	1 (2.27)	0 (0.00)	1.01	0.315
Respiratory depression n (%)	1 (2.27)	0 (0.00)	1.01	0.315
Total complications n (%)	15 (34.09)	3 (6.82)	10.29	0.001

Note: EGA: endotracheal general anesthesia; LMAGA: laryngeal mask airway general anesthesia. Data are presented as n (%).

status. Adults exhibit distinct physiological and psychological responses during the perioperative period. Preoperative emotional stress is known to activate the sympathetic nervous system (SNS) and the hypothalamic-pituitary-adrenal axis, leading to a series of neuroendocrine responses. This state of stress has been shown to promote adrenocorticotropic hormone release, which subsequently stimulates the adrenal cortex to secrete cortisol. At the same time, SNS activation results in greater secretion of catecholamines such as epinephrine and norepinephrine, leading to increased HR, blood pressure, and diaphoresis - i.e., the classic manifestations of the fight-or-flight response [7]. Previous research has shown that preoperative anxiety in adults not only complicates the smooth induction of anesthesia but is also associated with several adverse postoperative outcomes, such as emergence agitation, hyperalgesia, and delayed recovery, and even some long-term behavioral changes [8]. Inhalation anesthesia is generally used for induction because it enhances the effect of anesthetics and has a favorable safety profile. Sevoflurane is known to inhibit the cardiovascular stress response to intubation. In a study of adults with Down syndrome who underwent inhalation induction with sevoflurane, more than half experienced bradycardia attributed to SNS dysfunction. This finding indicated that sevoflurane may suppress sympathetic activity rather than effectively attenuating the stress response to intubation [9]. Although sevoflurane has been reported to have a relatively minor impact on hemodynamics and to exert stabilizing effects before and after cardiopulmonary bypass in cardiac surgery [10], other evidence indicated that in certain contexts - such as dental procedures - sevoflurane combined with propofol helped maintain higher blood pressure compared to local anesthesia. However, sevoflurane itself was not necessarily associated with effective suppression of the intubation stress response [11]. Furthermore, a study directly comparing the inhibitory effects of different pharmacologic agents on hemodynamic responses to laryngoscopy and tracheal intubation demonstrated that nebulized dexmedetomidine (1 μg/kg) and magnesium sulfate (40 mg/kg) were superior to nebulized fentanyl (1 μg/kg) in attenuating the stress response, with no mention of sevoflurane exhibit-

Table 7. Comparison of MoCA cognitive function scores between the two groups before and after surgery

Indicator	EGA group (n=44)	LMAGA group (n=44)	*t*	*P*
Language ability				
Pre-operative	4.23 ± 1.07	4.28 ± 1.08	0.23	0.819
Post-operative	3.43 ± 0.73	4.19 ± 1.04	4.15	0.001
Orientation				
Pre-operative	4.08 ± 1.21	4.10 ± 1.20	0.08	0.936
Post-operative	3.66 ± 0.83	4.01 ± 1.13	1.76	0.042
Abstract thinking				
Pre-operative	4.19 ± 1.17	4.21 ± 1.13	0.09	0.928
Post-operative	3.71 ± 0.91	4.10 ± 1.08	1.95	0.034
Calculation ability				
Pre-operative	4.13 ± 1.08	4.14 ± 1.07	0.05	0.961
Post-operative	3.51 ± 0.83	4.01 ± 1.01	2.68	0.009
Memory				
Pre-operative	4.05 ± 1.21	4.07 ± 1.24	0.09	0.972
Post-operative	3.13 ± 1.08	3.98 ± 1.18	3.62	0.001

Note: MoCA: Montreal Cognitive Assessment; EGA: endotracheal general anesthesia; LMAGA: laryngeal mask airway general anesthesia. Data are presented as mean ± standard deviation.

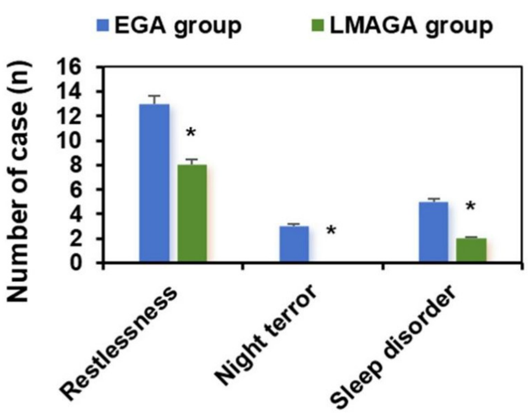

Figure 4. Medium- to long-term postoperative sleep-related complications in the two groups. EGA: endotracheal general anesthesia; LMAGA: laryngeal mask airway general anesthesia. *P < 0.05 vs EGA group. The bar for the LMAGA subgroup in the Night Terrors is not visible because the corresponding value is zero.

ing a superior inhibitory effect [12]. $PETCO_2$, as a noninvasive, simple, and continuous monitor of ventilation, can indicate insufficient ventilation when elevated, thereby increasing the likelihood of hypercapnia. The anesthetic protocol used in this study effectively ensured adequate intraoperative ventilation. The stress response is the process of endocrine and metabolic changes caused by trauma or stimulation. Excessive stress can lead to the release of large amounts of catecholamines, which may trigger various adverse events. Endotracheal intubation induced a sympathetic response, leading to elevated HR and blood pressure. Intubation was more likely to cause mechanical injury. In addition, pharmacologic interventions have been explored for their potential to attenuate the stress response to intubation. Dexmedetomidine and fentanyl are used to reduce fluctuations in blood pressure and HR, as well as the secretion of stress hormones such as cortisol, during surgery [13]. Sevoflurane itself, due to its relatively mild impact on hemodynamics, has also been considered to possess certain stabilizing properties. Although sevoflurane was found to reduce the expression of inflammatory factors such as IL-6 and IL-8 [14], its exposure during neurodevelopment has been implicated in inducing oxidative stress and cognitive dysfunction. It has been suggested that such adverse effects might be alleviated through the modulation of pathways involving prostate androgen-regulated transcript 1/microRNA-16-5p [15] or the expression of thioredoxin-interacting protein [16]. The present study found that cortisol levels in the LMAGA group were significantly lower than those in the EGA group at all measured time points, suggesting effective attenuation of undesirable stress responses. Furthermore, shorter times to loss of eyelash reflex, extubation, and awakening, as well as significantly earlier postoperative ambulation and oral intake, were observed in the LMAGA group (P < 0.05). Lower BIS and Narcotrend index values were also noted at T2 and T5 in this group (P < 0.05). This reflects reduced mechanical stimulation to the pharynx and larynx, diminished sympathetic activation, more stable anesthetic depth, faster recovery, and enhanced comfort. The differences in BIS and Narcotrend indices between groups at T2 and T5 in this study reflected the varying effects of different airway management methods on nociceptive stimulation conduction and anesthetic requirements. At T2, patients in the EGA group were about to undergo laryngoscope exposure and endotracheal intubation, with a significant increase in SNS excitability, leading to a higher degree of electroencephalographic desynchronization. The BIS and Narcotrend indices were relatively high or fluctuated greatly, requiring a deeper depth of anesthesia to suppress the intubation response. In the LMAGA group, only laryngeal mask insertion was involved, with significantly lower stimulation intensity; therefore, under the same anesthetic dosage, the degree of electroencephalographic suppression was greater, and the indices were lower. At T5, the surgery had entered a stable phase; however, continuous mechanical stimulation of the tracheal mucosa by the endotracheal tube might still cause mild arousal reactions or increased autonomic nervous system tension. Therefore, maintaining the same anesthesia depth index in the EGA group might require a higher concentration of inhaled or intravenous anesthetics. The laryngeal mask caused minimal airway stimulation, and patients in the LMAGA group were in a relatively calm state of anesthesia. When performing endotracheal anesthesia, clinicians should anticipate the strong stimulation caused by intubation and the presence of the indwelling tube, appropriately deepen anesthesia or combine with opioids to maintain suitable electroencephalographic indices, and avoid intraoperative awareness or severe hemodynamic fluctuations. For laryngeal mask anesthesia, caution should be taken to avoid excessively deep anesthesia due to weak stimulation, optimize drug dosages, and promote rapid postoperative awakening and cognitive function recovery. Endotracheal intubation has historically been accompanied by a higher risk of complications, such as postoperative sore throat, hoarseness, mucosal damage, coughing, and laryngospasm during insertion and removal. These complications not only reduce patient comfort but also prolong hospital stays and lower patient satisfaction [17]. On the other hand, although the laryngeal mask airway is a supraglottic airway device, it is placed above the glottis without the need for a laryngoscope to visualize the vocal cords. This placement has been shown to decrease significantly themechanical irritation and trauma to the airway mucosa [18]. Furthermore, in adenotonsillectomy, although endotracheal intubation is generally favored, the use of an laryngeal mask airway was associated with a lower incidence of laryngospasm and a superior safety profile [19]. In the present study, the overall incidence of respiratory complications (including hoarseness, sore throat, laryngospasm, coughing, regurgitation, and respiratory depression) was 34.09% (15/44) in the EGA group, which was significantly higher than that in the LMAGA group (6.82%, 3/44). These findings further support that the use of positive pressure ventilation via a laryngeal mask airway offers advantages in maintaining hemodynamic stability and reducing various postoperative respiratory complications. In this study, the LMAGA group exhibited a significantly lower complication rate and better postoperative cognitive function. Compared to endotracheal intubation, laryngeal mask placement did not require passing through the glottis, thereby avoiding direct mechanical injury to the tracheal mucosa and strong nociceptive stimulation, which significantly reduced intraoperative complications such as coughing, laryngospasm, and drastic hemodynamic fluctuations. This gentle airway management approach resulted in a lower degree of sympathetic-adrenal system activation and reduced release of endogenous stress hormones, thereby decreasing the damage of neuroinflammation to key cognitive brain regions such as the hippocampus. Additionally, because the laryngeal mask procedure required a shallower depth of anesthesia and less reliance on muscle relaxants, patients in the LMAGA group likely received a lower total amount of inhaled or intravenous anesthetics during surgery. This not only shortened the time for drug metabolism and clearance, facilitating rapid postoperative recovery, but also effectively mitigated the inhibitory effects and potential neurotoxicity of residual anesthetics on the central nervous system, thereby resulting in better cognitive recovery quality in the early postoperative period. For short-duration surgeries, prioritizing laryngeal mask ventilation is not only an optimal strategy for airway management but also an important measure to protect patients' perioperative brain function.

During anesthesia, the physiologic characteristics of patients often lead to adverse reactions during the induction period, including agitation, breath-holding, and laryngospasm. These factors significantly increase the difficulty and risk of anesthesia management. Therefore, to ensure perioperative safety, modern anesthesia requires rapid onset and high controllability of anesthetic drugs, maximal suppression of the stress response, maintenance of stable hemodynamics, and facilitation of postoperative recovery. These requirements impose higher demands on the choice of anesthetic regimens. Sevoflurane is a new generation of inhalation general anesthetic that can be considered an ideal agent for anesthesia due to its unique pharmacologic properties. A low blood/gas partition coefficient allows rapid equilibrium between alveolar and arterial concentrations, providing effective anesthesia and easy induction. Moreover, its minimal airway irritability facilitates mask induction in adults, thereby avoiding the fear and distress of venous puncture [20]. Sevoflurane undergoes minimal metabolic biotransformation and is mainly excreted through the lungs, enabling rapid recovery of consciousness and facilitating early postoperative evaluation and mobilization. Evidence has shown that, compared to propofol-based intravenous anesthesia, sevoflurane-based balanced anesthesia causes less circulatory depression and better preserves hemodynamics - i.e., blood pressure and cardiac output [21]. In this study, the neuromuscular blocking agent MC was used to further optimize the balance of anesthesia, muscle relaxation, and recovery. MC is rapidly hydrolyzed by plasma pseudocholinesterase, with a half-life of approximately two minutes, and this process is reversible [22]. MC is particularly suitable for surgical procedures that require rapid neuromuscular blockade and early recovery of spontaneous breathing. The risk of inadequate airway protection after extubation is significantly reduced, providing a physiologic basis for the safe removal of airway devices [23]. Fentanyl is characterized by rapid onset, significant analgesic effects, and a moderate duration of action, making it widely used during surgery. Fentanyl has minimal effects on myocardial contractility and peripheral vascular resistance and does not release histamine at conventional doses. Fentanyl produces a synergistic effect with sevoflurane, enhancing anesthesia and analgesia [24]. Positive pressure ventilation hrough a laryngeal mask airway represents a novel and valuable ventilation method. The laryngeal mask airway does not require tracheal intubation, thereby avoiding direct stimulation of the vocal cords and tracheal mucosa; it is easy to insert, allows rapid deployment, and causes minimal trauma [25]. Under sevoflurane anesthesia, sufficient relaxation of the pharyngeal and laryngeal muscles ensures a secure seal for positive pressure ventilation. The combination of sevoflurane and mivacurium for induction of anesthesia, along with positive pressure ventilation via laryngeal mask airway, constituted an effective application model.

The innovation of this study lies in its systematic evaluation of the combined effects of a triple induction regimen (sevoflurane, mivacurium, and fentanyl) during positive pressure ventilation by laryngeal mask airway. This study employed two electroencephalography indicators (BIS and Narcotrend) and the gold-standard stress biomarker serum cortisol to thoroughly investigate the inhibition of neuroendocrine stress responses achieved through the synergistic effects of this combination regimen. This study assessed the time to first ambulation and the time to first oral intake, confirming the efficacy of the combined medication. The findings of this study hold significant practical value for primary healthcare institutions and ambulatory surgery centers. However, this study had several limitations, including its single-center design, small sample size, exclusion of laparoscopic surgery and cases with high reflux risk, and the lack of long-term follow-up data. Future research could adopt multicenter randomized controlled trials with larger sample sizes to explore the applicability of laryngeal mask airway ventilation in various types of surgical procedures. Further investigation is also needed into the correlations involving inflammatory cytokines and neuroelectrophysiologic data.

Conclusion

When a laryngeal mask airway was used for positive pressure ventilation, the combination of sevoflurane, MC, and fentanyl for general anesthesia stabilized hemodynamic status, reduced the incidence of stress responses and respiratory complications, and achieved satisfactory anesthetic effects. In the future, the sample size needs to be expanded to determine the effect of different surgical types on anesthetic effects.

Acknowledgements

This work was supported by Tianjin Key Medical Discipline Construction Project (No. TJYXZDXK-3-019B).

Disclosure of conflict of interest

None.

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