ORIGINAL ARTICLE

Optimizing nonintubated laryngeal microsurgery: The effectiveness and safety of superior laryngeal nerve block with high-flow nasal oxygen—A prospective cohort study

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Abstract

Background: Laryngeal microsurgery (LMS) typically requires intubated general anesthesia (ITGA). Although nonintubated general anesthesia (NIGA) with high-flow nasal oxygen (HFNO) can be applied with LMS, a muscle relaxant is required, which can cause apnea and hypercapnia. This study evaluated the effectiveness of a superior laryngeal nerve block (SLNB) in improving safety during LMS.

Methods: This prospective cohort study enrolled a cumulative total of 61 adult patients received LMS under intravenous general anesthesia and allocated to three groups: ITGA group (n = 18), which patients performed intubation; neuromuscular blocking (NMB) group (n = 21), which patients administrated muscle relaxant without intubation and superior laryngeal nerve block (NB) group (n = 22), which patients performed SLNB without intubation or muscle relaxant.

Results: The average (SD) values of $PaCO_2$ after surgery in ITGA, NMB, and NB group were 50.8 (7.5), 97.5 (24.9), and 54.8 (8.8) mmHg, respectively. The mean postoperative pH values were 7.33 (0.04), 7.14 (0.07), and 7.33 (0.04), respectively. The results were all $p < 0.001$, and the average pH value of the NMB group was lower than that of the ITGA and NB groups. During the LMS, the mean heart rate (HR) (93.9 [18.1] bpm) and noninvasive blood pressure systolic (NBPs) (143.5 [28.2] mmHg) in the NMB group were higher than those in the ITGA group (HR = 77.4 [13.5] bpm and NBPs = 132.7 [20.8] mmHg) and NB group (HR = 82.3 [17.4] bpm and NBPs = 120.9 [25.0] mmHg). The results of p value by HR and NBPs are $p < 0.001$. The $PaCO_2$ and pH values are similar between ITGA group and NB group.

Conclusion: Our approach of using HFNO with SLNB was successful for performing nonintubated LMS, enabling the patients to maintain spontaneous breathing and effectively eliminate CO_2. This approach reduces the risks of hypercapnia and acidosis even when the duration of LMS exceeds 30 minutes.

Keywords: Laryngeal microsurgery; Nonintubation; Spontaneous breathing; Superior laryngeal nerve block

1. INTRODUCTION

Among the most common operations in otolaryngology, laryngeal microsurgery (LMS) requires administration of general anesthesia and endotracheal tube (ETT) intubation typically. In addition to providing stable gas exchange, ETT intubation can protect airways by preventing secretions from entering the lower respiratory tract. Parameters monitoring such as end-tidal CO_2 and tidal volume through ETT is also crucial.

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Another option is nonintubated anesthesia applied in combination with transnasal humidified rapid-insufflation ventilatory exchange or high-flow nasal oxygen (HFNO) for the estimated LMS time <30 minutes.[1] Its use in LMS can prevent the complications caused by ETT intubation such as oral soft tissue trauma, tracheal injuries, and dental injuries,[2] as well as enable comprehensive vocal cord inspection and treatment by providing a loosen clearer surgical field.[3] Currently, the practice of nonintubated anesthesia in LMS involves the administration of a muscle relaxant, which helps prevent bucking during the procedure. However, the muscle relaxant administration can lead to apnea and hypercapnia which may have negative effect on hemodynamics. The superior laryngeal nerve block (SLNB) is an efficacious intervention that mitigates laryngeal reflex responsiveness and sustains hemodynamic stability during laryngeal manipulations. As evidenced in the literature, administering 1 to 2 mL of 2% lidocaine in the region inferior and lateral to the greater horn of the hyoid bone yields proficient analgesic effects, lasting from 60 to 180 minutes post-injection.[4] The utilization of SLNB is noted for providing superior analgesic effects with extended duration. Therefore, this study investigates the effectiveness and safety of HFNO in conjunction with SLNB for the maintenance of spontaneous ventilation in patients undergoing nonintubated LMS.

2. METHODS

In this prospective cohort study, the efficacy of LMS with and without intubated general anesthesia was examined. Furthermore, we wanted to compare the safety and practicality of LMS with nonintubated general anesthesia using two different ventilation strategies. Ethics approval for this study was provided by the Institutional Review Board of Kaohsiung Veterans General Hospital (No. KSVGH20-CT9-09). Additionally, our study has been registered with ClinicalTrials.gov under the registration number NCT05420649. Written informed consent was obtained from all trial participants. The Declaration of Helsinki was followed in the conduct of this investigation. Enrollment in the study was open to patients between the ages of 20 and 80 who underwent LMS with intravenous general anesthesia at Kaohsiung Veterans General Hospital between October 2020 and December 2022. The exclusion criteria were as follows: presence of severe airway obstruction and severe airway disease, American Society of Anesthesiologists (ASA) physical state > III, pregnancy, or body mass index ≥40 kg/m^2. Patients requiring LMS under intravenous general anesthesia were recruited and stratified into three cohorts: the intubated general anesthesia group (ITGA), which involved endotracheal intubation; the neuromuscular blocking group (NMB) with HFNO, which did not involve intubation but included the administration of muscle relaxants; and the superior laryngeal nerve block group (NB) with HFNO, which proceeded without either intubation or neuromuscular blockade, utilizing SLNB to facilitate the surgical process. Peripheral intravenous access monitoring was performed for all patients preoperatively, including peripheral oxygen saturation (SpO_2), electrocardiogram, noninvasive blood pressure (BP), and GE Entropy EasyFit Sensor/bispectral (BIS) index (Medctronic, Minneapolis, MN) monitoring; train-of-four (TOF) monitoring was performed only in ITGA and NMB group. Glycopyrolate (0.2 mg), hydrocortisone (100 mg), and midazolam (1-5 mg) were administered intravenously as premedications before induction. Intravenous propofol (Schneider model effect-site target-controlled infusion [TCI] = 2.5-5 μg/mL), remifentanil (Minto model effect-site TCI = 0.5-3 ng/mL), and lidocaine (1-1.5 mg/kg) were administered at the start of induction. The target concentration of TCI propofol will be adjusted to maintain the value of Entropy or BIS around 40 to 60 during operation. Rocuronium (0.6 mg/kg) or cisatracurium (0.15 mg/kg) was administered at loss of consciousness in the ITGA group, and TOF monitoring helped maintain deep-to-moderate neuromuscular blocks for ETT intubation (5.0-5.5, I.D. mm) and for the entire LMS period. Rocuronium was administered before LMS initiation in the NMB group, and a deep-to-moderate neuromuscular block was maintained for the entire LMS period. A face mask with 100% O_2 at a flow rate of 6 L/min before induction was used for preoxygenation in the ITGA group. After intubation, the ventilator was set to operate in volume control mode, in which the tidal volume was set to 6 to 8 mL/kg, 50% O_2 was supplied at a flow rate of 2 L/min, and end-tidal CO_2 was maintained at <40 mmHg. For HFNO delivery in the two nonintubated groups, an Optiflow device (Fisher & Paykel Healthcare, Auckland, New Zealand) was used to perform preoxygenation with 100% O_2 at a flow rate of 20 L/min for at least 5 minutes before induction, followed by increasing the flow rate to 50 L/min after induction and for the entire LMS period. In the study, we conducted laser surgery by using a diode laser in the few patients in the ITGA, NMB, and NB groups. For the patients in the NMB and NB groups, we supplied HFNO by substituting 100% O_2 with pure air maintained at a flow rate of 50 L/min for 2 to 3 minutes before using the laser. During this period, we prepared 20 mL of normal saline in the syringe as a fire extinguisher. The oxygen supply with pure air could be turned off immediately at any time.[5] The HFNO was restored to 100% O_2 following the conclusion of the laser application. All diode laser operations were completed successfully without airway ignition.

The bilateral transverse-approach ultrasound-guided SLNB was executed subsequent to induction, utilizing a FUJIFILM SonoSite"X-Porte linear probe within the frequency range of 6 to 15 Hz, as delineated in the preceding literature.[6] The sonographic landmark, specifically the greater horn of the hyoid bone, was pinpointed under a transverse orientation of the cervical ultrasonography. Subsequently, a quantity of 1 to 2 mL of 2% lidocaine was meticulously infiltrated around the identified landmark using a 25-gauge needle for local anesthetic purposes.

On the basis of surgical plethysmographic index (SPI) values of 30 to 50, TCIs of remifentanil were administered to reduce the effect of LMS-induced stimulation and pain on vital signs. At the end of the LMS procedure, intravenous infusions ceased in the NB group, and the patients were allowed to breathe spontaneously as they emerged from general anesthesia. In the ITGA and NMB groups, intravenous sugammadex or neostigmine was administrated as reversal agent for rocuronium or cisatracurium. After extubation and recovery to spontaneous breathing in the ITGA group, and after face mask ventilation and HFNO cessation in the NMB group, the patients in both groups were transferred to the postanesthesia care unit (PACU).

Pre-LMS period measurements were obtained after the patient entered the operating room, and all monitors were set every 5 minutes three times. LMS period measurements were conducted every 5 minutes from the start of the LMS until the end of the LMS. PACU measurements were performed every 5 minutes after patients arrived at the PACU and were breathing with low-flow supplemental oxygen (2-4 L/min).

Arterial blood gas (ABG) measurements were performed at three-time points to assess the partial pressure of arterial carbon dioxide ($PaCO_2$), the partial pressure of arterial oxygen (PaO_2), and the pH in each group. These time points are described as follows: the first ABG measurement was performed before intubation in the ITGA group, before muscle relaxant administration in the NMB group, and before bilateral SLNB execution in the NB group (pre-LMS). The second ABG measurement was performed immediately after the end of the LMS (post-LMS). Finally, the third measurement was performed 15 minutes after the patient arrived in the PACU.

$EtCO_2$ was measured and maintained below 40 mmHg only in the ITGA group by using an ETT. Heart rate (HR) and noninvasive blood pressure (NBP) measurements were conducted every 5 minutes during the entire procedure.

The primary outcome was $PaCO_2$ measured immediately post-LMS (ie, the second ABG measurement time point). Moreover, the secondary outcomes were as follows: (1) pH and PaO_2 determined at the second ABG measurement time point; (2) $PaCO_2$, pH, PaO_2, and bicarbonate determined at the first and third ABG measurement time points; and (3) HR, systolic BP (BP_s), diastolic BP (BP_d), mean arterial pressure (MAP), and SpO_2 determined at the three measurement periods (pre-LMS period, LMS period, and PACU period).

The patients' characteristics are presented as absolute and relative percentages for categorical variables and as means and SD for continuous variables. We performed a one-way analysis of variance and Bonferroni post hoc multiple comparisons to compare the mean values of continuous data between the three groups. A chi-square test was used to compare the proportion of categorical variables among the three groups. A $p < 0.05$ was considered statistically significant. All statistical analyses were performed using SPSS (version 20; IBM, Armonk, NY). On the basis of several studies, we determined the sample size required for this study by using tools provided on ClinCalc.com (https://clincalc.com/stats/samplesize.aspx) to calculate the normal mean range for $PaCO_2$ (50 ± 5 mmHg) and the mean value of the lowest acceptable normal value of $PaCO_2$ (55 mmHg), and alpha is set at 0.05, beta is set at 0.2, and the power is set at 0.8. The minimum required sample size for each group is 16.[7,8]

3. RESULTS

From October 2020 to December 2022, a total of 63 patients successfully completed the study protocol. Among them, 18 were assigned to the ITGA group, 21 to the NMB group, and 24 to the NB group (Fig. 1). Two cases from the NB group were excluded due to missing ABG data. There were no significant differences observed between the groups in terms of most patient characteristics (Table 1). Within the three study groups, the number of patients who underwent laser surgery varied: in the ITGA group, there were seven patients; in the NMB group, four patients; and in the NB group, a total of eight patients received laser surgery. Table 2 provides information on the patients' surgical status and average operation duration times. The NMB group had the highest $PaCO_2$ values of the ABG measurements during LMS, while the ITGA group had the lowest ($p < 0.001$; Table 3). At the same time point, the NMB group had the significantly lowest mean pH value ($p < 0.001$; Table 3). The ITGA group had the lowest mean PaO_2 value of the ABG measurements during LMS (Table 3). There were no significant between-group differences in the mean SaO_2 values of the ABG measurements during LMS ($p = 0.055$; Table 3). No significant differences of the ABG measurement parameters were observed between pre-LMS and PACU.

We also found no significant differences in hemodynamic parameters, including HR, BPs, BPd, and MAP, between the pre-LMS and PACU measurements (Table 4). During the LMS period, the NMB group had the highest mean HR ($p < 0.001$; Table 4). Similarly, the NMB group had a higher mean BPs value compared to the ITGA and NB groups ($p < 0.001$; Table 4). However, the ITGA group had a higher mean BPd value than the NMB and NB groups ($p = 0.003$; Table 4). The mean MAP values during LMS did not differ significantly between the ITGA and NMB groups, but the NB group had a significantly lower MAP value ($p < 0.05$; Table 4).

In comparing the outcomes of LMS with and without laser surgery within the NMB and NB groups, notable differences emerged. Specifically, significant variations were observed in the $PaCO_2$ and SO_2 levels of the ABG measurements during LMS in the NMB group (Supplementary Table S1, http://links.lww.com/JCMA/A231). However, no significant differences were found in the ABG measurements within the NB group. Furthermore, in the realm of hemodynamic measurements during LMS, the NMB group exhibited significant differences in NBPs and SpO_2 (Supplementary Table S2, http://links.lww.com/JCMA/A231). In addition, there were marked differences in NBPs, noninvasive

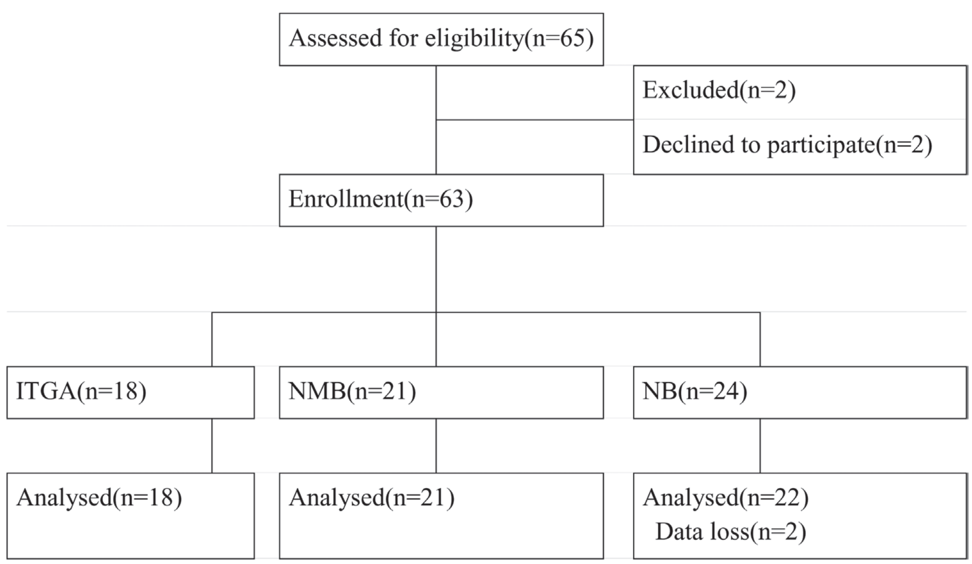

Fig. 1 Study protocol. ITGA = intubated general anesthesia; NB = nerve block; NMB = neuromuscular blocking.

Table 1
Demographics

	ITGA (n = 18)		NMB (n = 21)		NB (n = 22)		p
Age, y (mean, SD)	54.8	±13.5	52.2	±11.7	55.0	±12.5	0.739
BMI, kg/m² (mean, SD)	25.5	±4.8	26.1	±6.5	25.3	±2.8	0.848
Female (n, %)	6	33.3%	12	57.1%	10	45.5%	0.330
Male (n, %)	12	66.7%	9	42.9%	12	54.5%	
ASA I (n, %)	3	16.7%	8	38.1%	11	50.0%	0.021
ASA II (n, %)	15	83.3%	9	42.9%	8	36.4%	
ASA III (n, %)	0	0.0%	4	19.0%	3	13.6%	

Data are presented as mean (SD) or n (%) as indicated.
ASA = American Society of Anesthesiologists; BMI = body mass index; ITGA = intubation general anesthesia; NB = nonintubated general anesthesia and superior laryngeal nerve block; NMB = nonintubated general anesthesia and neuromuscular blocking.

Table 2

Surgical status

	ITGA (n = 18)		NMB (n = 21)		NB (n = 22)		p	Post hoc by Bonferroni
Operation duration (mean, min-max)	82.9	30-180	35.8	20-60	42.2	10-99	<0.001	ITGA > NMB ($p < 0.001$), ITGA > NB ($p < 0.001$)
The end of the operation to the recovery room (mean, SD)	21.4	±16.6	11.8	±5.3	13.0	±8.1	0.014	ITGA > NMB ($p = 0.021$), ITGA > NB ($p = 0.048$)
Vocal polyp (n, %)	2	11.1%	6	28.6%	6	27.3%	0.207	
Vocal cyst (n, %)	3	16.7%	3	14.3%	1	4.5%		
Vocal atrophy (n, %)	1	5.6%	5	23.8%	4	18.2%		
Vocal paralysis (n, %)	0	0.0%	2	9.5%	1	4.5%		
Vocal tumor (n, %)	1	5.6%	0	0.0%	0	0.0%		
Others (n, %)	11	61.1%	5	23.8%	10	45.5%		

Data are presented as mean (SD) or n (%) as indicated.
ITGA = intubation general anesthesia; NB = superior laryngeal nerve block; NMB = nonintubated general anesthesia and neuromuscular blocking.

Table 3

Results of ABG measurements at three-time points for each group

	ITGA (n = 18)		NMB (n = 21)		NB (n = 22)			
	Mean	SD	Mean	SD	Mean	SD	p	Post hoc by Bonferroni
Pre-LMS								
pH	7.36	0.03	7.35	0.04	7.35	0.04	0.649	-
$PaCO_2$	48.6	4.5	51.8	7.4	52.3	7.7	0.200	-
PaO_2	303.5	123.6	342.7	144.2	332.7	200.9	0.740	-
SO_2	99.2	2.6	99.6	0.9	98.5	2.9	0.246	-
HCO_3^-	27.7	1.5	28.7	2.1	29.1	2.5	0.103	-
During LMS								
pH	7.33	0.04	7.14	0.07	7.33	0.04	<0.001	ITGA > NMB ($p < 0.001$), NMB < NB ($p < 0.001$)
$PaCO_2$	50.8	7.5	97.5	24.9	54.8	8.8	<0.001	ITGA < NMB ($p < 0.001$), NMB > NB ($p < 0.001$)
PaO_2	183.1	57.6	262.6	135.1	356.7	137.2	<0.001	ITGA < NB ($p < 0.001$), NMB < NB ($p = 0.031$)
SO_2	99.4	1.1	98.3	2.9	99.7	0.5	0.055	-
HCO_3^-	27.0	2.0	33.0	3.3	28.7	2.4	<0.001	ITGA < NMB ($p < 0.001$), NMB > NB ($p < 0.001$)
In PACU								
pH	7.38	0.02	7.37	0.03	7.38	0.03	0.120	-
$PaCO_2$	43.6	3.7	47.0	5.7	45.0	5.2	0.101	-
PaO_2	120.5	57.4	108.2	37.9	132.3	70.9	0.394	-
SO_2	97.8	1.5	97.5	1.3	98.1	1.4	0.339	-
HCO_3^-	25.7	1.7	27.1	2.3	27.1	2.2	0.065	-

Data are presented as the mean (SD).
The symbol '-' in the post hoc column indicates 'no post hoc analysis performed due to the insignificance of the p-value'.
HCO3 = bicarbonate; ITGA = intubation general anesthesia; LMS = laryngeal microsurgery; NB = superior laryngeal nerve block; NMB = nonintubated general anesthesia and neuromuscular blocking; $PaCO_2$ = pressure of arterial carbon dioxide; PACU = postanesthesia care unit; PaO_2 = partial pressure of arterial oxygen; SO_2 = Oxygen saturation.

blood pressure diastolic (NBPd), and MAP during LMS in the NB group.

4. DISCUSSION

The primary aim of this investigation was to assess the effectiveness and safety of HFNO when used in conjunction with SLNB in the context of nonintubated LMS, by examining relevant anesthetic parameters. The analysis indicated that the $PaCO_2$, pH values, and hemodynamic measures during the LMS procedure in the NB group were comparable to those observed in the ITGA group, thereby validating the efficacy and security of SLNB in this surgical context.

Nonintubated LMS combined with HFNO and muscle relaxant was reported in previous study.[3] Yang et al reported HFNO with 100% O_2 at the flow rate of 50 L/min could maintain adequate oxygenation in apneic patients. But no further information about retention of CO_2 was noted in previous study; hence, we planned to find out by arranged ABG measurement right after the end of the LMS in our study. Our ABG measurement results reveal that the degree of CO_2 accumulation during LMS was higher in the NMB group than in the ITGA and NB groups. These results are consistent with those of a previous study on HFNO and apnea.[9] Booth et al reported a mean (SD) $PaCO_2$ of 89 (16.5) mmHg in the patients with apnea after 30 minutes of GA with HFNO composed of 100% O_2 supplied at a flow rate of 70 L/min. In our study, the mean (SD) $PaCO_2$ of the NMB group was 97.5 (24.9) mmHg at the end of the LMS, which is higher than that reported by the aforementioned study; our apnea group also had a shorter apnea time (mean: 15.1 minutes). We speculate that the HFNO flow rate has a certain degree of correlation with the CO_2 removal efficiency in patients with apnea. In addition to a shorter operation time, the use of a sufficiently high-flow rate and effective humidity–temperature maintenance may be an effective ventilation strategy for patients with apnea.[10,11]

Previous trial revealed that the infusion of intraoperative remifentanil may engender patients who received LMS under nonintubated general anesthesia with spontaneous breathing a reduced respiratory rate or shallow ventilation causing apnoea-like hypercapnia and respiratory acidosis.[12] A bilateral SLNB reduces LMS-induced stimulation or pain and reduces

Table 4

Intraoperative continuous monitoring results and comparison of the three groups before and after surgery

	ITGA (n = 18)		NMB (n = 21)		NB (n = 22)			
Vital sign	Mean	SD	Mean	SD	Mean	SD	p	Post hoc by Bonferroni
Pre-LMS								
HR	69.5	10.1	67.7	8.6	68.3	11.9	0.562	-
NBPs	137.0	18.7	138.9	20.5	139.2	26.3	0.811	-
NBPd	80.7	12.4	79.2	10.8	81.2	16.0	0.615	-
SpO_2	96.4	2.4	96.7	2.9	96.3	2.4	0.615	-
MAP_LMS	99.5	13.8	99.1	13.1	100.5	18.8	0.827	-
During LMS								
HR	77.4	13.5	93.9	18.1	82.3	17.4	<0.001	ITGA < NMB (p < 0.001), ITGA < NB (p = 0.006), NMB > NB (p < 0.001)
NBPs	132.7	20.8	143.5	28.2	120.9	25.0	<0.001	ITGA < NMB (p = 0.001), ITGA > NB (p < 0.001), NMB > NB (p < 0.001)
NBPd	81.8	14.2	79.1	16.7	73.9	16.2	<0.001	ITGA > NB (p < 0.001), NMB > NB (p = 0.029)
SpO_2	98.5	1.4	95.5	7.5	97.4	3.0	<0.001	ITGA > NMB (p < 0.001), ITGA > NB (p = 0.010), NMB < NB (p < 0.001)
MAP_LMS	98.7	15.9	100.6	19.5	89.6	18.8	<0.001	ITGA > NB (p < 0.001), NMB > NB (p < 0.001)
In PACU								
HR	79.9	8.5	80.9	19.3	84.6	14.3	0.567	-
NBPs	135.8	23.7	129.0	20.5	125.3	16.2	0.258	-
NBPd	83.7	15.8	81.5	12.5	79.8	11.7	0.656	-
SpO_2	98.3	1.6	98.3	1.5	98.0	2.0	0.834	-
MAP_LMS	101.1	17.9	97.3	14.5	94.9	12.5	0.437	-

Data are presented as the mean (SD).

The symbol '-' in the post hoc column indicates 'no post hoc analysis performed due to the insignificance of the p-value'.

HR = heart rate; ITGA = Intubation general anesthesia; LMS = laryngeal microsurgery; MAP = mean arterial blood pressure; NB = superior laryngeal nerve block; NBPd = noninvasive blood pressure diastolic; NBPs = noninvasive blood pressure systolic; NMB = neuromuscular blocking; PACU = postanesthesia care unit; SpO_2 = arterial oxygen saturation.

the dosage and effect of remifentanil on breathing.[13–15] Anton et al reported that patients who received spontaneous ventilation through the supply of HFNO composed of 100% O_2 at a flow rate of 70 L/min after 30 minutes had a mean $PaCO_2$ of 55 mmHg and a mean pH of 7.29. By contrast, our NB group had a lower mean (SD) $PaCO_2$ (54.8 [8.8] mmHg) but a higher mean (SD) pH (7.33 [0.04]). In addition, we observed that the longest LMS time in the NB group was 99 minutes, and the $PaCO_2$ and pH values derived for this LMS procedure at the second ABG measurement time point were 54.8 mmHg and 7.33, respectively. We noted no significant differences between the ITGA and NB groups in terms of $PaCO_2$ or pH. Thus, we speculate that a combination of an SLNB with spontaneous ventilation provided by supplying HFNO composed of 100% O_2 at a flow rate of 50 L/min can achieve a similar CO_2 removal capacity as intubated GA. This excellent oxygenation and CO_2 removal capacity can be maintained, even during prolonged surgery.

A previous study revealed no significant difference in hemodynamic data between the apnea and spontaneous ventilation patients undergoing microlaryngoscopy using HFNO during 30 minutes of tubeless anesthesia.[9] In our study, the mean MAP was significantly lower in the NB group than in the other groups. The lower hemodynamic profile of NB group may be influence by lower pain score. As previous study showed that hypercapnia caused elevated HR and BP_s in the apnea patients during tubeless anesthesia.[16] In the NB group, SLNB facilitated the stabilization of spontaneous ventilation and yielded a CO_2 removal capability comparable to that of the ITGA group. This stabilization might contribute to the lower MAP observed in the NB group relative to the other two groups.

In the NMB group, five patients had LMS <15 minutes; four exhibited $PaCO_2$ >100 mmHg and pH <7.15. The third ABG showed NMB group's values within safe limits without adverse effects. Severe respiratory acidosis poses risks, particularly in patients with cardiac or pulmonary issues, but its full impact is unknown.[17–19] Our data suggest that while HFNO at 50 L/min with 100% O_2 ensures oxygenation, it doesn't prevent hypercapnia in apneic patients. A flow of 70 L/min with minimized apnea duration is recommended to avert severe hypercapnia. Stable spontaneous ventilation is preferable during nonintubated LMS, with $PcCO_2$ measurement serving as a noninvasive $PaCO_2$ indicator, reducing hypercapnia risk. The NB group's mean PaO_2 was highest post-LMS (356.67 mmHg), implying SLNB allows for lower remifentanil doses and better ventilation. Conversely, the ITGA and NMB groups had reduced PaO_2, although NMB maintained good oxygenation via HFNO (PaO_2 = 262.6 mmHg), with no desaturation incidents reported.

Airway ignition is another potential risk during airway laser surgery under an HFNO supply.[20] In the recent work, Novakovic et al[21] demonstrated that for nonintubated LMS using HFNO, an FiO_2 delivery decrease from 100% to 30% may be possible to achieve a safe time window. This viable safe time window for the use of laser during LMS while using HNFO at a 30% oxygen concentration. Additionally, it was noted that jet ventilation rescue was required for 36% of the patients involved in this study, highlighting a combined ventilation techniques consideration in the clinical application of this technique.

There are a few limitations in our study. First, it is characterized as a small, single-center study with a limited sample size, which necessitates larger-scale studies to confirm these findings. Second, the inability to blind the anesthesia investigators to the different methods of anesthesia used for each group could potentially introduce the selection bias. Third, while the study included participants with a BMI of up to 35 kg/m², the highest BMI in the nonintubated group did not exceed 29.4 kg/m². Therefore, this study couldn't definitively ascertain HFNO's efficacy in severely obese patients. Fourth, in our study, LMS procedures both with and without laser surgery in the NMB and NB groups involved varying levels of FiO_2 delivery. This variation in FiO_2 during LMS could potentially influence the outcomes observed in ABG and hemodynamic measurements. Consequently, further research is warranted to elucidate the impact of differing durations of FiO_2 reduction on the patient's ABG parameters and hemodynamic changes.

In conclusion, HFNO at 50 L/min is confirmed to be effective for oxygenation in nonintubated LMS, suitable for both apneic events and spontaneous breathing. Muscle relaxants may introduce risks of hypercapnia, acidosis, and consequent hemodynamic instability. Conversely, an SLNB supports spontaneous respiration and mitigates the risk of acid-base disturbances, proving to be beneficial even in procedures exceeding 30 minutes in duration.

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APPENDIX A. SUPPLEMENTARY DATA

Supplementary data related to this article can be found at http://links.lww.com/JCMA/A231.

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