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ORIGINAL RESEARCH

Prospective Single-Arm Study of Remifentanil-Propofol Anesthesia with Manual Right Hypochondrial Compression for Painless Gastroscopy in Obese Patients

Mengxia Wang[1,*], Jieke Tang[1,*], Zhaojie Pan[2], Hongxue Jiang[1], Donghua Hu[1], Beibei Zhu[2], Zhaojia Liang[1], Xiangfeng Zhao[1], Yalan Li[1]

[1]Department of Anesthesiology, The First Affiliated Hospital of Jinan University, Guangzhou, Guangdong Province, People's Republic of China; [2]Department of Digestive Endoscopy Center, The First Affiliated Hospital of Jinan University, Guangzhou, Guangdong Province, People's Republic of China

*These authors contributed equally to this work

Correspondence: Yalan Li, Department of Anesthesiology, The First Affiliated Hospital of Jinan University, No. 613, Huangpu West Avenue, Tianhe District, Guangzhou, Guangdong Province, 510630, People's Republic of China, Email tyalan@jnu.edu.cn

Purpose: The provision of comfortable and safe environment for painless gastroscopy in obese patients is an urgent clinical problem. This study aimed to determine the efficacy and safety of the novel Li anesthetic protocol for obesity (LAPO) which included remifentanil-propofol regimen, manual right hypochondrial compression (MRHC), easy-to-create mask, and jaw thrust at preoperative painless gastroscopy in obese patients.

Patients and Methods: This prospective, single-center, single-arm trial recruited 106 participants underwent LAPO for gastroscopy. The primary outcome was the incidence of hypoxemia (peripheral oxygen saturation [SpO_2]: 75% ≤ SpO_2 <90%, for >10 s and ≤60 s). Second outcomes included severe hypoxemia, the lowest SpO_2 (L-SpO_2), duration of hypoxemia, and other events.

Results: The 98 obese patients under LAPO, the median body mass index (BMI) was 39.2 kg/m^2 and the incidence of hypoxemia was 27.5%, while the conventional anesthetic protocol for obesity (CAPO) in the reference was 40.4% with BMI 31.4 kg/m^2. With the increase of class of obesity, a significant rise in the incidence of hypoxemia was observed, from class I by 11.8%, to 15.1% in class II, and 41.7% in class III. Paired *t* test showed that the L-SpO_2 was significantly higher than L-SpO_2 in overnight polysomnography (Nadir SpO_2) (92% vs 76%, P<0.001). Moreover, severe obstructive sleep apnea (OSA) was associated with a 4.019-fold higher risk of hypoxemia (Odds ratios [OR], 4.019; 95% confidence interval [CI], 1.184 to 14.610; P=0.028); diabetes was associated with a 4.790-fold higher risk of hypoxemia (OR, 4.790; 95% CI, 1.288 to 23.600; P=0.030).

Conclusion: Compared with CAPO, LAPO reduced the incidence of hypoxemia from 40.4% to 27.5%, so, LAPO was safe and effective for painless gastroscopy. The finding might provide some new schedules for anesthetic management in the absence of advanced airway support instruments.

Clinical Trial Registration: ChiCTR2300077889.

Plain Language Summary: With the advancement of comfortable-oriented medication, gastroscopy is mostly performed under sedation and anesthesia. However, for obesity, there are changes in airway anatomy structure such as short neck, round chin, and large tongue, which makes them prone to airway obstruction after sleep or anesthesia, blocking the passage of oxygen in and out, which will cause hypoxemia over time and further cause damage to the body. Therefore, it is necessary to explore a safe and effective anesthesia management for painless gastroscopy in obesity. Our team's work demonstrates that the novel Li anesthetic protocol (strategic anesthesia management of remifentanil combined with propofol and effective respiratory support through MRHC and jaw thrust, increased oxygen reserve via a novel mask) for obesity for painless gastroscopy with lacking advanced airway management devices is safe and efficient. Furthermore, our findings contribute to the understanding of the lowest SpO_2 values that obese patients can tolerate during such procedures, establishing Nadir SpO_2 as the cut-off point. We also identified severe OSA and diabetes as independent

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predictive risk factors for hypoxemia. If these findings are supported by further research, LAPO could aid anesthesiologists in developing specific anesthesia protocols and managing the risk of hypoxemia during painless gastroscopy for obese patients. Ultimately, this could expand access to comfortable and safe medical treatment for a broader spectrum of patients with obesity.

Keywords: compression, hypoxemia, obese patient, obstructive sleep apnea, painless gastroscopy, propofol, remifentanil

Introduction

Obesity is a chronic and multisystemic disease, and its prevalence is increasing worldwide.[1–3] It is estimated that the prevalence of obesity will rise from 14% of the world's population to 24% between 2020 and 2035, affecting nearly 2 billion adults, adolescents, and children by 2035.[4] Due to the relationship between obesity and obesity-related comorbidities such as dyslipidemia, hypertension, diabetes, cardiovascular disease, and even certain types of cancer, it is necessary and important to actively control and treat obesity.[1,2] Studies have confirmed that surgery is a highly effective and beneficial method, especially for patients with BMI ≥40 kg/m^2 or BMI ≥35 kg/m^2 with obesity-related complications.[1,5,6] For this population, gastroscopy is strongly recommended, either for preoperative examination for bariatric surgery or for the diagnosis and treatment of gastrointestinal diseases.[7]

With the advancement of comfort-oriented medicine, gastroscopy is performed under sedation and anesthesia, which has become a common and important medical option.[8] However, according to the literature, the incidence of hypoxemia for normal BMI patients during this process is 26–85%.[9] Furthermore, for obesity, it was reported that the incidence of severe hypoxemia increased about six-fold compared with patients with normal BMI.[10] Therefore, a safe and comfortable anesthetic management for painless gastroscopy in obese patients is required for clinical work.

At present, international guidelines recommend the use of short-acting intravenous anesthetics, such as propofol and remifentanil, for sedation during upper gastrointestinal endoscopy.[11,12] Therefore, the anesthetic regimen used in this study was remifentanil combined with propofol. Accordingly, during painless gastroscopy, respiratory depression has always been one of the common adverse reactions.[9,13] As for assisted ventilation strategies, although researchers have already utilized some devices for sedation to prevent hypoxemia,[14] such as high-flow nasal cannula,[9,15] supraglottic jet oxygenation and ventilation,[11,16] and bilevel positive airway pressure,[17] these facilities were not always available in 66.4% of the nationwide hospitals.[18] Interestingly, a device-independent method of modified manual chest compression was reported to prevent and treat respiratory depression, but it was for non-obese patients.[19] In our clinical work, we performed the jaw thrust and manual right hypochondrial compression (MRHC) which were the components of Li anesthetic protocol for obesity (LAPO) in obese patients to relieve the obstruction of the upper airway and prevent and correct respiratory depression properly by only using the anesthesiologist's hands in a non-invasive manner.

Therefore, our study aimed to evaluate the efficacy and safety of novel LAPO in obese patients for their gastroscopy. We hope that this novel anesthesia management could offer a reference for medical institutions lacking advanced airway management devices.

Materials and Methods

Ethics and Trial Registration

This prospective, single-center, single-arm study was approved by the scientific research ethics committee of The First Affiliated Hospital of Jinan University (Ethics Number: KY-2023-274; 26/10/2023) and registered in the Chinese Clinical Trial Registry (ChiCTR2300077889). All patients provided written informed consent. Data was collected from October 2023 to April 2024 at The First Affiliated Hospital of Jinan University in accordance with the Declaration of Helsinki.

Inclusion and Exclusion Criteria

Obese patients who required painless gastroscopy before bariatric surgery were recruited for this study. The patients eligible for study participation were as follows: 1) patients aged between 18 and 60 years; 2) those with a BMI ≥30 kg/m^2; 3) those with American Society of Anesthesiologists (ASA) physical status I, II, or III.

Patients were excluded as follows: 1) they had a history of abnormal recovery from anesthesia, such as delayed awakening after anesthesia, unplanned secondary tracheal intubation, and unplanned transfer to the ICU after surgery; 2) those who had severe cardiopulmonary disorders (such as heart failure, stroke with neurologic deficit, under dialysis); 3) those who had allergized to known emulsions or opioids; 4) those who were lactating; 5) those who had had a history of chronic pain; 6) those who had poor compliance and inability to communicate; 7) those procedure time of gastroscopy was more than 30 min.

Study Interventions Process

All examinations of the patients was performed by one of the two regular endoscopists, anesthetic administration was performed by one experienced anesthesiologist, and the other supported the jaw thrust. The nurse anesthetist conducted relevant questionnaires and records including the patient's general characteristic, injection pain, body movement, cough, aspiration, and satisfaction of the anesthesia.

All patients adhered to a pre-procedure fasting protocol. Establishment of peripheral venous access were obtained before gastroscopy. After entering the endoscopy room, the patient was placed in the left head-up ramped position (head height 15–30°). The vital signs of patients were monitored, and a non-invasive blood pressure cuff was uniformly placed on the left arm. Nasal cannula at a flow of 5 L/min was placed for 3 min and patients were instructed to take deep breaths for more than five times. Furthermore, an easy-to-create mask was fabricated using the outer packaging of a nasal catheter. This mask was positioned over the patient's nose to enhance the fraction of inspired oxygen at no additional expense (Figure 1A). The information displayed on the interface of the multifunctional monitor was recorded throughout the whole process (Figure 1B).

At the beginning of anesthesia, the patient was instructed to look straight ahead with both eyes. Remifentanil 20 μg (diluted to 4 μg/mL in normal saline, 5 mL in total) was intravenously injected at a rate of 1 μg/s as base analgesia by one anesthesiologist. Propofol was subsequently administered at a rate of 2.5 mg/s, until the eyelash reflex disappeared, which was judged to be Modified Observer's Assessment of Alertness/Sedation score (MOAA/S)=0. At the same time, another anesthesiologist used the EC clamp technique with two hands to support the jaw thrust and slightly stabilize the two sides of the bite, as shown in Figure 1C. Subsequently, the endoscopists performed the procedure. If the respiratory amplitude was weakened and SpO_2 demonstrated a tendency to decrease, the anesthesiologist performed MRHC (compression site: the right hypochondriac region of the nine-part division of the abdomen, compression depth: 2–3 cm, compression frequency: 20–40 times/min, as shown in Figure 1D) until the respiratory amplitude recovered. After the procedure was completed and the patient's orientation was restored, the patient was transferred to the recovery area. The patient remained at the recovery area until reaching the standard of discharge (Aldrete score ≥9), and observation time was more than 30 min.

According to the physical response of the patient, an additional 10–20 mg of IV propofol would be administered. If the SpO_2 was less than 50%, mask ventilation was performed, and tracheal intubation was prepared.

Primary and Secondary Outcome

The primary outcome was the incidence of hypoxemia. From the combined studies of Wang and Zheng,[17,20] hypoxemia was defined as: 75% ≤ SpO_2 <90%, for >10 s and ≤60 s, and severe hypoxemia as: 75% ≤ SpO_2 <90% for >60 s, or SpO_2 <75% at any time.

The secondary outcomes included the L-SpO_2, duration of hypoxemia, the maximum and minimum heart rate (HR), body movement, cough, aspiration, total dose of propofol, satisfactory score, Nadir SpO_2, basal mean arterial pressure (MAP), and the HR, SpO_2, and respiratory rate at six time points: the baseline, before induction, when MOAA/S score=0, when the gastroscope was inserted, when the gastroscope was removed, and during awakening.

Procedure time was defined as the time between the insertion and removal of the gastroscope. Induction time was defined as the time between the start of drug administration to MOAA/S score=0. We defined eye opening as a sign of awakening, and the ability to touch the nose with fingers on command as a sign of recovery of orientation. Therefore, the recovery time was the time from the end of gastroscopy to awakening, and the recovery time of orientation was the time from the end of gastroscopy to the touch of nose. Time available to discharge was defined as time from the end of the

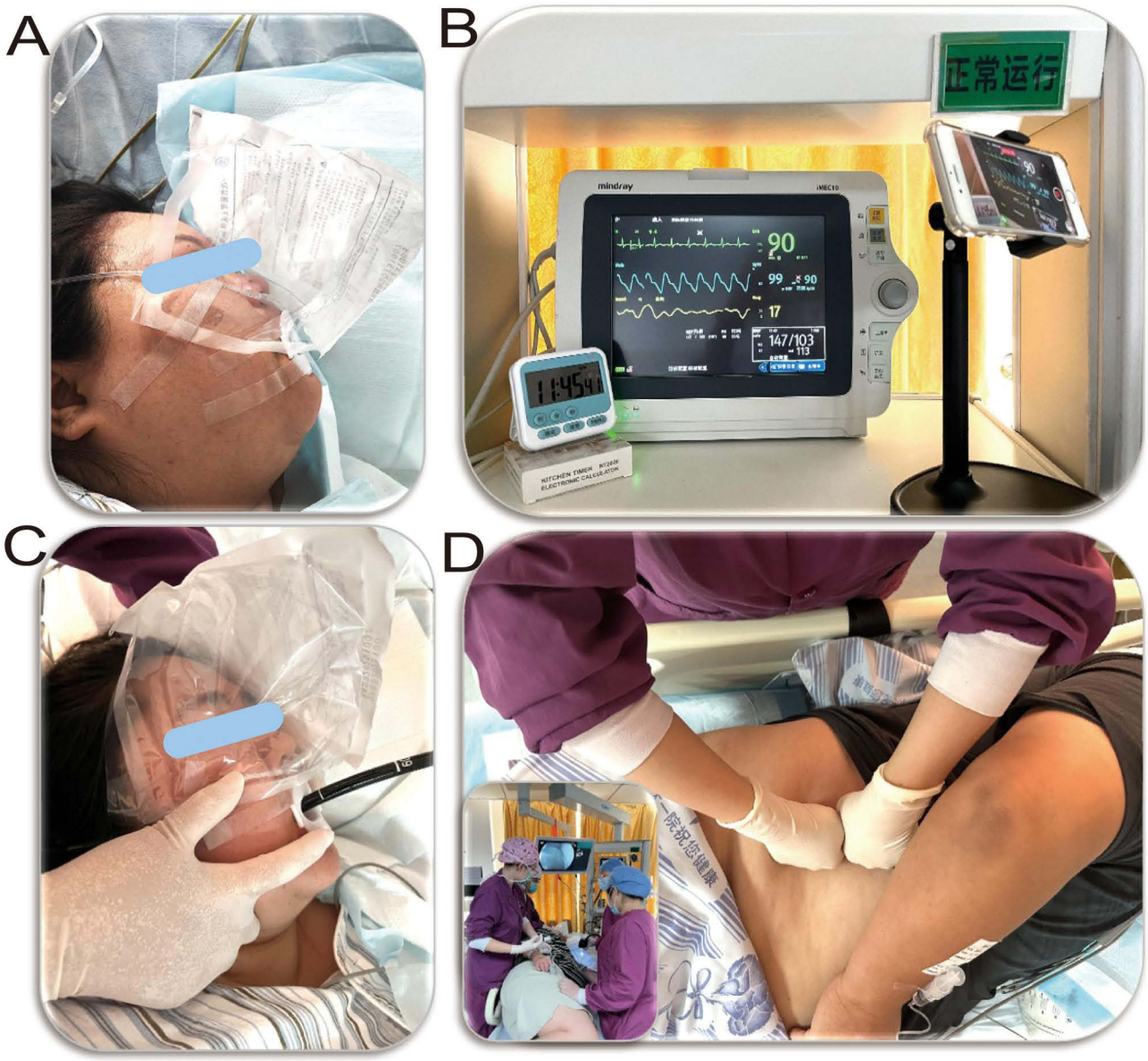

Figure 1 Visualization of procedure enhancements and techniques. (**A**) An easy-to-create mask, crafted from the outer packaging of a nasal cannula, was adapted by tearing along a diagonal line to approximate the volume and shape of a face mask. This mask was positioned over the nasal cannula and the patient's nose to augment the fraction of inspired oxygen. (**B**) A video recording setup captured the patient's vital signs, induction time, procedure duration, and other relevant metrics during anesthesia and the procedure. (**C**) The anesthesiologist employed the EC method to facilitate jaw thrust, using the index fingers to gently stabilize the sides of the bite. (**D**) Manual right hypochondrial compression (MRHC) was performed by the anesthesiologist, accompanied by a schematic illustration of the operating room layout optimized for painless gastroscopy in patient with obesity.

procedure to Aldrete score ≥9. Time to discharge was defined as time from the end of the procedure to departure of the room. Satisfactory score of the patient, endoscopist, and anesthesiologist were rated from 0 to 10, while 0 indicated dissatisfied and 10 indicated completely satisfied.

Sample Size Calculation

According to the clinical study of Zheng, the incidence of hypoxemia during painless gastroscopy with propofol alone under the conventional anesthetic protocol for obesity (CAPO) was 40.4%.[20] By various treatment measures, the difference of incidence between 6% and 25% was considered clinically significant.[17] Our preliminary study found that the incidence of hypoxemia under LAPO was 26.7%, which was within the range of clinical significance compared with

CAPO. The type I error α=0.05 (two-sided) and type II error β=0.2 were set for the test. The statistical single-group sample size estimation was used to calculate that 88 patients were required.[21] Assuming fall off at a rate of 10%, the minimum sample size was increased to 98 patients.

Statistical Analysis

GraphPad Prism 10.0 (GraphPad Software, CA, USA) was used for statistical analysis and mapping. Categorical data were expressed as the numbers and percentages. Shapiro–Wilk test was used to perform analysis of normality. If the data met the normal distribution, the results were expressed as mean and standard deviation (SD); if not met, results were presented as median (interquartile range). According to the data characteristics, Mann–Whitney *U*-test, Chi-square test (One-sided), one-way ANOVA with Tukey multiple comparison test, Paired *t* test, and Multiple Logistic Regression were used to test the data as appropriate. A P value ≤0.05 was considered statistically significant.

Results

In this study, a total of 106 obese patients who were undergoing bariatric surgery participated in painless gastroscopy. Of these, 8 were excluded due to not meeting inclusion criteria: 1 declined to participate, 2 had an ASA status greater than III, and 5 were under the age of 18. Consequently, 98 participants were allocated to undergo LAPO for general analysis. Out of these, 17 participants did not undergo polysomnography because of the relatively high cost of the inspection, leaving 81 participants included in the subsequent logistic analysis. Study flowchart depicting participant selection and inclusion process is presented in Figure 2.

Patient General Characteristics

Table 1 lists the characteristics of patients. Thirty-eight were male and 60 were female. Their mean age was 33 years old, median BMI was 39.2 kg/m^2, and median neck circumference was 42.5 cm. Intermittent waking up at night occurred in 43.9% patients. According to the WHO classification of obesity and ASA physical status,[22] the number of patients with class I, II, and III obesity was 17, 33, and 48, respectively, 13 individuals were categorized as ASA physical status I, 37 patients as ASA physical status II, and 48 patients as ASA physical status III. These patients had a median base SpO_2 of 95% and a mean basal HR of 85 beats per minute (bpm) and basal MAP of 101 mmHg. In terms of personal history,

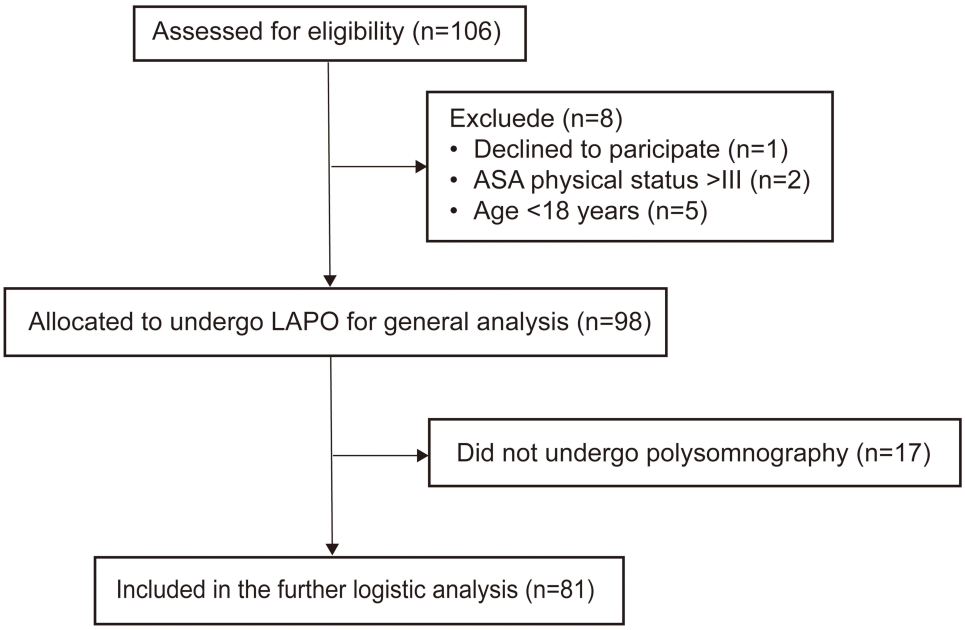

Figure 2 Study flowchart depicting participant selection and inclusion process.
Abbreviations: ASA, American Society of Anesthesiology; LAPO, Li anesthetic protocol for obesity.

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Table 1 The Demographics and Baseline Characteristics of Patients

Characteristic	Value (n=98)
Gender, M/F	38/60
Age, years	33±8.7
BMI, kg/m^2	39.2 [35.6 to 44.2]
BMI category, n (%)	
Class I (30–34.9 kg/m^2)	17 (17.3)
Class II (35–39.9 kg/m^2)	33 (33.7)
Class III (≥40 kg/m^2)	48 (49.0)
ASA Physical Status, n (%)	
I	13 (13.3)
II	37 (37.7)
III	48 (49.0)
Neck circumference, cm	42.5 [39.5 to 45.0]
Intermittent waking up at night, n (%)	43 (43.9)
Baseline SpO_2, %	95 [94.0 to 96.3]
Baseline HR, bpm	85±13
Baseline MAP, mmHg	101±16
Smoking, n (%)	37 (37.8)
Drinking, n (%)	38 (38.8)
Hypertension, n (%)	49 (50)
Diabetes, n (%)	61 (62.2)
Coronary artery heart disease, n (%)	1(1.02)
Fatty liver, n (%)	79 (80.6)
Gastroesophageal reflux, n (%)	29 (29.6)

Notes: Data are presented as mean±standard deviation, median [interquartile range] or number (%).
Abbreviations: BMI, Body Mass Index; ASA, American Society of Anesthesiologists. SpO_2, peripheral oxygen saturation.

37.8% of the patients smoked and 38.8% consumed alcohol. As for complications, 50% of patients had different degrees of high blood pressure, 62.2% of patients had diabetes, 80.6% of the patients had fatty liver, and 29.6% of the patients had gastroesophageal reflux.

The Incidence of Hypoxemia

Under LAPO, the rate of hypoxemia of 27.5% was statistically significantly lower than 40.4% by CAPO. Although a Chi-square test was performed on the incidence of hypoxemia in two studies and the result was P=0.054, the incidence of hypoxemia of LAPO was lower than the CAPO's confidence interval of 40.4% (90% CI, 0.289 to 0.519). Therefore, we concluded that performing LAPO could significantly reduce the incidence of hypoxemia during painless gastroscopy in obese patients (Figure 3).

The Duration of Procedure and Preoperative Outcomes

Outcomes related to the procedure, such as procedure time, induction time, recovery time, recovery time of orientation, time available to discharge, time to discharge are presented in Table 2.

During anesthesia, severe hypoxemia occurred in 7 patients (7.1%). The median L-SpO_2 was 92%, and duration of hypoxemia was 34 s. The median highest HR was 95 bpm, and the lowest HR was 71 bpm. Thirty-five patients experienced injection pain due to propofol (35.7%). The median dose of propofol was 120 mg (Table 2).

Regarding the method of anesthesia which they would choose for the next gastroscopy, 95.9% patients indicated that they would choose the method that was employed during the study again. The patient, endoscopist, and anesthesiologist satisfactory score was 10 (Table 2).

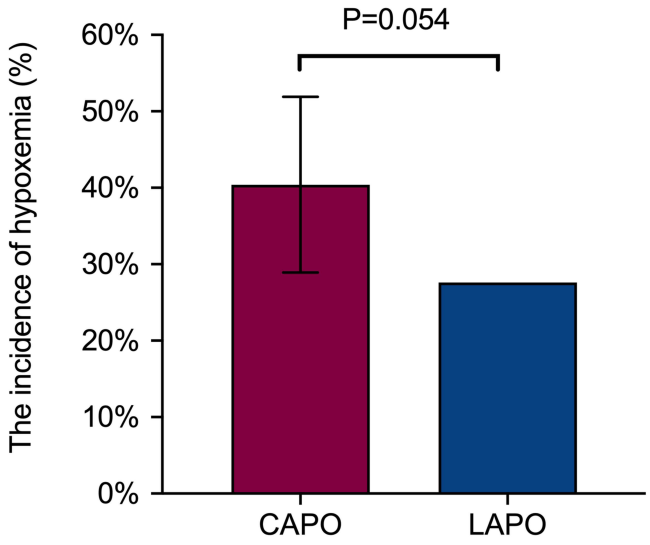

Figure 3 The incidence of hypoxemia of CAPO and LAPO for obesity during painless gastroscopy. The incidence of hypoxemia under the LAPO (27.5%) was lower than that under the CAPO (lower limit of 90% CI: 90% CI, 0.289 to 0.519).
Abbreviations: CAPO, the conventional anesthetic protocol for obesity; LAPO, Li anesthetic protocol for obesity.

Hemodynamic Results

The patient's SpO_2, respiration, and HR at baseline when entering the operating room, before induction, MOAA/S=0, start of procedure, end of procedure, and recovery are shown in Figure 4.

Table 2 Procedural Characteristics and Perioperative Outcomes

Variables	Value (n=98)
Procedural characteristics	
Procedure time, s	98 [86 to 112]
Induction time, s	114 [96 to 135]
Recovery time, s	40 [13 to 87]
Recovery time of orientation, s	85 [53 to 149]
Time available to discharge, min	18.2 [14.8 to 21.6]
Time to discharge, min	30 [30 to 30]
Hypoxemia, n (%)	27 (27.5)
Severe hypoxemia, n (%)	7 (7.1)
The L-SpO_2, %	92 [87 to 95]
Duration of hypoxemia, s	34 [15 to 56]
The maximal HR, bpm	95 [86 to 105]
The minimal HR, bpm	70.6±11.8
Injection pain, n (%)	35 (35.7)
Body movement, n (%)	36 (36.7)
Cough, n (%)	8 (8.2)
Aspiration, n (%)	0 (0)
Total propofol dose, mg	120 [110 to 136.3]
Postoperative score	
A painless gastroscopy will be chosen for review, n (%)	94 (95.9)
Patient satisfactory score	10 [10 to 10]
Endoscopist satisfactory score	10 [9 to 10]
Anesthesiologist satisfactory score	10 [10 to 10]

Note: Data are presented as mean±standard deviation, median [interquartile range] or number (%).
Abbreviation: SpO_2, peripheral oxygen saturation.

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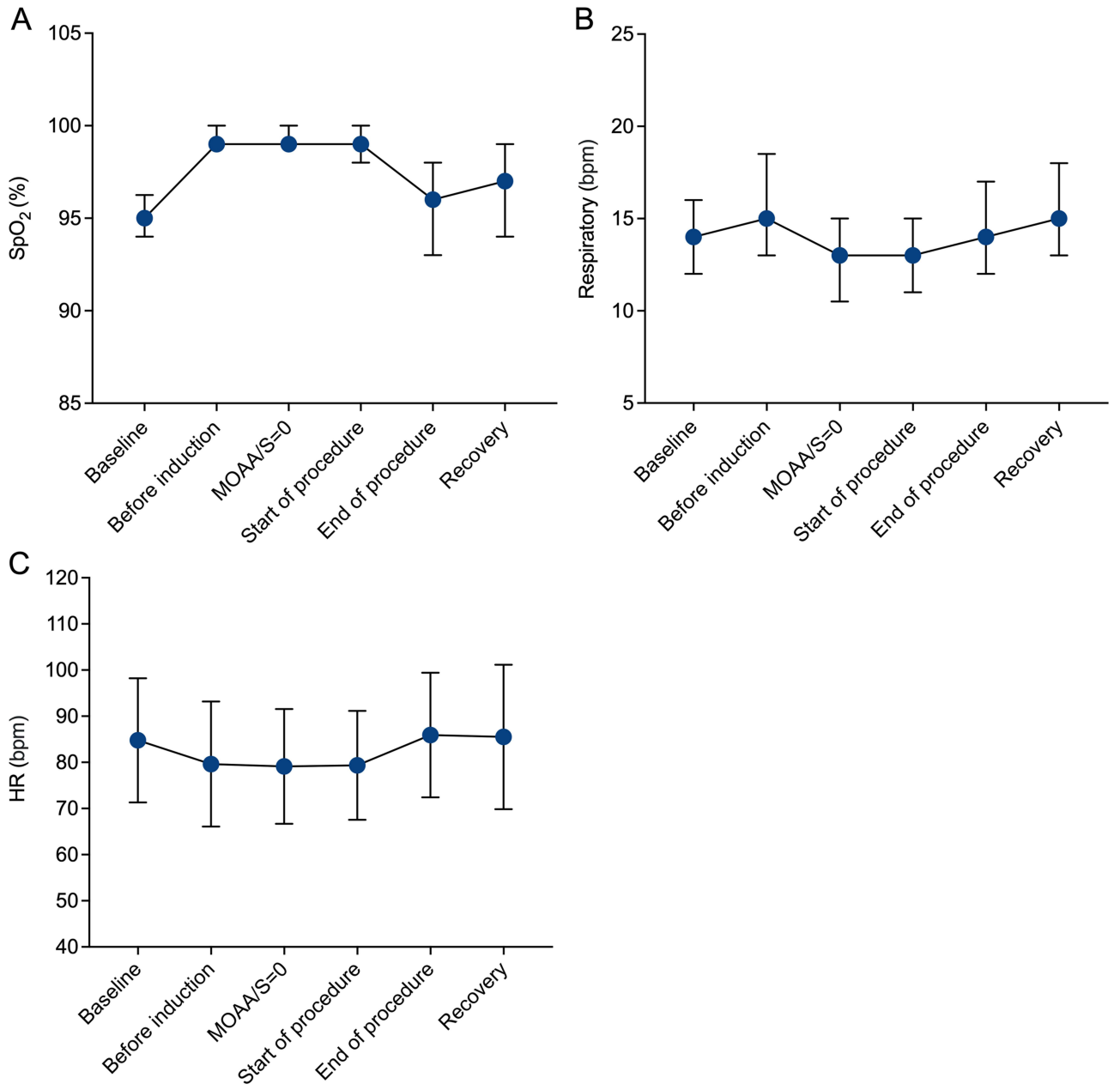

Figure 4 The changes of SpO_2, respiratory rate, and heart rate (HR) of patients were observed at each time point. (**A**) SpO_2 of each time point; (**B**) Respiratory rate of each time point; (**C**) HR of each time point. Filled circles represent median and vertical lines identify interquartile range in A and B, and mean and standard deviation in **C**.

Factors That Might Influence the Development of Hypoxemia

We performed stratified analyses according to the class of obesity and searched for factors that might influence the development of hypoxemia. The results showed that with the increase of obesity level, the incidence of hypoxemia also increased, and there was a significant statistical difference (class I vs class II vs class III, 11.8% vs 15.1% vs 41.7%, P=0.009). The same was true for BMI (class I vs class II vs class III, 32.7 kg/m^2 vs 36.6 kg/m^2 vs 44.4 kg/m^2, P<0.001) and neck circumference (class I vs class II vs class III, 39.9 cm vs 41.4 cm vs 44.7 cm, P<0.001) in patients with different levels of obesity. However, there was no significant difference in the consumption of propofol (class I vs class II vs class III, 120 mg vs 125 mg vs 120 mg, P=0.450) and intermittent waking up at night (class I vs class II vs class III, 23.5% vs 39.4% vs 54.2%, P=0.075) (Table 3).

Table 3 Incidence of Hypoxemia in Different Obesity Classes and Possible Influencing Factors

Variables	Class I (n=17)	Class II (n=33)	Class III (n=48)	P value
Hypoxemia, n (%)	2 (11.8)	5 (15.1)	20 (41.7)	0.009
BMI, kg/m^2	32.7 [31.4 to 34.0]	36.6 [35.6 to 37.0]	44.4 [41.5 to 49.0]	<0.001
Neck circumference, cm	39.9±2.8	41.4±3.6	44.7±4.1	<0.001
Total propofol dose, mg	120 [105 to 130]	125 [110 to 137.5]	120 [110 to 145]	0.450
Intermittent waking up at night, n (%)	4 (23.5)	13 (39.4)	26 (54.2)	0.075

Note: Data are presented as mean±standard deviation, median [interquartile range] or number (%).
Abbreviation: BMI, Body Mass Index.

The Relationship of Nadir SpO_2 and L-SpO_2

Finally, we conducted further analysis on 81 patients who underwent overnight monitored polysomnography and performed a Paired *t* test on the L-SpO_2 in overnight polysomnography (Nadir SpO_2) and the L-SpO_2 during anesthesia. The result showed that the L-SpO_2 during anesthesia was significantly higher than the Nadir SpO_2 (L-SpO_2 vs Nadir SpO_2, 92% vs 76%, P<0.001) (Figure 5).

Predictors That May Cause Hypoxemia

Through two-factor logistics regression analysis, the factors affecting the occurrence of hypoxemia with statistical differences were screened out: BMI, neck circumference, OSA, and diabetes. These four factors were then included in a multivariate logistics regression analysis. Among them, patients with OSA were divided into two groups, severe group and non-severe group, and neck circumference and BMI were selected for continuous variables. The results showed that, severe OSA (OR, 4.019; 95% CI, 1.184 to 14.610; P=0.028) and diabetes (OR, 4.790; 95% CI, 1.288 to 23.600; P=0.030) were independent risk factors affecting the occurrence of hypoxemia. However, BMI (OR, 1.097; 95% CI, 0.995 to 1.220; P=0.070) and neck circumference (OR, 0.985; 95% CI, 0.824 to 1.172; P=0.865) were not an independent risk factor. Therefore, it can be considered that a 4.019-fold higher risk of hypoxemia was associated with each increase of severe OSA grade, and a 4.790-fold higher risk of hypoxemia associated with diabetes (Figure 6).

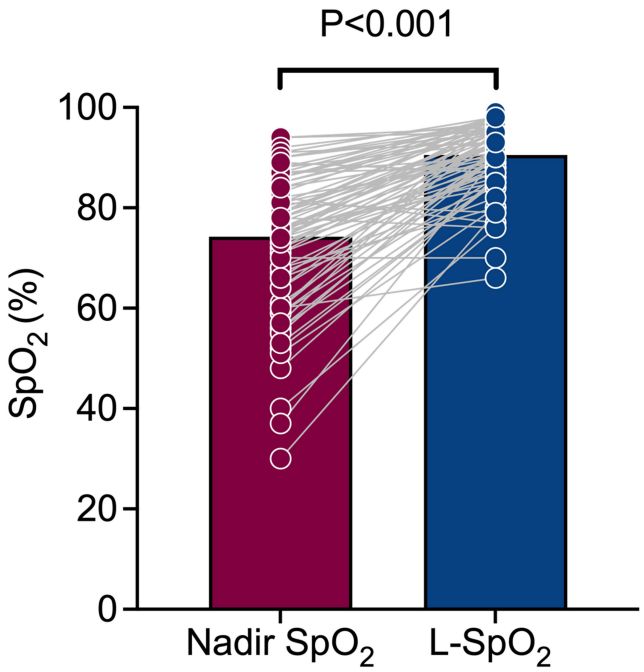

Figure 5 The relationship between the Nadir SpO_2 and the L-SpO_2. Paired *t* test was performed for the Nadir SpO_2 and L-SpO_2 in patients who underwent polysomnography. The red dot represents the patient's Nadir SpO_2, the corresponding blue dot is the patient's L-SpO_2, and the two are connected by a gray line.

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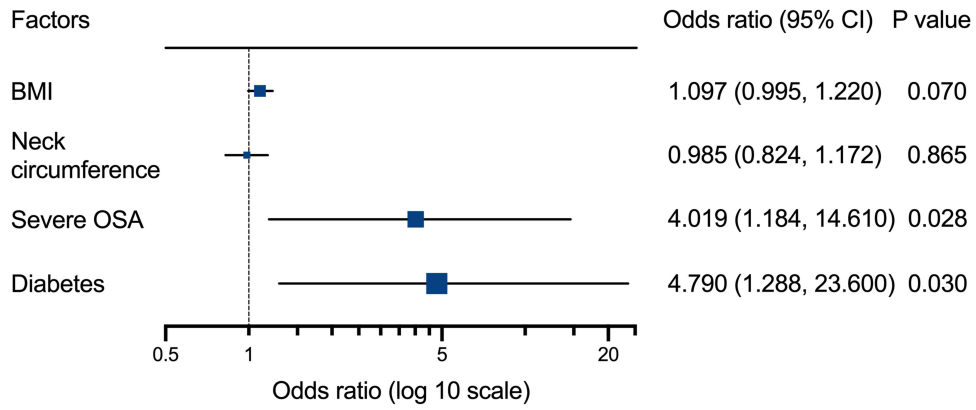

Figure 6 Multiple logistic regression analysis of predictors that may cause hypoxemia and represent by Forest Plot. The primary outcome was the incidence of hypoxemia. Multiple logistic regression analysis was performed to determine the independent risk factors for hypoxemia during painless gastroscopy in obese patients.

Discussion

This prospective single-arm study was conducted to assess the safety and efficacy of the novel LAPO for obese patients undergoing painless gastroscopy. We found that (1) LAPO is a safe and effective intervention for this demographic; (2) the anesthesia effect used during the procedure received high satisfaction ratings from patients, endoscopists, and anesthesiologists alike; (3) the Nadir SpO_2 level could serve as a reliable cut-off point for the L-SpO_2 during anesthesia management; (4) the incidence of hypoxemia among the obese patient cohort was predominantly linked to severe OSA and diabetes, underscoring the need for tailored anesthetic strategies in patients with those conditions.

Advantages of LAPO Culminated in a Significantly Low Incidence of Hypoxemia

Hypoxemia is a common and potentially life-threatening complication during anesthesia for painless gastroscopy. Reducing the incidence of hypoxemia and severe hypoxemia has become a critical focus for anesthesiologists. In this study, the LAPO technique not only achieved the required depth of anesthesia for gastroscopy but also minimized respiratory depression and hypoxemia to the greatest extent possible. Our findings indicate that LAPO has three main advantages. First, it employs remifentanil and propofol, which are short-acting anesthetics with rapid onset and brief duration,[7] allowing for precise control over anesthesia timing. In China, the prevalent regimen for painless gastroscopy typically involves a combination of propofol and opioids, which helps reduce the dosage of propofol and mitigate its adverse effects.[17,18] The study by Robert showed that propofol-remifentanil could provide a comfortable condition for the patient and endoscopist, while obtaining a faster recovery to reach the standard for discharge.[23] Therefore, we selected the anesthetic plan of remifentanil combined propofol. Specifically, a slow speed intravenous bolus of remifentanil 20 μg was performed as base analgesia. Even if respiratory depression occurs, spontaneous breathing can be quickly restored because of the small dose of drugs used and their rapid metabolism. Second, the LAPO has a component of jaw thrust with two hands, which largely keeps the airway open and restores efficient ventilation.[24,25] Even in cases where there is a decrease in respiratory amplitude or apnea, the novel MRHC technique can provide vital ventilation support through synchronized cooperation. This approach effectively prevents and manages hypoxemia. Li's team was the pioneer in introducing a modified manual chest compression technique, which was employed without advanced airway instruments.[19] Their research demonstrated that this method could prevent and treat respiratory depression during gastroscopy in non-obese patients, highlighting its potential applicability and effectiveness in clinical settings. However, in obese patients, the compliance of the chest is reduced, making it challenging to achieve satisfactory effects with previously reported compression techniques. Consequently, we employed the novel MRHC approach specifically for obese patients. This technique promotes cyclic compression and relaxation of the right chest, aiding in the circulation of oxygen and respiratory recovery, thus fulfilling the objective of augmenting oxygen delivery to the body.

Additionally, under the LAPO protocol, we utilized an innovative, cost-free method to boost the fraction of inspired oxygen using an easy-to-create mask, thereby increasing the patient's oxygen reserve. It is noteworthy that the majority of centers (95.5%) provided continuous nasal cannula oxygen to patients undergoing painless gastroscopy.[18] Simply

adding a surgical mask on the face of patients with nasal cannula could significantly increase oxygenation and their SpO_2 directly.[26] A nebulization mask or simple oxygen mask could also improve the oxygenation of patients.[27] Inspired by the need for enhanced oxygen delivery, we devised an easy-to-create mask to increase the fraction of inspired oxygen. Our patients not only understood the rationale behind this innovation but also agreed to its use without reporting any subjective discomfort or adverse side effects. In conclusion, the integration of these three key advantages of the LAPO approach (strategic anesthesia management and effective respiratory support through MRHC and jaw thrust, increased oxygen reserve via a novel mask) has culminated in a significantly low incidence of hypoxemia, reported at 27.5%, among patients with a median BMI of 39.2 kg/m^2, compared with a rate of hypoxemia of 40.4% under CAPO and their mean BMI of 31.4 kg/m^2. This comprehensive approach has garnered high satisfaction rates from patients, endoscopists, and anesthesiologists, underscoring its effectiveness and acceptability in clinical practice.

The Nadir SpO_2 May Serve as a Critical Threshold for the L-SpO_2 in Anesthesia Management for Obesity

Although hypoxemia and severe hypoxemia are well defined, little is known about the allowable L-SpO_2 during anesthesia for obese patients, especially in patients with OSA. Evidence has conclusively shown that OSA is a common complication for obesity, with 20% incidence in patients with class I obesity and 30% with class III.[28] Intermittent hypoxemia is one of its hallmark features.[29] Currently, overnight polysomnography (PSG) is the gold-standard for the diagnosis of OSA, and information regarding hypoxemia including the Nadir SpO_2 during sleep can be obtained.[30,31] To prevent complications, preoperative detection and treatment of OSA is recommended for surgical patients.[31] A study of 20 patients with class I and II obesity had a mean baseline Nadir SpO_2 of 77%.[32] In a study by Perger, 48 patients with class III obesity underwent PSG, and the mean Nadir SpO_2 was 73%,[28] which was below the threshold (75%) that defines severe hypoxemia. For morbid obesity, PSG reports from 175 patients were analyzed, demonstrating a mean Nadir SpO_2 of 72.2%.[33] For very severe OSA in obesity, Sata reported that the Nadir SpO_2 could be 49±30%.[34] In a meta-analysis of the effects of bariatric surgery on nocturnal hypoxemia in obese patients with OSA, the Nadir SpO_2 of relevant clinical studies were listed, and it was found that the mean value ranged from 64.7% to 84%.[35] These studies collectively suggested that the lowest tolerable SpO_2 in obese patients was much lower than the value that defines hypoxemia (<90%), and some even lower than the value that defines severe hypoxemia (<75%). In this study, 81 patients performed PSG with a median Nadir SpO_2 of 76%, in line with the range reported. In addition, we performed a Paired *t* test of L-SpO_2 during gastroscopy and Nadir SpO_2 in these 81 patients and Nadir SpO_2 was significantly lower than L-SpO_2 ($P<0.001$) (Figure 5). Based on this, we have a novel proposal that the Nadir SpO_2 could be used as the cut-off point of safety for the L-SpO_2 during painless gastroscopy for obesity.

The Occurrence of Hypoxemia Correlates Negatively with Both Severe OSA and Diabetes

Finally, we investigated the possible specific factors predicting hypoxemia during painless gastroscopy of obese patients. Li found that patients with a higher BMI and thicker neck circumference (>40 cm) were more likely to develop hypoxemia during painless gastrointestinal endoscopy.[36] They suggested that both BMI and neck circumference in the hypoxemia group were significantly higher than those in the non-hypoxemia group ($P<0.001$).[36] Similar results were observed from our study, where there was a simple and negative correlation between the L-SpO_2 and BMI, as well as neck circumference. Furthermore, Goudra found that history of OSA could be used as a reference predictor of hypoxemia during painless gastroscopy.[37] We explored the relationship between some common complications, smoking history, alcohol history and hypoxemia in obese patients, and found that the L-SpO_2 in diabetic patients was significantly different from that in non-diabetic patients. Based on this, to evaluate BMI, neck circumference, OSA and diabetes in the context of hypoxemia during painless gastroscopy for obese patients, we conducted multiple logistic regression analysis. The results indicated that severe OSA and diabetes were independent of potential confounders for hypoxemia, but BMI and neck circumference were not. Once a patient was diagnosed with severe OSA, they were at a 4.019-fold higher risk of hypoxemia. For diabetics, there was an associated 4.790-fold higher risk of hypoxemia. This was another novel finding of our study.

Limitation

Several limitations of this study warrant consideration. First, due to the high BMI of the obese patients treated at our center, a control group was not established to ensure patient safety under anesthesia. Each component of the LAPO is crucial and indispensable, impacting the occurrence of hypoxemia. Consequently, we treated LAPO as an integral whole and conducted a single-arm study. This has the disadvantages of single-center design and absence of blinding. Moreover, although the group with severe comorbidities or ASA status greater than III was excluded from this study, in our clinical work, most patients in this group use LAPO for painless gastroscopy. Second, three patients in this study experienced airway obstruction with regular breathing movements but without effective oxygen circulation, despite active interventions. The resolution of airway obstruction hinged on the rapid recovery of consciousness. For some patients with severe OSA, however, the use of advanced airway devices would likely be more appropriate. Third, our study did not employ a precise formula to calculate the required dose of propofol; instead, we used a dose sufficient to achieve a MOAA/S of 0 as a reference. This aspect of our dosing strategy will be the subject of further investigation.

Conclusion

For obese patients requiring painless gastroscopy without access to advanced airway management devices, our study demonstrates that LAPO is both safe and effective in reducing the incidence of hypoxemia under CAPO (from 40.4% to 27.5%). Our findings contribute to the understanding of the L-SpO_2 values that obese patients can tolerate during such procedures, establishing Nadir SpO_2 as the cut-off point. Furthermore, our analysis identified severe OSA and diabetes as independent predictive risk factors for hypoxemia. If these findings are supported by further research, LAPO could aid anesthesiologists in developing specific anesthesia protocols and managing the risk of hypoxemia during painless gastroscopy for obese patients. Ultimately, this could expand access to comfortable and safe medical treatment for a broader spectrum of patients with obesity.

Data Sharing Statement

The data that support the findings of this study are available upon reasonable request. Researchers interested in the datasets can contact Mengxia Wang with email: wangmengxia@jnu.edu.cn for further information and data sharing arrangements.

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Disclosure

The authors report no conflicts of interest in this work.

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