

Transnasal Humidified Rapid-Insufflation Ventilatory Exchange in Preoperative Hypoxemic Patients During General Anesthesia Induction and Recovery: A Prospective Randomized Controlled Trial

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Research Article

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Abstract

Background

Hypoxemia during induction and recovery from general anesthesia is a clinically important perioperative complication, particularly in patients with pre-existing hypoxemia. Transnasal Humidified Rapid-Insufflation Ventilatory Exchange (THRIVE) may improve perioperative oxygenation by delivering heated, humidified high-flow oxygen, washing out upper-airway dead space, and generating a low level of positive airway pressure. However, evidence regarding its role across both induction and post-anesthesia recovery remains limited.

Objective

This study aimed to evaluate whether THRIVE improves perioperative oxygenation in preoperative hypoxemic patients undergoing elective surgery under general anesthesia.

Methods

This prospective randomized controlled trial enrolled 108 preoperative hypoxemic patients with room-air PaO₂ of 60–80 mmHg who underwent elective surgery under general anesthesia between November 2025 and April 2026. Patients were randomly assigned to the THRIVE group or the conventional oxygenation group at a 1:1 ratio. The THRIVE group received heated humidified high-flow nasal oxygen during induction and early recovery, whereas the control group received standard face-mask oxygenation before induction and conventional low-flow nasal oxygen after extubation. The primary outcome was the proportion of patients whose oxygenation index decreased below the pre-induction baseline during the PACU stay. Secondary outcomes included oxygenation parameters at predefined perioperative time points, SpO₂, PaO₂, PaCO₂, pH, lactate level, intubation/apnea time, PACU length of stay, and adverse events. Because several continuous variables were non-normally distributed, between-group comparisons were mainly performed using the Mann–Whitney U test. Categorical variables were compared using the χ^2 test or Fisher's exact test. For repeated comparisons across multiple time points, Bonferroni or false discovery rate correction was applied where appropriate. Multivariable regression analyses were additionally performed to adjust for baseline imbalance in sex and BMI.

Results

Baseline SpO₂ and PaO₂ were comparable between the two groups. However, sex distribution and BMI differed significantly between groups and were therefore included as covariates in adjusted analyses. Compared with the conventional oxygenation group, the THRIVE group showed significantly higher PaO₂ immediately after preoxygenation and better oxygenation maintenance during the PACU period. The

proportion of patients whose oxygenation index decreased below baseline during PACU stay was significantly lower in the THRIVE group than in the control group. This difference remained significant after adjustment for sex and BMI. The THRIVE group also had a shorter intubation/apnea time and shorter PACU length of stay. Lactate levels were lower in the THRIVE group at several postoperative time points; however, because direct microcirculatory or tissue perfusion indicators were not measured, this finding should be interpreted as a possible association rather than direct evidence of improved tissue perfusion. The incidence of non-oxygenation-related adverse events, including hypotension, arrhythmia, laryngospasm, cough, nausea, and vomiting, did not differ significantly between groups.

Conclusion

THRIVE improved perioperative oxygenation and reduced the risk of recovery-phase oxygenation deterioration in preoperative hypoxemic patients undergoing general anesthesia. Its potential effects on acid-base balance and lactate levels require further investigation using larger multicenter studies with direct tissue perfusion measurements. This work was supported by Scientific Research General Project of Shanghai Municipal Health Commission, 202440226. Trial registration: Chinese Clinical Trial Registry ChiCTR2500103273. Registered on 27 May 2025.

Introduction

Hypoxemia is a common and clinically important complication during induction and recovery from general anesthesia. It may increase the risk of perioperative cardiovascular events, neurological injury, delayed recovery, unplanned respiratory support, and postoperative pulmonary complications. Patients with preoperative hypoxemia are particularly vulnerable because their pulmonary reserve is already reduced before anesthesia induction^[1].

Conventional oxygen therapy, including face-mask oxygenation before induction and low-flow nasal oxygen after extubation, is widely used in routine anesthetic practice. However, these methods may be insufficient for patients with limited pulmonary reserve, obesity, reduced functional residual capacity, or pre-existing gas-exchange impairment^[2]. Therefore, strategies that can improve oxygen reserve during induction and maintain oxygenation during early recovery are of considerable clinical value.

Transnasal Humidified Rapid-Insufflation Ventilatory Exchange (THRIVE) is a high-flow nasal oxygenation technique that delivers heated and humidified oxygen at high flow rates. Its potential physiological advantages include continuous nasopharyngeal dead-space washout, improved oxygen delivery, reduced rebreathing, and generation of a low level of positive airway pressure^[3]. Previous studies have explored the use of THRIVE or high-flow nasal oxygen in airway management, procedural sedation, obese patients, and postoperative recovery^[4]. Nevertheless, evidence remains limited regarding its continuous application across both anesthesia induction and early recovery in patients with preoperative hypoxemia.

This prospective randomized controlled trial was designed to evaluate the effect of THRIVE on perioperative oxygenation in preoperative hypoxemic patients undergoing elective surgery under general anesthesia. We hypothesized that, compared with conventional oxygenation, THRIVE would reduce the proportion of patients whose oxygenation index decreased below baseline during PACU stay^[5]. Secondary objectives were to compare perioperative oxygenation parameters, arterial blood gas indices, lactate levels, intubation/apnea time, PACU length of stay, and adverse events between groups.

Materials and Methods

Study Design and Ethics Approval

This study was designed as a prospective, randomized, controlled clinical trial. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Medical Ethics Committee of Shanghai Changzheng Hospital (approval number: 2025SL041). Written informed consent was obtained from all participants before enrollment. The reporting of this study followed the general principles of the CONSORT statement for randomized controlled trials^[6].

The study compared THRIVE with conventional oxygenation in preoperative hypoxemic patients undergoing elective surgery under general anesthesia.

Study Period

Patients were enrolled from November 2025 to April 2026. The original study period was revised because the previous description of “November 2025 to December 2026” was inconsistent with the actual data collection stage and the current manuscript preparation time.

Participants

Patients scheduled for elective surgery under general anesthesia were screened for eligibility. Inclusion criteria were as follows: age 18–85 years; ASA physical status I–III; preoperative hypoxemia, defined as PaO_2 of 60–80 mmHg on room air; planned tracheal intubation and general anesthesia; and ability to provide written informed consent^[7].

Exclusion criteria were as follows:

1. Contraindications to THRIVE, including severe nasal obstruction, skull base fracture, recent nasal surgery, or suspected intracranial hypertension;

2. Severe gastroesophageal reflux or high risk of aspiration;

3. Acute respiratory failure requiring emergency ventilatory support;

4. Severe unstable cardiopulmonary disease;

5. Refusal to participate;

6. Missing key perioperative oxygenation data.

7. Randomization and Allocation Concealment

Eligible patients were randomly assigned to the THRIVE group or the conventional oxygenation group in a 1:1 ratio using a computer-generated random sequence. Randomization was performed by an investigator who was not involved in patient recruitment, anesthesia management, outcome assessment, or statistical analysis^[8].

Allocation was concealed using sequentially numbered, opaque, sealed envelopes. After the patient entered the operating room and eligibility was reconfirmed, the envelope was opened by an anesthesia provider responsible for implementing the assigned intervention.

Blinding

Because the oxygenation devices were visibly different, blinding of anesthesia providers and patients was not feasible. However, outcome assessors responsible for extracting arterial blood gas results and PACU data were blinded to group allocation whenever possible. The investigator responsible for statistical analysis was also blinded to group assignment until the primary analysis was completed^[9]. Group labels were coded as Group A and Group B during data cleaning and statistical analysis.

Sample Size Estimation

The sample size was calculated based on the primary outcome: the proportion of patients whose oxygenation index decreased below the pre-induction baseline during PACU stay. Based on preliminary clinical observation and previous related studies, we assumed that this event would occur in approximately 80% of patients receiving conventional oxygenation and 50% of patients receiving THRIVE^[10]. With a two-sided α of 0.05 and a power of 80%, at least 45 patients were required in each group. Considering a possible dropout or incomplete-data rate of approximately 15%, the final target sample size was set at 54 patients per group, for a total of 108 patients.

Interventions

All patients received standard preoperative preparation, including routine fasting and water restriction. After entering the operating room, venous access was established and routine monitoring was applied, including electrocardiography, non-invasive blood pressure, pulse oxygen saturation, and end-tidal carbon dioxide after intubation.

Anesthesia induction was performed using a standardized protocol. Patients received midazolam 0.05 mg/kg, propofol 1.5–2.5 mg/kg, sufentanil 0.3–0.5 µg/kg, and rocuronium 0.6 mg/kg. Tracheal intubation was performed after adequate muscle relaxation.

THRIVE Group

Patients in the THRIVE group received high-flow nasal oxygen using a heated humidified high-flow oxygen system. Before induction, THRIVE was applied for 5 minutes with a flow rate of 70 L/min, FiO₂ 1.0, temperature 37°C, and full humidification^[11]. Oxygenation was maintained during induction and intubation according to the study protocol.

After surgery, THRIVE was restarted immediately after extubation. During recovery, the flow rate was set at 30 L/min, with FiO₂ adjusted between 0.30 and 0.40 according to clinical oxygenation status. THRIVE was continued for 30 minutes or until the patient met PACU discharge criteria, whichever occurred first.

Conventional Oxygenation Group

Patients in the conventional oxygenation group received standard face-mask oxygenation before induction with 100% oxygen at 10 L/min for 5 minutes. After extubation, patients received conventional low-flow nasal oxygen at 2–5 L/min until PACU discharge, according to routine clinical practice^[12].

Data Collection

Data were collected at predefined perioperative time points:

T₀: pre-induction baseline;

T₁: immediately after preoxygenation and before intubation;

T₂: 5 minutes after intubation;

T₃: immediately after extubation;

T₄: 5 minutes after extubation;

T₅: 15 minutes after extubation;

T₆: 30 minutes after extubation or before PACU discharge.

Collected variables included SpO₂, heart rate, mean arterial pressure, end-tidal carbon dioxide, PaO₂, PaCO₂, pH, lactate level, intubation/apnea time, extubation time, PACU length of stay, intraoperative blood loss, infusion volume, and adverse events.

Adverse events included hypoxemia, hypotension, arrhythmia, laryngospasm, cough, nausea, and vomiting. Hypoxemia was defined as SpO₂ < 90% or a clinically significant decrease in oxygenation

requiring intervention.

Outcomes

Primary Outcome

The primary outcome was the proportion of patients whose oxygenation index decreased below the pre-induction baseline during PACU stay. This outcome was selected because the study focused on whether THRIVE could maintain oxygenation stability during the vulnerable early recovery period.

Secondary Outcomes

Secondary outcomes included:

- 1. SpO₂ and PaO₂ at predefined perioperative time points;**
- 2. PaCO₂, pH, and lactate levels at predefined time points;**
- 3. Proportion of patients whose oxygenation index decreased below baseline at 15 minutes after extubation;**
- 4. Intubation/apnea time;**
- 5. PACU length of stay;**
- 6. Incidence of postoperative hypoxemia;**
- 7. Incidence of non-oxygenation-related adverse events, including hypotension, arrhythmia, laryngospasm, cough, nausea, and vomiting.**

The indicator “oxygenation index below baseline at 15 minutes after extubation” was treated as a secondary outcome rather than another primary outcome.

Exploratory Analysis

The correlation between BMI and lactate level was analyzed as an exploratory post hoc analysis. This analysis was not included in the original primary or secondary outcome framework and was therefore interpreted as hypothesis-generating only.

Statistical Analysis

SPSS 26.0 was used for statistical analysis. The normality of continuous variables was assessed using the Shapiro–Wilk test and visual inspection of histograms and Q-Q plots. Because many continuous variables showed non-normal distributions, they were expressed as median and interquartile range [IQR]. Between-group comparisons for non-normally distributed continuous variables were performed using the Mann–Whitney U test. Normally distributed variables were expressed as mean $\pm$ standard deviation and compared using the independent-samples t test.

Categorical variables were expressed as number and percentage and compared using the χ^2 test or Fisher's exact test, as appropriate.

For repeated measurements across multiple time points, within-group and between-group comparisons were performed using appropriate repeated-measures methods. When multiple pairwise comparisons were conducted, Bonferroni correction or false discovery rate correction was applied to reduce the risk of type I error.

Because sex distribution and BMI were significantly imbalanced between the two groups at baseline, multivariable regression analyses were performed to adjust for potential confounding. Binary logistic regression was used for binary outcomes, and linear or rank-based regression models were used for continuous outcomes where appropriate. Adjusted models included group assignment, sex, BMI, and other clinically relevant baseline variables.

A two-sided P value < 0.05 was considered statistically significant. For multiple comparisons, adjusted P values were reported or interpreted according to the correction method.

Results

Baseline Characteristics

A total of 108 patients were enrolled and randomized, with 54 patients in the THRIVE group and 54 patients in the conventional oxygenation group. Baseline oxygenation parameters were comparable between groups. However, significant baseline imbalance was observed in sex distribution and BMI. These differences were considered clinically relevant and were adjusted for in subsequent multivariable analyses^[13].

Preoperative SpO₂ was 96.85% [96.33–97.20] in the THRIVE group and 96.80% [96.40–97.30] in the control group, with no significant difference. Preoperative PaO₂ was also similar between groups. However, the proportion of male patients was higher in the THRIVE group than in the control group, and BMI was lower in the THRIVE group.

Table 1
Baseline demographic and clinical characteristics

Variable	THRIVE Group (n = 54)	Control Group (n = 54)	P value
Age, years	65.00 [59.00–72.00]	66.00 [61.25–71.00]	0.868
Male sex, n (%)	38 (70.4%)	18 (33.3%)	< 0.001
BMI, kg/m ²	25.66 [22.95–26.69]	27.37 [24.42–30.73]	< 0.001
Preoperative SpO ₂ , %	96.85 [96.33–97.20]	96.80 [96.40–97.30]	0.944
Preoperative PaO ₂ , mmHg	73.25 [70.05–76.33]	71.90 [69.95–74.97]	0.465

Baseline oxygenation status was comparable, but the imbalance in sex and BMI indicated that crude between-group comparisons alone might overestimate or underestimate the intervention effect. Therefore, both unadjusted and adjusted analyses were performed for key outcomes.

Primary Outcome

The primary outcome was the proportion of patients whose oxygenation index decreased below the pre-induction baseline during PACU stay. The event rate was significantly lower in the THRIVE group than in the control group. After adjustment for sex and BMI, THRIVE remained independently associated with a lower risk of oxygenation index reduction below baseline^[14].

In the THRIVE group, 48.1% of patients experienced oxygenation index reduction below baseline during PACU stay, compared with 87.0% in the control group. The unadjusted comparison showed a statistically significant difference between groups. After adjustment for sex and BMI, THRIVE remained independently associated with a lower risk of oxygenation index reduction below baseline.

This result supports the primary hypothesis that THRIVE improves oxygenation stability during early post-anesthesia recovery.

Table 2
Primary outcome

Outcome	THRIVE Group	Control Group	P value
Oxygenation index below baseline during PACU stay, n (%)	26 (48.1%)	47 (87.0%)	< 0.001

Secondary Oxygenation Outcomes

The THRIVE group demonstrated better oxygenation performance at several perioperative time points. Immediately after preoxygenation, PaO₂ was substantially higher in the THRIVE group than in the control group. This oxygenation advantage persisted during the recovery phase, particularly at the PACU minimum and PACU discharge time points^[15].

At PACU minimum, PaO₂ was 111.00 [97.20–128.00] mmHg in the THRIVE group and 79.90 [71.25–97.90] mmHg in the control group. SpO₂ at PACU discharge was also higher in the THRIVE group than in the control group.

After correction for multiple comparisons, the differences in several key oxygenation indicators remained statistically significant. In adjusted analyses including sex and BMI, THRIVE remained associated with improved PACU oxygenation.

Table 3
Selected oxygenation outcomes

Variable	THRIVE Group	Control Group	P value
SpO ₂ after preoxygenation, %	99.70 [99.60–99.88]	99.50 [98.43–99.67]	< 0.001
PaO ₂ after preoxygenation, mmHg	413.50 [336.75–450.75]	258.00 [233.50–297.25]	< 0.001
PaO ₂ at PACU minimum, mmHg	111.00 [97.20–128.00]	79.90 [71.25–97.90]	< 0.001
SpO ₂ at PACU discharge, %	97.05 [94.72–97.80]	93.70 [91.80–96.50]	< 0.001

Oxygenation Index Below Baseline at 15 Minutes After Extubation

The proportion of patients whose oxygenation index decreased below baseline at 15 minutes after extubation was analyzed as a secondary outcome. This event occurred in 38.9% of patients in the THRIVE group and 83.3% of patients in the control group. The difference remained statistically significant after adjustment for baseline sex and BMI.

This finding further indicates that the oxygenation benefit of THRIVE was not limited to the induction phase but extended into early post-extubation recovery.

Acid-Base Balance and Lactate

The THRIVE group showed higher pH values and lower lactate levels at several time points. However, lactate is affected by multiple factors, including oxygen delivery, tissue oxygen utilization, surgical stress, hemodynamic status, catecholamine response, and fluid management. Therefore, lower lactate levels should be interpreted as a possible association rather than direct evidence of improved tissue perfusion^[16].

For example, at 15 minutes after extubation, lactate was 1.10 [0.90–1.48] mmol/L in the THRIVE group and 1.75 [1.12–2.70] mmol/L in the control group. After correction for multiple comparisons, some differences remained statistically significant.

Because this study did not directly measure mixed venous oxygen saturation, cardiac output, microcirculatory perfusion, or tissue oxygen extraction, lower lactate levels cannot be directly interpreted as definitive evidence of improved tissue perfusion. Rather, the observed lactate difference suggests a

possible association between THRIVE use and improved metabolic stability, which requires further verification.

Intubation/Apnea Time and PACU Length of Stay

The THRIVE group had a shorter intubation/apnea time than the control group. The median intubation/apnea time was 159.00 [140.25–185.75] seconds in the THRIVE group and 206.50 [174.00–248.00] seconds in the control group. PACU length of stay was also shorter in the THRIVE group, with a median of 26.00 [24.00–28.00] minutes compared with 35.00 [30.25–43.50] minutes in the control group.

These findings suggest that THRIVE may improve perioperative respiratory management efficiency. However, because PACU discharge can be influenced by institutional protocols, staffing, surgical type, analgesia, and hemodynamic status, this result should be interpreted in the context of the single-center study setting.

Adverse Events and Safety Outcomes

Oxygenation-related deterioration was significantly less frequent in the THRIVE group. However, other adverse events did not differ significantly between groups. Specifically, there were no statistically significant between-group differences in hypotension, arrhythmia, laryngospasm, cough, nausea, or vomiting.

Table 4
Adverse events

Adverse event	THRIVE Group	Control Group	P value
Hypoxemia / oxygenation deterioration	Lower	Higher	< 0.001
Hypotension	No significant difference	No significant difference	> 0.05
Arrhythmia	No significant difference	No significant difference	> 0.05
Laryngospasm	No significant difference	No significant difference	> 0.05
Cough	No significant difference	No significant difference	> 0.05
Nausea and vomiting	No significant difference	No significant difference	> 0.05

The lack of significant differences in non-oxygenation-related complications indicates that the major observed benefit of THRIVE was improved oxygenation stability rather than a broad reduction in all

perioperative adverse events. This may be because events such as hypotension and arrhythmia are affected more by anesthetic depth, vasoactive drug use, baseline cardiovascular status, surgical stimulation, and fluid status than by oxygenation strategy alone. Similarly, laryngospasm, cough, nausea, and vomiting are multifactorial events and may not be substantially altered by THRIVE in a sample of this size.

Exploratory Correlation Analysis Between BMI and Lactate

An exploratory post hoc analysis was conducted to examine the relationship between BMI and lactate levels. In the control group, BMI was positively correlated with lactate level. In contrast, this correlation was not statistically significant in the THRIVE group.

Because this analysis was not prespecified and the correlation in the THRIVE group was not significant, the finding should be regarded as hypothesis-generating only. It cannot support the conclusion that THRIVE definitively reduces obesity-related metabolic stress. A more appropriate interpretation is that THRIVE may have potential value in patients with higher BMI, but this possibility requires confirmation in future studies specifically designed for obese or high-BMI populations.

Discussion

This prospective randomized controlled trial evaluated the effect of THRIVE on perioperative oxygenation in preoperative hypoxemic patients undergoing elective surgery under general anesthesia. The main finding was that THRIVE significantly reduced the proportion of patients whose oxygenation index decreased below baseline during PACU stay. This finding remained significant after adjustment for baseline imbalance in sex and BMI, suggesting that the observed oxygenation benefit was not fully explained by these baseline differences.

The oxygenation benefit of THRIVE was evident during both induction and recovery. Immediately after preoxygenation, patients in the THRIVE group achieved substantially higher PaO₂ than those in the conventional oxygenation group. This finding is consistent with the physiological mechanism of high-flow nasal oxygenation, including high inspired oxygen concentration, reduced entrainment of room air, and upper-airway dead-space washout^[17].

During the recovery phase, the THRIVE group maintained higher oxygenation levels, including higher PaO₂ at PACU minimum and higher SpO₂ at PACU discharge. This result is clinically meaningful because extubation and early PACU recovery are vulnerable periods for patients with limited pulmonary reserve^[18]. Residual anesthetic effects, reduced respiratory drive, airway obstruction, atelectasis, pain-related shallow breathing, and ventilation-perfusion mismatch may all contribute to postoperative oxygenation deterioration. The continuous oxygen delivery and mild positive airway pressure-like effect provided by THRIVE may help maintain alveolar recruitment and reduce early post-extubation oxygenation decline.

The primary outcome focused on oxygenation index decline below baseline during PACU stay. This endpoint reflects not merely absolute oxygenation level but also the patient's ability to maintain oxygenation relative to the preoperative state. The significantly lower event rate in the THRIVE group indicates better oxygenation stability after general anesthesia. The similar finding at 15 minutes after extubation, which was analyzed as a secondary outcome, further supports the recovery-phase benefit of THRIVE.

The study also found shorter intubation/apnea time and shorter PACU length of stay in the THRIVE group. Improved oxygen reserve may provide a safer airway management window, allowing clinicians to complete intubation with less urgency caused by desaturation. The shorter PACU stay may be related to more stable oxygenation after extubation. Nevertheless, PACU length of stay is influenced by multiple clinical and operational factors, including surgical type, analgesia, hemodynamic recovery, nursing workflow, and discharge criteria. Therefore, although this finding is promising, it should be interpreted cautiously and verified in larger multicenter studies.

Another finding was that THRIVE was associated with higher pH values and lower lactate levels at several perioperative time points. These changes may suggest improved respiratory and metabolic stability. However, lactate is not a specific marker of tissue perfusion. It may be affected by stress response, ventilation status, liver metabolism, hemodynamics, medication use, and surgical factors. Because this study did not include direct measurements of cardiac output, mixed venous oxygen saturation, regional tissue oxygen saturation, or microcirculatory perfusion, it would be inappropriate to conclude that THRIVE directly improved tissue perfusion. The lactate findings should therefore be interpreted as supportive but exploratory physiological observations.

The exploratory analysis of BMI and lactate also requires cautious interpretation. Although BMI was positively correlated with lactate in the control group, no significant correlation was found in the THRIVE group. Because this analysis was not prespecified, the result should only be used to generate hypotheses for future studies focusing on obese or high-BMI populations^[19].

The safety results showed that THRIVE mainly reduced oxygenation-related deterioration, while non-oxygenation-related adverse events such as hypotension, arrhythmia, laryngospasm, cough, nausea, and vomiting were not significantly different between groups. This finding is clinically reasonable. THRIVE primarily acts through respiratory and oxygenation mechanisms, whereas cardiovascular events and airway reflex complications are affected by many other perioperative factors. The absence of significant differences in these outcomes also suggests that the study may not have been sufficiently powered to detect differences in relatively infrequent complications.

Several limitations should be noted. First, this was a single-center study with a relatively limited sample size, which may restrict generalizability. Second, although randomization was used, sex distribution and BMI were significantly imbalanced between groups. Third, blinding of patients and anesthesia providers was not feasible. Fourth, multiple indicators were measured at multiple time points, and although multiple-comparison correction was applied, the possibility of false-positive findings cannot be fully

eliminated^[20]. Fifth, some analyses, including the correlation between BMI and lactate, were exploratory and should not be interpreted as confirmatory evidence. Sixth, the study focused mainly on short-term perioperative outcomes. Longer-term pulmonary outcomes, postoperative respiratory support requirement, and hospital length of stay were not fully evaluated.

Despite these limitations, this study provides evidence that THRIVE can improve oxygenation stability during both induction and early recovery in preoperative hypoxemic patients. The findings support the clinical application of THRIVE as a perioperative oxygenation strategy for selected high-risk patients, while also highlighting the need for larger, multicenter, adequately blinded outcome-assessment studies.

Conclusion

In preoperative hypoxemic patients undergoing elective surgery under general anesthesia, Transnasal Humidified Rapid-Insufflation Ventilatory Exchange improved perioperative oxygenation and reduced the proportion of patients whose oxygenation index decreased below baseline during PACU stay. The oxygenation benefit was observed during both induction and early recovery and remained significant after adjustment for baseline sex and BMI imbalance.

THRIVE was also associated with shorter intubation/apnea time and shorter PACU length of stay. Lower lactate levels and higher pH values were observed in the THRIVE group at several time points, but these findings should be interpreted cautiously because direct tissue perfusion indicators were not measured. Non-oxygenation-related adverse events did not differ significantly between groups.

Overall, THRIVE appears to be a useful perioperative oxygenation strategy for preoperative hypoxemic patients. Future multicenter randomized controlled trials with larger sample sizes, stricter allocation concealment, blinded outcome assessment, prespecified subgroup analyses, and direct tissue oxygenation or microcirculatory measurements are needed to confirm these findings.

Abbreviations

THRIVE

Transnasal Humidified Rapid-Insufflation Ventilatory Exchange

PACU

Post-anesthesia care unit

PaO₂

Partial pressure of oxygen in arterial blood

PaCO₂

Partial pressure of carbon dioxide in arterial blood

SpO₂

Pulse oxygen saturation

BMI

Body mass index
ASA
American Society of Anesthesiologists
IQR
Interquartile range

Declarations

Ethics approval and consent to participate

This study was approved by the Medical Ethics Committee of Shanghai Changzheng Hospital (approval number: 2025SL041, date of approval not specified in manuscript but study period started November 2025). All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments. Written informed consent was obtained from all individual participants included in the study.

Consent for publication

Not applicable. This manuscript does not contain any individual person's data in any form (including any images, videos, or personal/clinical details that could compromise anonymity).

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Author Contribution

Y. (Hao Yin) and L. (Rongrong Li) designed the study, performed data collection and analysis, and wrote the main manuscript. Y. (Hongbin Yuan) and H. (Xingying He) supervised the study, revised the manuscript critically, and approved the final version. All authors reviewed the manuscript.

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The full trial protocol is available from the corresponding author upon reasonable request.

Data Availability

The datasets generated and/or analysed during the current study are available from the corresponding author upon reasonable request.

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Figures

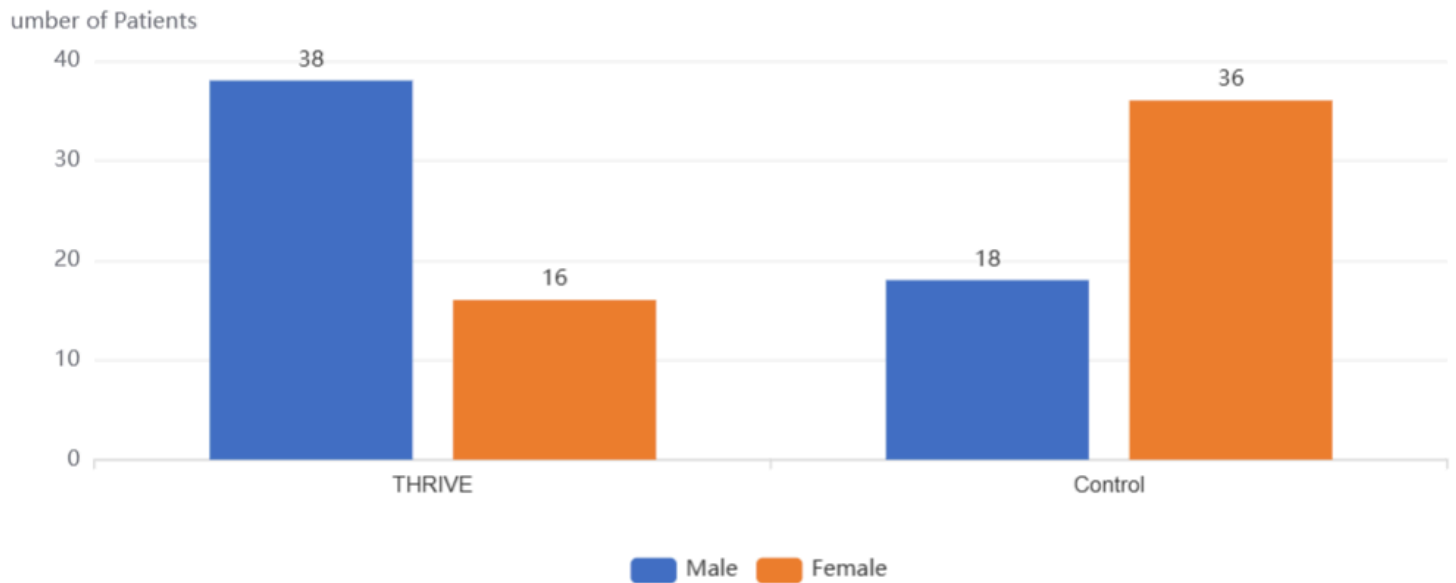


Figure 1

Comparison of sex distribution between the THRIVE and control groups

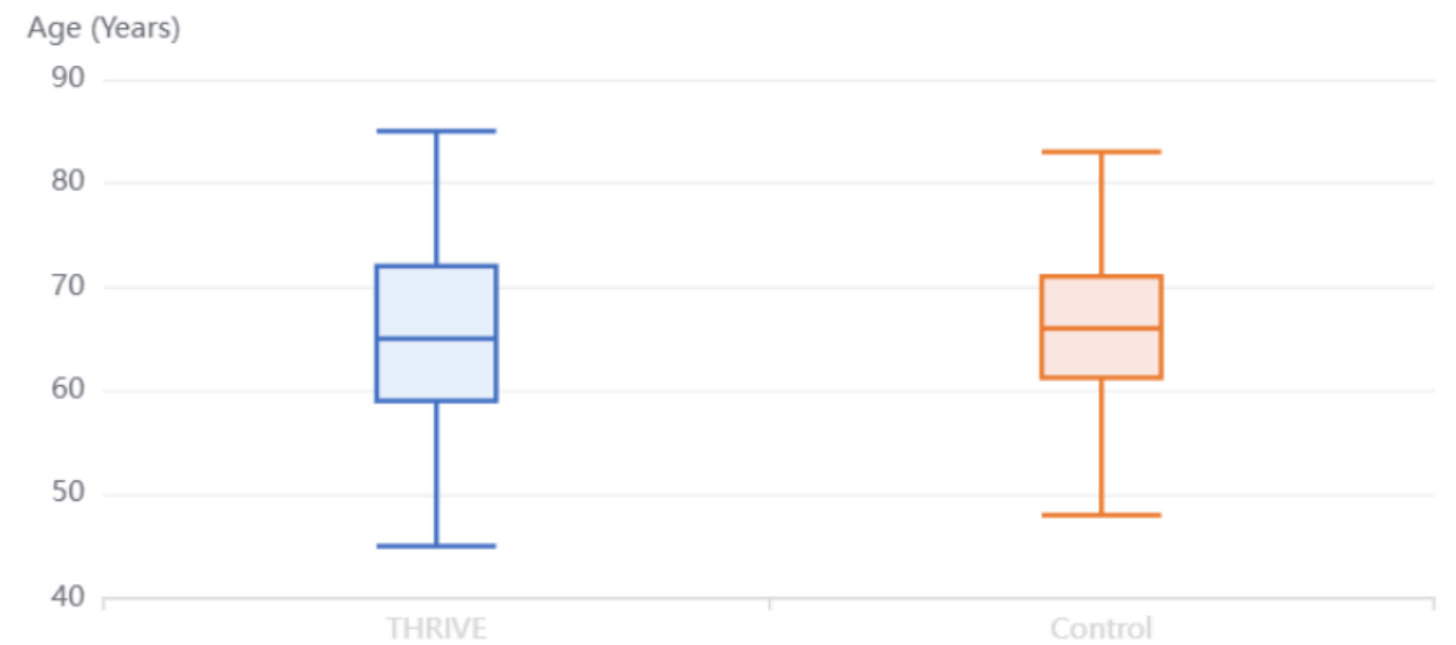


Figure 2

Age distribution of patients in the THRIVE and control groups

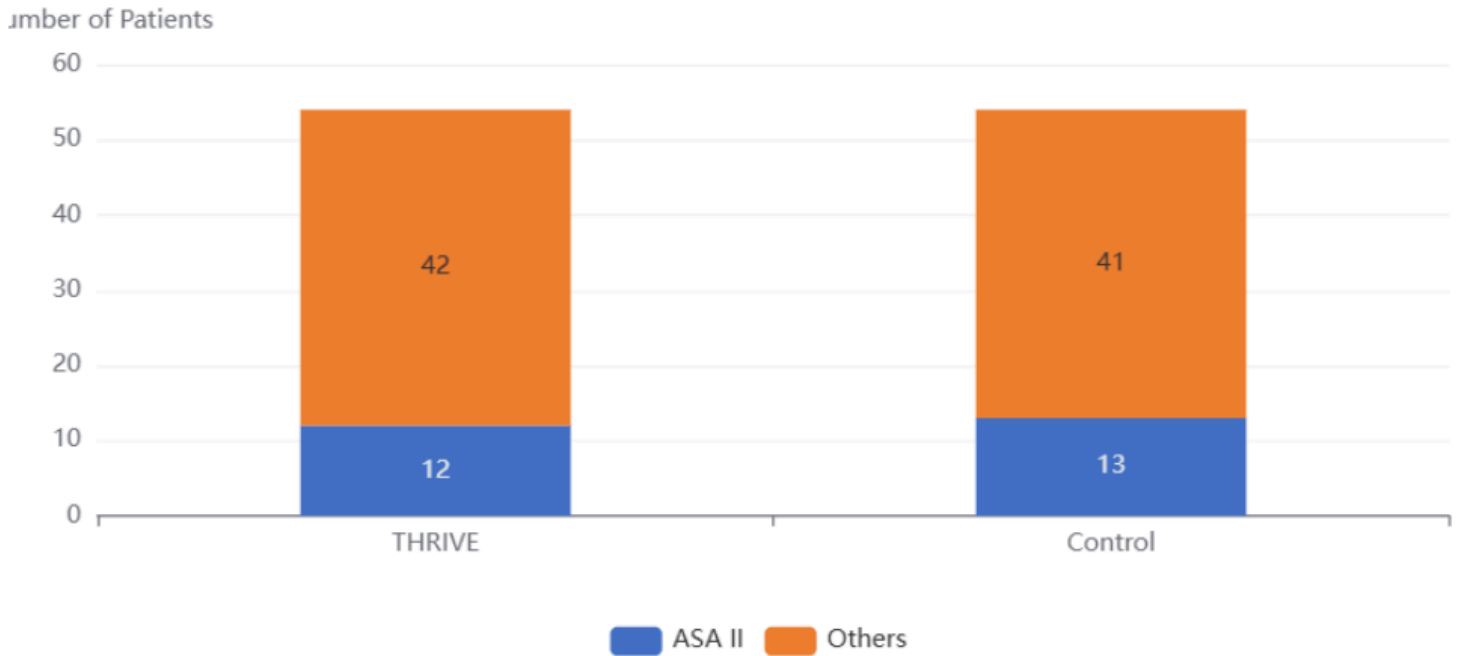


Figure 3

ASA physical status distribution of patients in the two groups

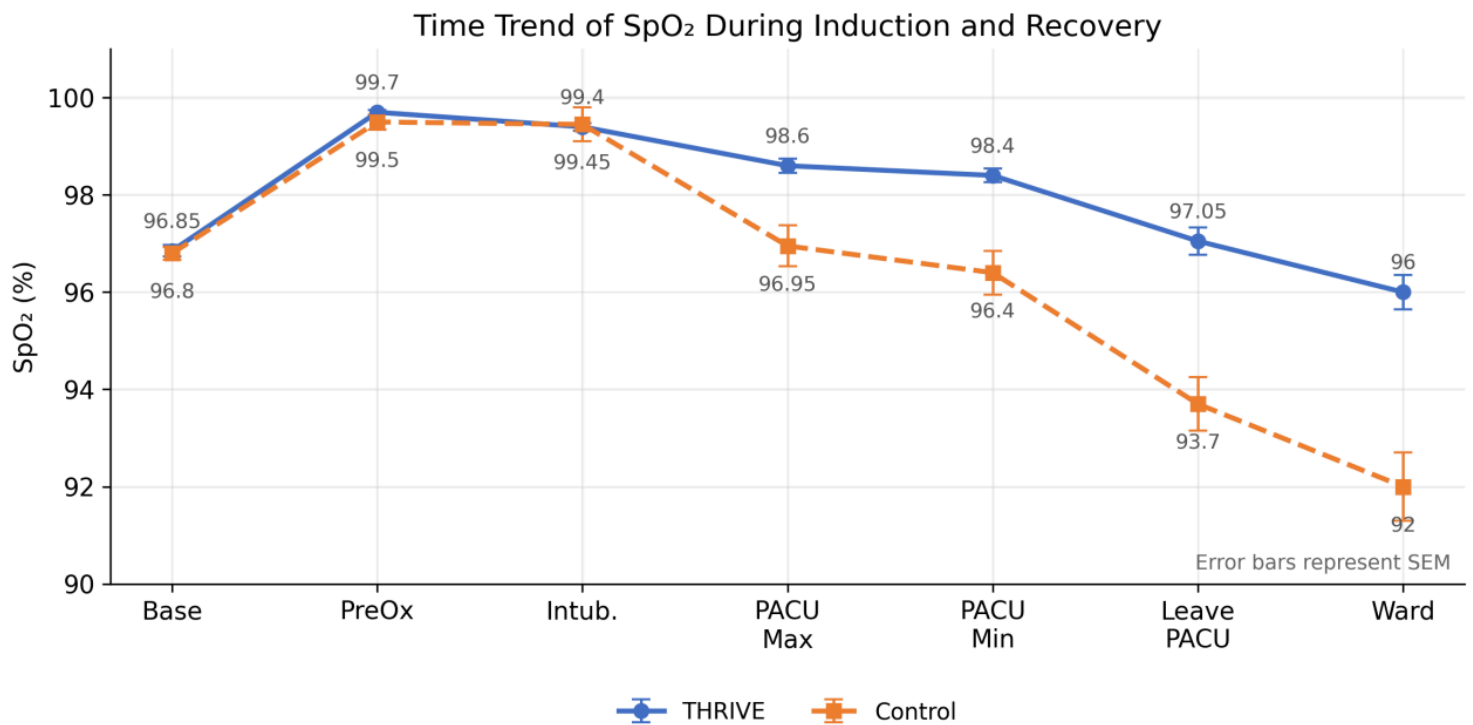


Figure 4

Time trend of SpO₂ during induction and recovery

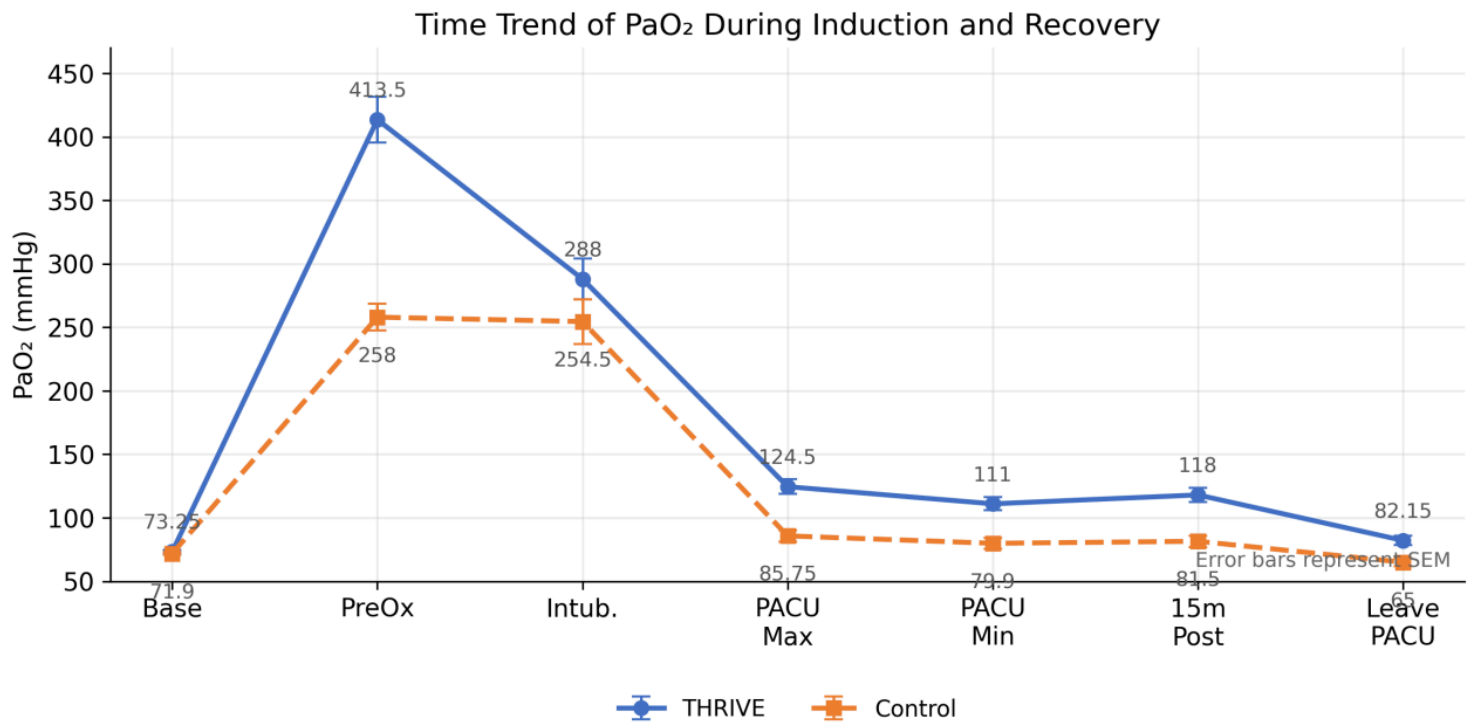


Figure 5

PaO₂ levels at different perioperative time points

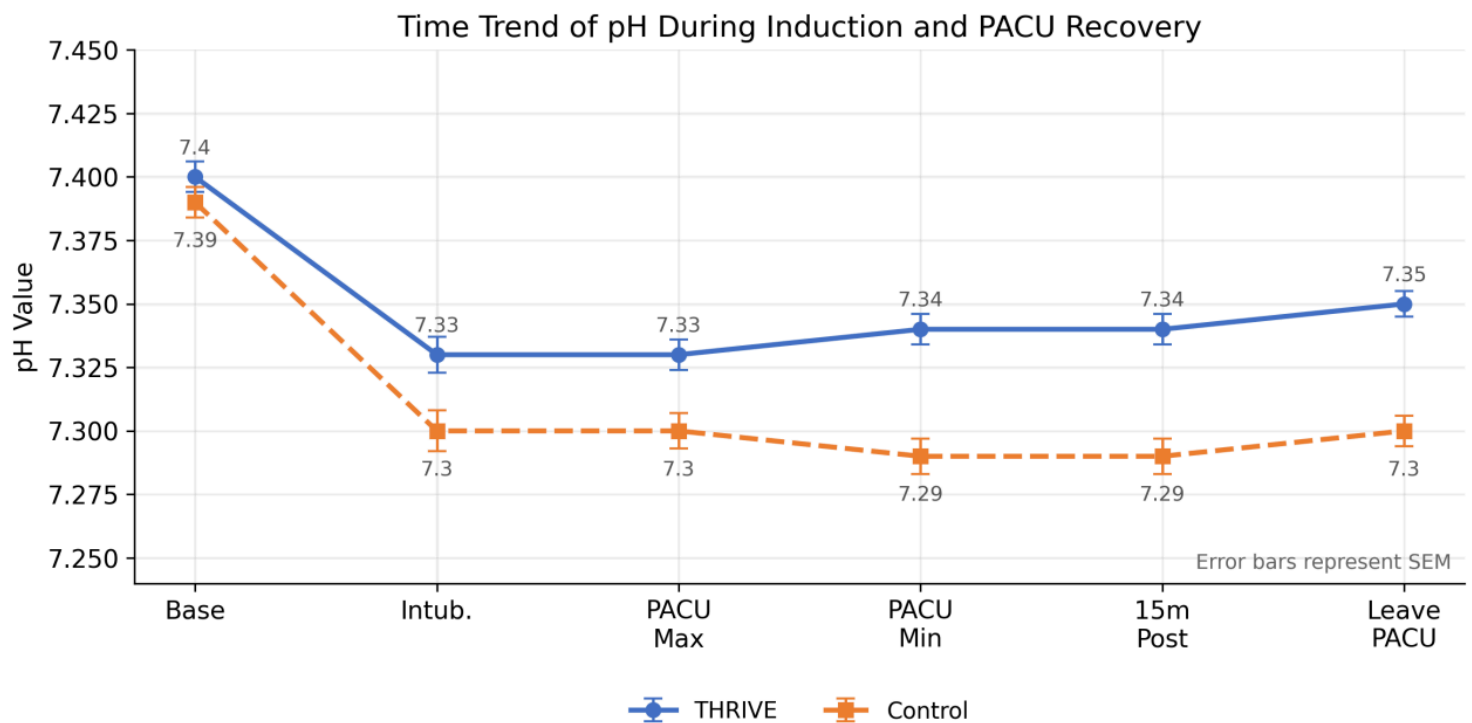


Figure 6

Comparison of pH values during induction and recovery

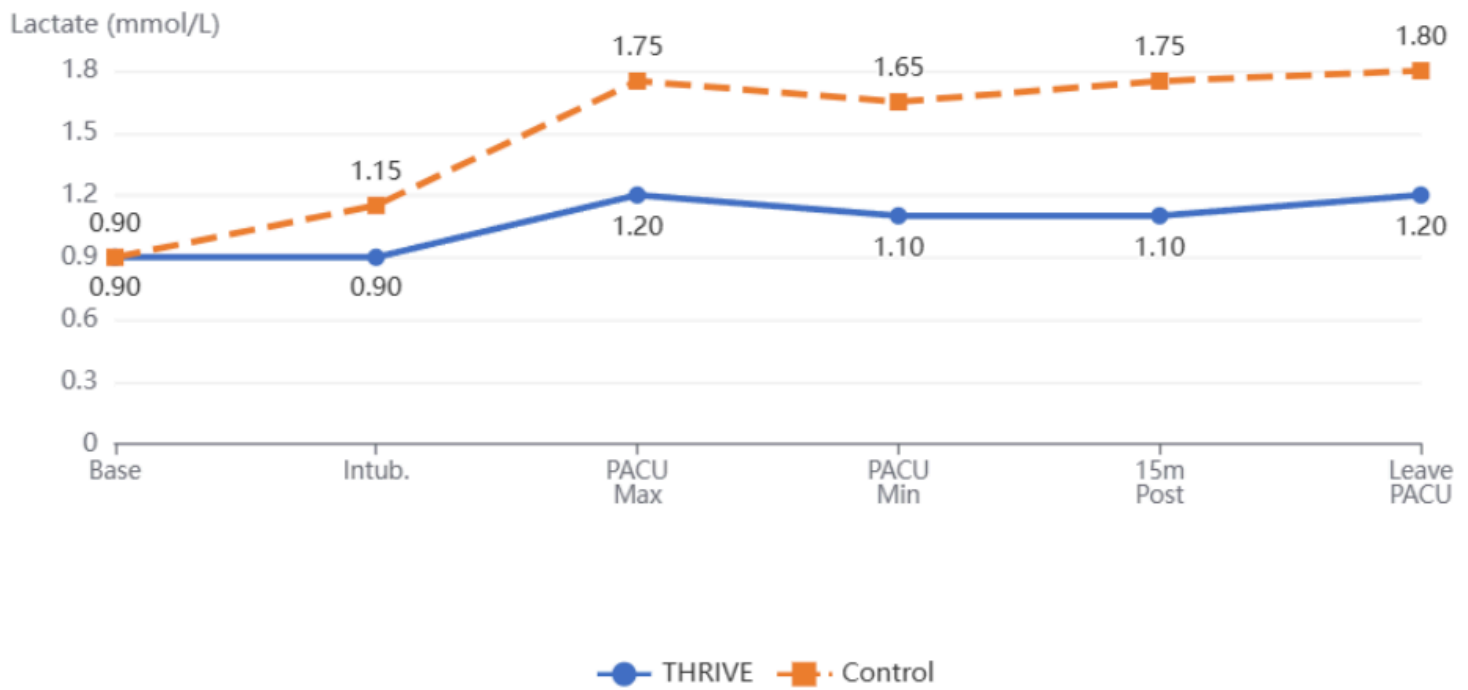


Figure 7

Lactate levels at different perioperative time points

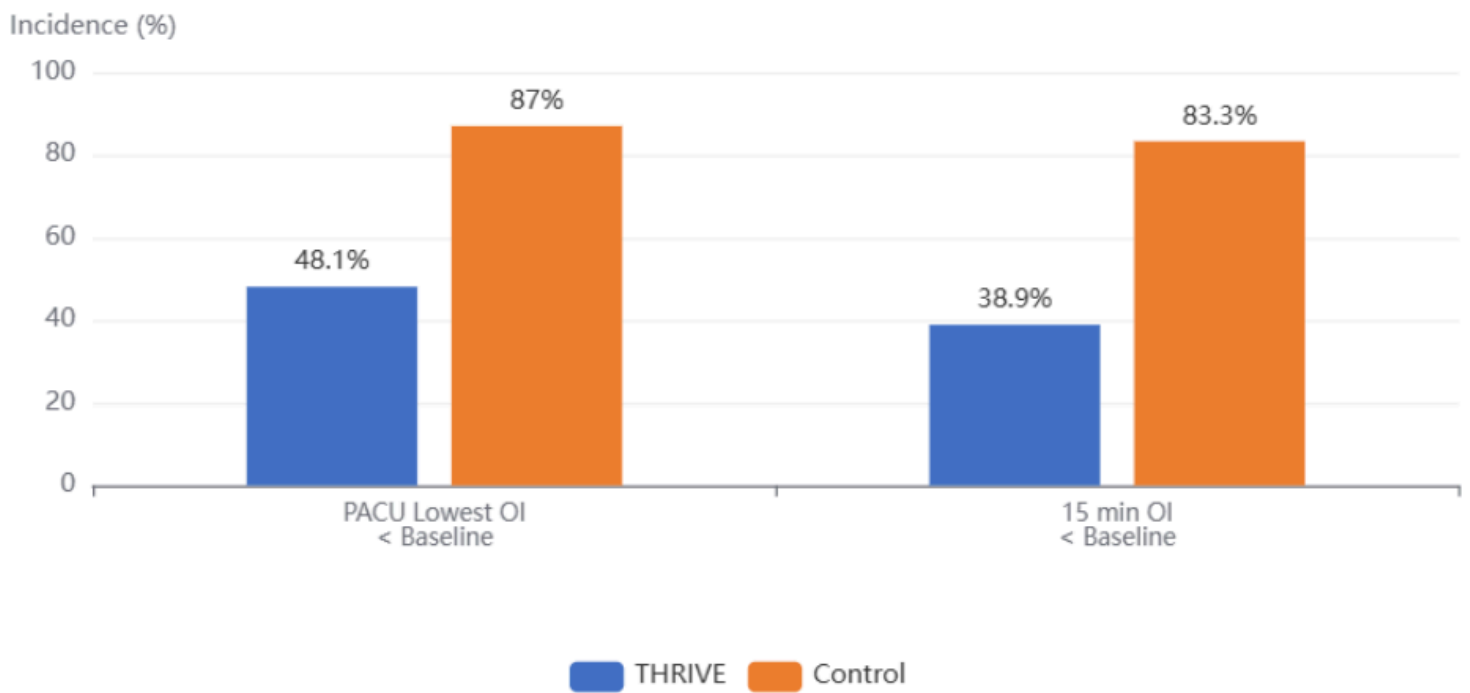


Figure 8

Comparison of adverse events between groups

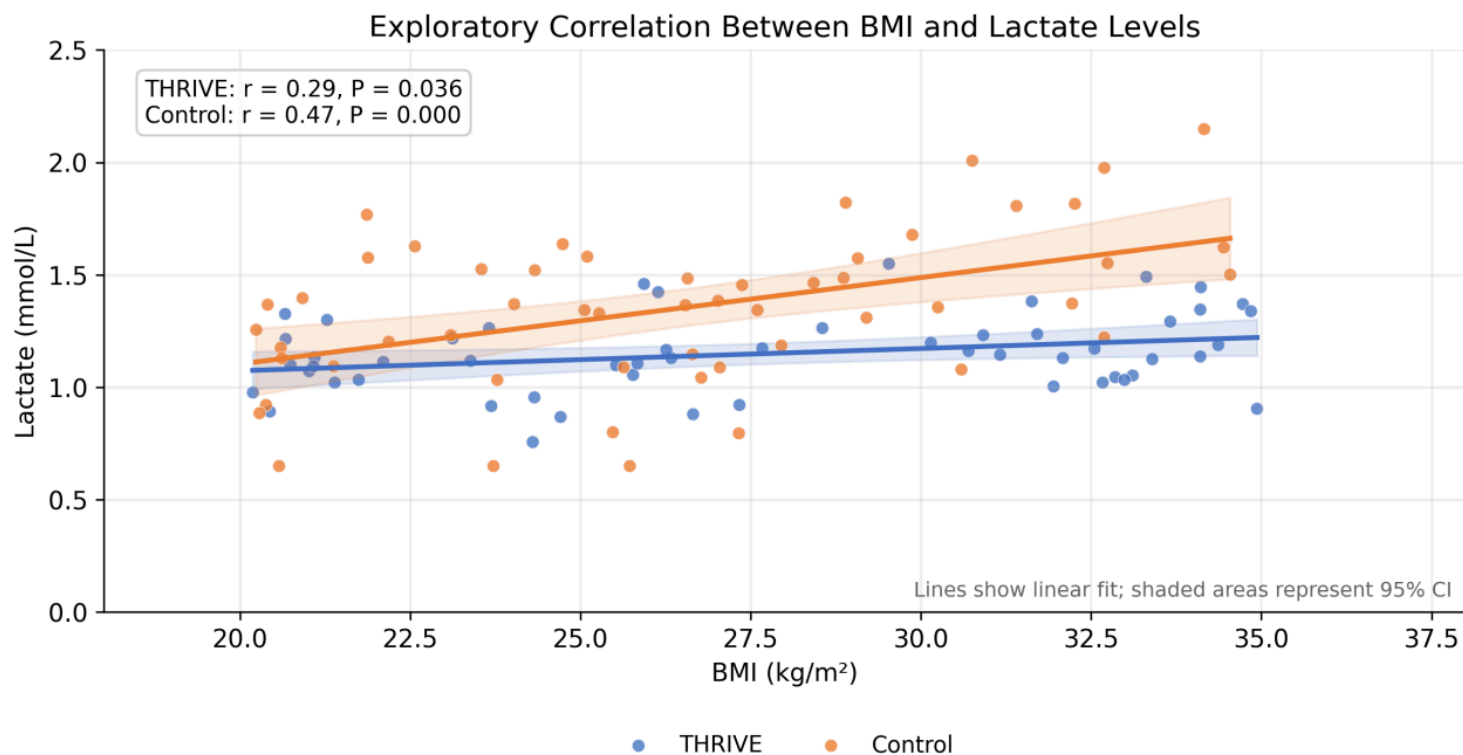


Figure 9

Exploratory correlation between BMI and lactate level

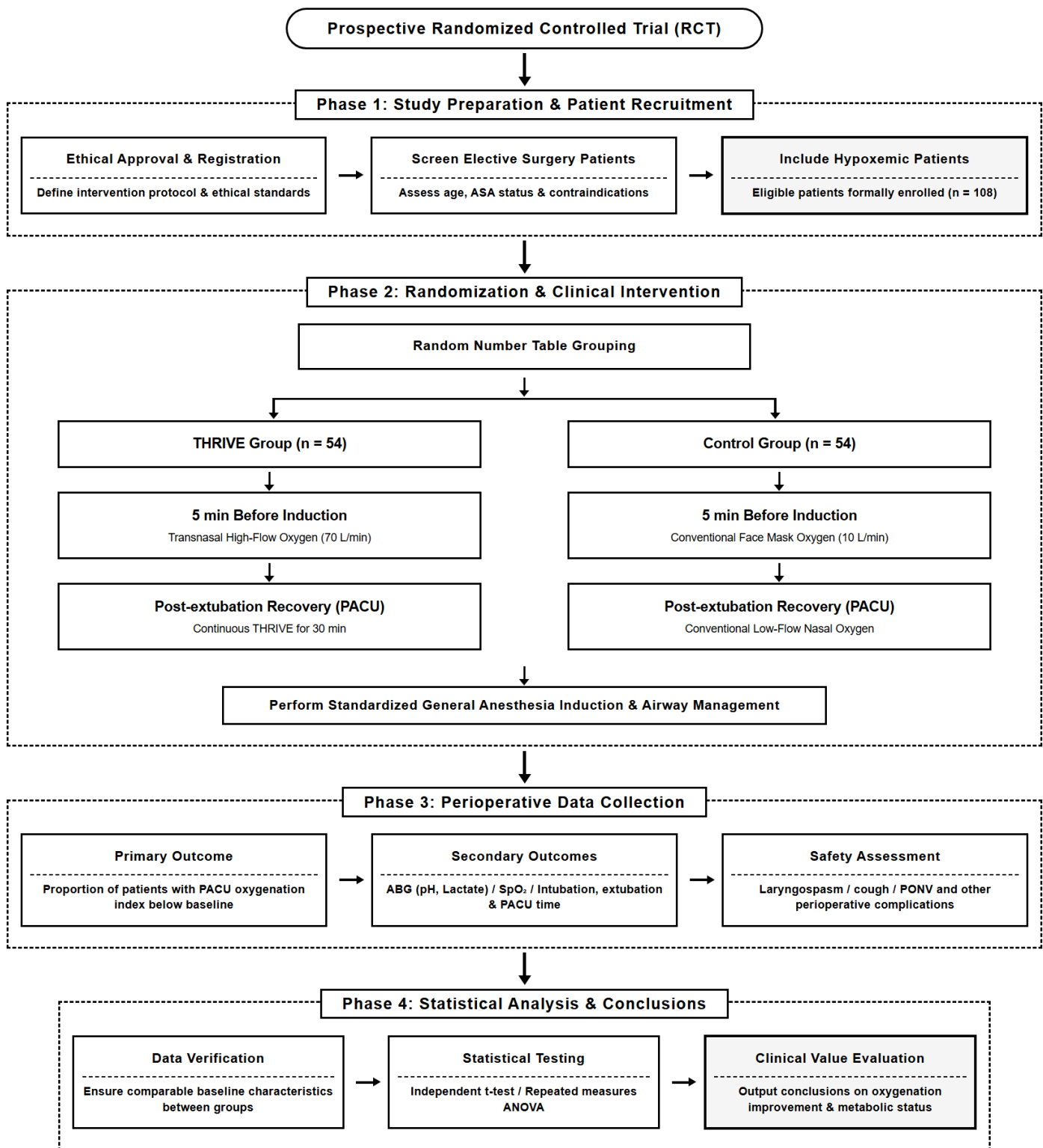


Figure 10

Unnumbered image in the Materials and Methods section.

Flow Chart