

Analysis of the Application Effect of High-Flow Nasal Cannula Oxygen Therapy in Painless Transesophageal Echocardiography: A Prospective Single-Blind Study

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Abstract

Background: Transesophageal echocardiography (TEE) is a commonly used clinical examination method. Most patients requiring TEE suffer from heart diseases, and hypoxia represent the most common adverse events associated with painless TEE, which poses higher risks for patients with heart conditions. High-flow nasal cannula (HFNC) oxygen therapy has gained widespread clinical application. Accordingly, the present study seeks to evaluate the safety and effectiveness of HFNC oxygen therapy in mitigating hypoxia among patients undergoing deeply sedated TEE.

Methods: We conducted a single-center, randomized, single-blind, parallel-controlled trial. Eligible patients were scheduled for elective TEE under deep sedation at Shanghai East Hospital from April 2025 to December 2025. Sedation was administered with sufentanil in combination with propofol, and participants randomly assigned to the control group or the HFNC group. The primary endpoint was the occurrence of hypoxia during the TEE under deep sedation. Other adverse events were also recorded.

Results: Between April 2025 and December 2025, 138 patients were scheduled to undergo TEE under deep sedation. Seven patients in the control group and 5 patients in the HFNC group were excluded due to changes in treatment plans, while 1 additional control group patient was excluded as their examination duration surpassed 30 minutes. One hundred and twenty-five patients completed the study (61 in the control group and 64 in the HFNC group). In comparison to conventional nasal cannula oxygen therapy, HFNC oxygen therapy led to a significant reduction in the incidence of hypoxia, with the incidence rate decreasing from 16.4% (10/61) to 3.1% (2/64). The incidence of hypoxemic events declined from 39.3% (24/61) to 12.59% (8/64). No statistically significant difference was observed between the two groups in the incidence of other sedation-related adverse events.

Conclusion: HFNC oxygen therapy during painless TEE significantly reduces hypoxia without elevating the risk of other adverse events.

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Introduction

Transesophageal echocardiography (TEE) is a commonly used clinical examination displaying cardiac structures in detail, such as atrial appendages, heart valves, and major blood vessels. TEE serves as a supplementary method to transthoracic echocardiography (TTE) and can provide more diagnostic information compared with TTE¹. Since TEE is a semi-invasive procedure, patients without sedation may experience discomfort such as nausea, vomiting and anxiety during the examination, which may increase the risk of upper gastrointestinal tract injury^{2,3}. TEE also correlates with these risks, including non-sustained ventricular tachycardia, atrial fibrillation, bradycardia, angina pectoris, upper airway obstruction and others, which arise from the patient's pre-existing comorbidities and the diagnostic or therapeutic process.^{4,5}.

Similar to gastroscopy, deep sedation can provide patients with a comfortable experience during TEE, create optimal procedural conditions for examining physicians, and improve the efficiency and quality of the examination. However, studies have demonstrated that approximately half of the patients undergoing TEE under deep sedation are at risk of developing respiratory complications of varying severity⁶. Hypoxia are also the most common complication during other painless diagnostic and treatment procedures. Prolonged hypoxia may result in neurological impairment, arrhythmias, myocardial ischemia, and even mortality^{7,8,9}. Since most patients undergoing TEE have underlying heart diseases, reducing hypoxia during the examination is crucial for patients' life safety.

High-flow nasal cannula (HFNC) oxygen therapy is an advanced oxygen delivery method. A specialized system is used to deliver oxygen at high flow rates to patients, which can reach a maximum of 70 L/min¹⁰. The gas is heated, humidified and adjustable in temperature and oxygen concentration maybe adjusted if required¹¹. HFNC oxygen therapy generates positive airway pressure, thereby augmenting end-expiratory lung volume and rapidly clearing carbon dioxide from the nasopharyngeal cavity¹². The combination of these mechanisms have been demonstrated to effectively prevent hypoxemia in various clinical application scenarios. Lin et al¹³ have shown demonstrated that HFNC oxygen therapy significantly reduces the incidence of hypoxia and severe hypoxemia during sedation in patients who undergo painless gastroscopy.

TEE shares similarities with gastroscopy in terms of operation methods and examination positions. Drawing inspiration from such studies, we postulate that HFNC oxygen therapy may decrease the occurrence of hypoxia during TEE under deep sedation, which is of great importance to patients undergoing this examination.

Methods

Study design

Conducted between April 2025 and December 2025, this single-center randomized controlled trial obtained ethical approval for its protocol from the Ethics Committee of Shanghai East Hospital (2025YS-083) and was registered with the Chinese Clinical Trial Registry (ChiCTR2500100987,17/04/2025). All researchers had received training on HFNC oxygen therapy.

Participants

This study enrolled adult inpatients aged 18–80 years with the ASA Physical Status Classification I–II who were scheduled for TEE under deep sedation. All patients provided written informed consent. Exclusion criteria were as follows: 1.ASA Physical Status Classification > II; 2. Body Mass Index (BMI) > 30 kg/m²; 3. Complex congenital heart disease; 4. Uncontrolled severe heart failure; 5. Uncontrolled severe ventricular arrhythmia; 6. Obstructive sleep apnea syndrome; 7. Contraindications to TEE(e.g.,

esophageal diverticulum); 8. Other contraindications to anesthesia (e.g., upper respiratory tract infection). Withdrawal criteria: Circumstances that made it inappropriate to continue the study during treatment, including aggravation of the patient's condition, adverse drug reactions, need for changes in the treatment plan, poor compliance, or voluntary withdrawal (for any reason).

Randomization and masking

Participants were randomly assigned in a 1:1 ratio to either the control group or the HFNC group using a random number table method, with allocation concealment achieved via opaque sealed envelopes. Anesthesiologist determined patient eligibility based on the predefined inclusion and exclusion criteria, and opened the envelopes sequentially according to the enrollment order. Only the participants were blinded to group allocation.

Trial procedure

For each patient, peripheral intravenous access was obtained in the right upper limb, and invasive arterial blood pressure monitoring was performed via the left upper limb. Subsequently, each patient adopted the left lateral decubitus position with both a nasal cannula and an HFNC nasal cannula (Optiflow Thrive™ system, Fisher & Paykel Healthcare Ltd., Auckland, New Zealand). All patients underwent the examination in the same examination room, and the high-flow nasal oxygenation device was kept at their bedside at all times.

Each examination room was staffed with one sonographer, one nurse, and one anesthesiologist. All patients received preoxygenation at 3 L/min for 1 minute before sedation. Subsequently, 5 µg of sufentanil was administered, followed by intravenous injection of propofol at 1 mg/kg within 30 seconds until loss of consciousness (LOC), with LOC defined as the disappearance of the corneal reflex. If LOC was not achieved after the initial propofol injection, an supplementary 0.5 mg/kg of propofol was given; if LOC still was not attained 2 minutes after this supplementary dose, another additional dose was administered.

Oxygen flow was increased to 6 L/min in the control group and 30 L/min in the HFNC group once patients lost consciousness in each respective group. Continuous assessment of sedation depth via the Ramsay Sedation Scale was conducted throughout the examination. To maintain a sedation depth of Ramsay Sedation Score ≥ 5 , supplementary intermittent 0.2 mg/kg boluses of propofol administered until the examination concluded.

Arterial blood gas analysis was conducted at three distinct time points: before oxygen administration, at the end of the examination (when the TEE probe was withdrawn from the oral cavity), and 5 minutes after the patient regained consciousness.

Data collection and outcome measures

During the pre-anesthesia evaluation phase, basic information of all patients was recorded, including name, age, gender, ASA physical status classification, weight, height, BMI, and Modified Mallampati classification(MMC).

During the examination, the patients' heart rate(HR), mean arterial pressure (MAP), and peripheral oxygen saturation(SpO₂) were continuously monitored. MAP, HR and SpO₂ were continuously recorded via the DoCare information system (Medicalsystem Co., Ltd). Nurses documented data using paper case report forms (CRFs). The induction dose of propofol administered during anesthesia, as well as any supplementary doses and the usage of vasoactive agents also recorded. Other data describing patient characteristics, examination details, and anesthetic medications were retrieved from electronic anesthesia records or patients' clinical medical records.

When SpO₂ dropped below 95%, the jaw-thrust maneuver was used to establish a patent airway. If patients in either group developed severe hypoxia (SpO₂< 75% or SpO₂ between 75% and 90% lasting for more than 60 seconds), mask ventilation was initiated. In cases where severe hypoxia failed to be resolved with mask ventilation, the anesthesiologist would determine whether endotracheal intubation was necessary.

All painless-related adverse events that arose during the procedure were documented utilizing the reporting instrument developed by the International Sedation Task Force of the World Society of Intravenous Anesthesia (WSIVA)¹³. After anesthesia emergence, HFNC-related adverse events were recorded, including nasal dryness, nasal pain, sore throat, headache, and barotrauma¹². Upon completion of the examination, patients were observed in the post-anesthesia care unit for 1 hour before being transferred back to the ward.

Missing data were excluded from the analysis.

Main study endpoint

The main study endpoint was the occurrence of hypoxia throughout TEE under deep sedation.

Secondary endpoints

Secondary outcomes included the incidence of hypoxemic events, the incidence of hypercapnia, changes in vital signs, the incidence of painless-related adverse events, the dose of propofol administered, and TEE-related parameters. Hypoxemic events included the subclinical respiratory depression, hypoxia, and severe hypoxia. Subclinical respiratory depression was defined as an SpO₂ of 90% ≤ SpO₂ < 95%; hypoxia as an SpO₂ of 75% ≤ SpO₂ < 90% for < 60 seconds; and severe hypoxia as an SpO₂ < 75% for any duration or 75% ≤ SpO₂ < 90% for ≥ 60 seconds.

Sample size estimation

Based on the results of our pilot study, the incidence of hypoxia was 20% when conventional nasal cannula oxygen therapy was used during deeply sedated TEE, and 4% when HFNC oxygen therapy was used. With the overall type I error set at $\alpha = 0.05$, power at 0.80, and attrition rate at 10%, the above parameters were calculated using PASS 15 software under a two-tailed test, with a 1:1 ratio. From this, the estimated sample size was 138 cases, equally divided into the control group and the HFNC group (69 patients per group).

Statistical analysis

Two-tailed statistical tests were used for all analyses, with statistical significance defined as a P-value < 0.05. All statistical calculations were performed using SPSS software (version 26.0).

Normally distributed continuous data were presented as mean $\pm$ standard deviation ($\bar{x} \pm s$), and independent-samples t-tests were used for between-group comparisons. Categorical variables were expressed as frequencies and percentages (n, %), and the chi-square test or Fisher's exact test was applied for between-group comparisons as appropriate.

No additional subgroup or sensitivity analyses were performed in this study.

Results

From January to September 2025, 138 patients were recruited in this study. Among these individuals, 7 control group patients and 5 HFNC group patients were excluded due to changes in the treatment plan before the examination. Additionally, one patient from the control group was withdrawn from the study because the examination duration exceeded 30 minutes. The final analytical cohort consisted of 125 patients, with 61 allocated to the control group and 64 to the HFNC group. No significant differences in concomitant care, including fluid management, were observed between groups.

General characteristics

Table 1 summarizes the baseline characteristics of patients in both groups, encompassing age, gender, ASA physical status classification, weight, height, BMI, medical history, Modified Mallampati classification (MMC), and baseline SpO₂. No statistically significant disparities were observed across these variables.

Table 1
Baseline characteristics of patients

Characteristic	Control group, no. (%) (n = 61)	HFNC group, no.(%) (n = 64)	P value
Age(years), mean (SD)	68.1 ± 9.0	68.4 ± 10.9	0.843
Sex			0.790
Male	31(50.8)	31(48.4)	
Female	30(49.2)	33(51.6)	
ASA grade			0.424
I	32(52.5)	29(45.3)	
II	29(47.5)	35(54.7)	
Weight (kg), mean (SD)	67.0 ± 10.4	64.8 ± 9.4	0.219
Height,mean (SD)	165.6 ± 7.5	165.2 ± 7.9	0.798
BMI (kg/m ²), mean (SD)	24.4 ± 3.0	23.7 ± 2.8	0.200
Hypertension			0.875
Y	45(73.8)	48(75.0)	
N	16(26.2)	16(25.0)	
Diabetes			0.200
Y	14(23.0)	9(14.1)	
N	47(77.0)	55(85.9)	
Coronary Heart Disease			0.854
Y	20(32.8)	20(31.3)	
N	41(67.2)	44(68.8)	
Fibrillation			0.665
Y	54(88.5)	55(85.9)	
N	7(11.5)	9(14.1)	
MMC			0.698
I	40(65.6)	39(60.9)	
II	19(31.1)	21(32.8)	
III	2(3.3)	4(6.3)	
IV	0(0)	0(0)	

Characteristic	Control group, no. (%) (n = 61)	HFNC group, no. (%) (n = 64)	P value
Baseline SpO ₂ (%),mean (SD)	98.9 ± 1.7	98.7 ± 1.9	0.415

No significant differences were found between the two groups for all baseline characteristics.

IQR,interquartile range;SD,standard deviation.

Table 2 presents the painless TEE examination duration, propofol dosage, and probe insertion difficulty of patients in the two groups, difficulty in probe insertion was defined as ≥ 3 attempts to insert the TEE probe into the esophagus.

Table 2
Propofol administration and TEE Procedure-Related Data

Duration (minutes), mean (SD)	Control group, no. (%) (n = 61)	HFNC group, no. (%) (n = 64)	P value
	10.9 ± 2.6	11.3 ± 3.0	0.428
Probe insertion difficulty	7(11.5)	10(15.6)	0.499
Dose of propofol (mg), mean (SD)	97.0 ± 23.8	94.3 ± 28.0	0.568
Dose of propofol (mg/kg), mean (SD)	1.4 ± 0.2	1.5 ± 0.4	0.847

No significant differences were found between the two groups in these indicators.

Adverse events

Table 3 presents the hypoxemic events and the incidence of hypercapnia. Hypoxia rate was markedly reduced in the HFNC group relative to the control group, and HFNC reducing this rate from 16.4% to 3.1% ($P = 0.012$).

The HFNC group had lower incidences of hypoxemic events versus the control group, decreased from 38.5% to 10.9% ($P = 0.001$). No significant differences were noted between the two groups in the rates of Subclinical respiratory depression, severe hypoxia, mild hypercapnia, moderate hypercapnia, and overall hypercapnia, and no patients experienced severe hypercapnia in either group.

Table 3
Hypoxemic events and hypercapnia

Adverse events	Control group, no. (%) (n = 61)	HFNC group, no. (%) (n = 64)	P value
Primary outcome Hypoxia	10(16.4)	2(3.1)	0.012
Hypoxemic events	24(39.3)	8(12.5)	0.001
Subclinical respiratory depression	13(21.3)	6(9.4)	0.063
Severe hypoxia	1(1.6)	0(0)	0.488
Total number of hypercapnia	49(80.3)	49(76.6)	0.609
Mild hypercapnia	17(27.9)	21(32.8)	0.548
Moderate hypercapnia	32(52.5)	28(43.8)	0.330
Severe hypercapnia	0(0)	0(0)	NE

Mild hypercapnia was defined as an arterial carbon dioxide partial pressure (PaCO_2) of $45 \text{ mmHg} \leq \text{PaCO}_2 < 50 \text{ mmHg}$, moderate hypercapnia as $50 \text{ mmHg} \leq \text{PaCO}_2 < 70 \text{ mmHg}$, and severe hypercapnia as a $\text{PaCO}_2 \geq 70 \text{ mmHg}$.

NE: No events occurred in both groups

Table 4 displays changes in vital sign and PaCO_2 parameters during painless TEE examination. No statistically meaningful differences in MAP and HR were observed across all time points between the two groups, with no significant variations in PaCO_2 identified at baseline, the end of TEE examination, and 5 minutes following recovery.

Table 4
Change of vital parameters and PaCO₂ throughout TEE examination

		Control group (n = 61)	HFNC group (n = 64)	P value
MAP(mmHg)	Baseline	106.7 ± 12.6	104.6 ± 13.3	0.379
	After induction	89.0 ± 14.1	90.9 ± 15.0	0.272
	Probe insertion	88.4 ± 16.1	93.4 ± 15.9	0.083
	5min after probe insertion	79.8 ± 12.5	82.5 ± 12.0	0.225
	Probe withdrawal	83.2 ± 11.1	85.6 ± 11.9	0.247
HR(bpm)	Baseline	81.9 ± 15.4	80.6 ± 17.5	0.662
	After induction	74.5 ± 13.6	74.3 ± 14.5	0.953
	Probe insertion	75.1 ± 15.8	74.5 ± 14.4	0.825
	5min after probe insertion	68.8 ± 11.9	69.7 ± 13.6	0.674
	Probe withdrawal	68.3 ± 11.6	70.0 ± 13.0	0.455
PaCO ₂ (mmHg)	Before initiating oxygen therapy	37.8 ± 3.3	37.5 ± 3.3	0.632
	Probe insertion	48.8 ± 4.9	48.6 ± 5.7	0.907
	5 min after recovery	43.2 ± 4.6	43.2 ± 3.9	0.883

Table 5 presents the incidence of hypotension, bradycardia, and rescue drug use in the two groups.

Table 5
Sedation-related adverse events and corresponding interventions

Hypotension	Control group, no. (%) (n = 61)	HFNC group, no. (%) (n = 64)	P value
Y	16(26.2)	15(23.4)	0.718
N	45(73.8)	49(76.6)	
Bradycardia			0.720
Y	21(34.4)	24(37.5)	
N	40(65.6)	40(62.5)	
Nausea/vomit			NE
Y	0(0.0)	0(0.0)	
N	61(100.0)	64(100.0)	
Recovery delay			NE
Y	0(0.0)	0(0.0)	
N	61(100.0)	64(100.0)	
Atropine			1.000
Y	1(1.6)	1(1.6)	
N	60(98.4)	63(98.4)	
Vasopressors			0.632
Y	4(6.6)	2(3.1)	
N	57(93.4)	62(96.9)	

Hypotension is defined as a > 25% decrease from the baseline. Bradycardia is defined as a heart rate < 60 bpm.

NE: No events occurred in both groups.

Throughout the entire study period, no patients in either group required mask ventilation or endotracheal intubation. In this study, HFNC-related adverse events were rare. All patients in the HFNC group did not experience nasal dryness, nasal pain, headache, or subcutaneous emphysema, and no other serious complications occurred.

Discussion

This randomized controlled trial evaluated the efficacy of HFNC in TEE under deep sedation. Given the high incidence of hypoxia with deep sedation, most institutions have discontinued painless TEE, resulting in patient discomfort and inaccurate results—problems that HFNC may help resolve. Our

findings confirmed that HFNC significantly lowered the incidence of hypoxia in deeply sedated TEE patients. No intergroup differences were found in sedation-related adverse events or hemodynamic changes, and no severe HFNC-related adverse events were observed throughout the study.

The results of the present study showed that the incidence of hypoxia in patients undergoing deeply sedated TEE with HFNC oxygen therapy was 3.1%(2/64), which was significantly lower than that in patients receiving conventional nasal cannula oxygen therapy. In the control group, the incidence of hypoxia in deeply sedated TEE examinations using conventional nasal cannula oxygen therapy was as high as 16.4%(10/61). We also considered overall hypoxemic events, including subclinical respiratory depression, hypoxia, and severe hypoxia. HFNC oxygen therapy significantly reduced the incidence of hypoxemic events, which decreased from 39.3% (24/61) to 12.5% (8/64). Although more than half of hypoxemic events were subclinical respiratory depression, this high incidence remains the reason why our institution and other medical centers remain cautious in performing painless TEE.

HFNC oxygen therapy is a novel strategy. Studies have reported that using HFNC in patients under certain conditions of deep sedation can reduce the incidence of hypoxemia^{14,15,16}, which is in agreement with the results of our research. Wang et al¹⁷ proposed that HFNC oxygen therapy is characterized by adjustable oxygen concentration support, and high-flow gas flushing effect. In our study, we administered 100% oxygen concentration to patients receiving HFNC oxygen therapy. Furthermore, the high flow rate of HFNC delivered dynamically adjusted low-level positive end-expiratory pressure (PEEP), thereby reducing respiratory workload^{18,19,20}. These factors collectively contributed to a decreased incidence of hypoxemic events and facilitated a more rapid recovery of oxygen saturation following the jaw-thrust maneuver.

High-flow gas flushing effect helps clear the anatomical dead space, and significantly reduces carbon dioxide rebreathing²¹. We hypothesized that HFNC oxygen therapy would reduce carbon dioxide accumulation in patients during sedation and subsequently verified this hypothesis. In our study, PaCO₂ was measured three times in patients, yet the results showed no significant effect of HFNC oxygen therapy on this parameter.

We recorded the variations in vital parameters over sequential time points and the incidence of various adverse events in the study patients. Analysis revealed that MAP and HR exhibited no statistically significant variation between the two groups at all time points. However, due to the fact that most of the included patients had a history of atrial fibrillation, the statistics of HR may not be sufficiently accurate. Additionally, no significant differences were observed between the two groups in the incidence and severity grade of hypercapnia, nor were there any notable differences in the incidence of other complications. No patients in the HFNC group encountered any HFNC-related adverse events, which indicates that HFNC has high safety in the application of painless TEE.

After patients lost consciousness, the oxygen flow rate was adjusted to 6 L/min in the control group and 30 L/min in the HFNC group. Conventional nasal cannula oxygen therapy at 6 L/min results in an FiO₂ of

about 45%, with no effective elevation of inspired oxygen concentration by further increasing the flow rate, whereas HFNC at a fixed 30 L/min allows the inspired oxygen concentration to approximate the preset value^{22,23}. For patients with ASA class II-III, HFNC oxygen therapy can also prolong the safe apnea time to 20 minutes^{24,25}. In this study, approximately half of the patients had an ASA class II. However, their examination time was all less than 20 minutes; even if transient apnea occurred, most patients could still maintain oxygenation.

Notably, TEE is similar to gastroscopy in terms of procedure: the probe is inserted through the upper gastrointestinal tract. However, compared with relevant studies, a higher incidence of hypoxemic events was observed in the control cohort of this research. This is thought to be due to the fact that the TEE probe lacks the visualization structure, air insufflation, and other functions of digestive endoscope probes, making it hard to pass through the oral cavity. The difficulty in probe insertion observed in the results also confirms this phenomenon. In intubated patients, videolaryngoscopy significantly improves TEE probe insertion success and reduces complications¹. This issue also occurred in our deeply sedated patients: even with the same experienced sonologist performing the procedure, some experienced difficulty with TEE probe insertion, which was ultimately accomplished with videolaryngoscopic assistance.

Regarding the selection of anesthetic drugs, although the guidelines on performing comprehensive TEE examinations mention the effects, adverse reactions, and potential hazards of sedative drugs, they do not provide specific guidance on sedation strategies²⁶. Respiratory and cardiovascular impairment that may be caused by the employment of multiple agents remains a major hurdle to safeguarding patient safety. Regardless of the pharmacologic agent chosen for deep sedation, respiratory complications represent the most common adverse events. If hypoxia is severe or persists for an prolonged duration, it could result in severe adverse events, including arrhythmia, permanent neurological impairment, cardiopulmonary arrest, or even death. Therefore, reducing the occurrence of hypoxia is particularly important for patients with cardiovascular diseases. In this study, sufentanil combined with propofol was used to achieve deep sedation. Opioid drugs are often used as adjuvant medications to alleviate discomfort during probe insertion and the examination procedure. Propofol is a widely used short-acting intravenous anesthetic that is highly lipophilic, rapidly crosses the blood-brain barrier, and exhibits widespread tissue distribution, rendering it favorable for its rapid onset, controllable depth of sedation, and predictable recovery profile²⁷. Moreover, when propofol is used in most endoscopic examinations, the incidence of cardiopulmonary adverse events is similar, while it can provide better sedative effects, higher patient compliance, and higher postoperative patient satisfaction²⁸. We recorded and compared the total propofol dosage and the propofol dosage calculated by body weight between the two groups, the results showed no notable differences, and propofol dosage was not significantly associated with the difference in hypoxia occurrence between the groups.

To summarize, HFNC oxygen therapy is capable of mitigating the risk of hypoxia among individuals undergoing painless TEE in clinical practice. This is of great significance for the safety of painless TEE

and also provides a reliable guarantee for the popularization of painless TEE. Additionally, HFNC is easy to operate, does not interfere with the examination performed by sonographers, and thus facilitates its application in clinical settings.

Limitations of study and future research

Challenges in blinding implementation: HFNC oxygen therapy is inherently different from conventional nasal cannula oxygen therapy, making it difficult for anesthesiologists to implement blinding. Therefore, this trial did not blind anesthesiologists. However, SpO₂, vital signs, and arterial blood gas analysis, as objective assessment indices, help to minimize bias.

Challenges in HR and pulse rate (PR) monitoring: This study included patients who needed to undergo deeply sedated TEE examination, most of whom had cardiovascular diseases of varying degrees—especially patients with atrial fibrillation, and some of these patients had undergone cardioversion prior to the examination. This made the monitoring and statistical analysis of patients' HR and PR more difficult.

Limitations of the study population: The present study only included patients with an ASA Physical Status Classification I–II and aged < 80 years. Patients with an ASA classification > Grade II carry a higher risk of developing various complications, while those aged ≥ 80 years are more prone to respiratory and circulatory complications during deep sedation. Although HFNC oxygen therapy may provide effective support for such patients, they were excluded from this study to ensure the safety of the study participants. We will conduct further clinical studies in these patients to verify whether HFNC-assisted painless TEE provides benefits in high-risk patients.

Insufficient ethnic representation: All patients in this study were from the Chinese population, which means the conclusions of this study may not be generalizable to populations from other regions of the world.

Conclusion

HFNC oxygen therapy during painless TEE can significantly reduce hypoxia without elevating the risk of adverse events.

Abbreviations

TEE

Transesophageal echocardiograph

HFNC

high-flow nasal cannula

TTE

transthoracic echocardiography

ASA
American Society of Anesthesiologists
CRFs
case report forms
LOC
loss of consciousness
SpO₂
peripheral oxygen saturation
BMI
Body Mass Index
MAP
Mean arterial pressure
WSIVA
World Society of Intravenous Anesthesia
PACU
post-anesthesia care unit
MMC
Mallampati Classification
PaCO₂
carbon dioxide in arterial blood
HR
Heart Rate
FiO₂
fraction of inspired oxygen
PR
pulse rate
IQR
interquartile range
SD
standard deviation.

Declarations

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Author's contributions

Kan He, Lianghua Xia and Xiaomei Guo contributed equally to this work. Kan He: Conceptualization, Writing–Original Draft Preparation. Lianghua Xia: Methodology, Resources. Xiaomei Guo: Formal Analysis. Yaping Liu: Study Coordination, Data Curation. Zhijun Fan: Formal Analysis. Bingqing Wang: Methodology. Minghao Yang: Study Coordination. Yilin Wang: Data Curation. Jiesong Liu: Data Curation. Lihua Huang: Data Curation. Zhenmin Ding: Writing–Review & Editing. Huihong Lu: Writing–Review & Editing, Supervision.

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Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study protocol was approved by the Ethics Committee of Shanghai East Hospital(2025YS-083) and performed in accordance with the Declaration of Helsinki. The study protocol was registered with the Chinese Clinical Trial Registry (ChiCTR2500100987) and followed the CONSORT guidelines. Written informed consent was obtained from all patients before randomization.

Consent for publication

Not applicable

Competing interests

The authors declare no competing interests.

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Figures

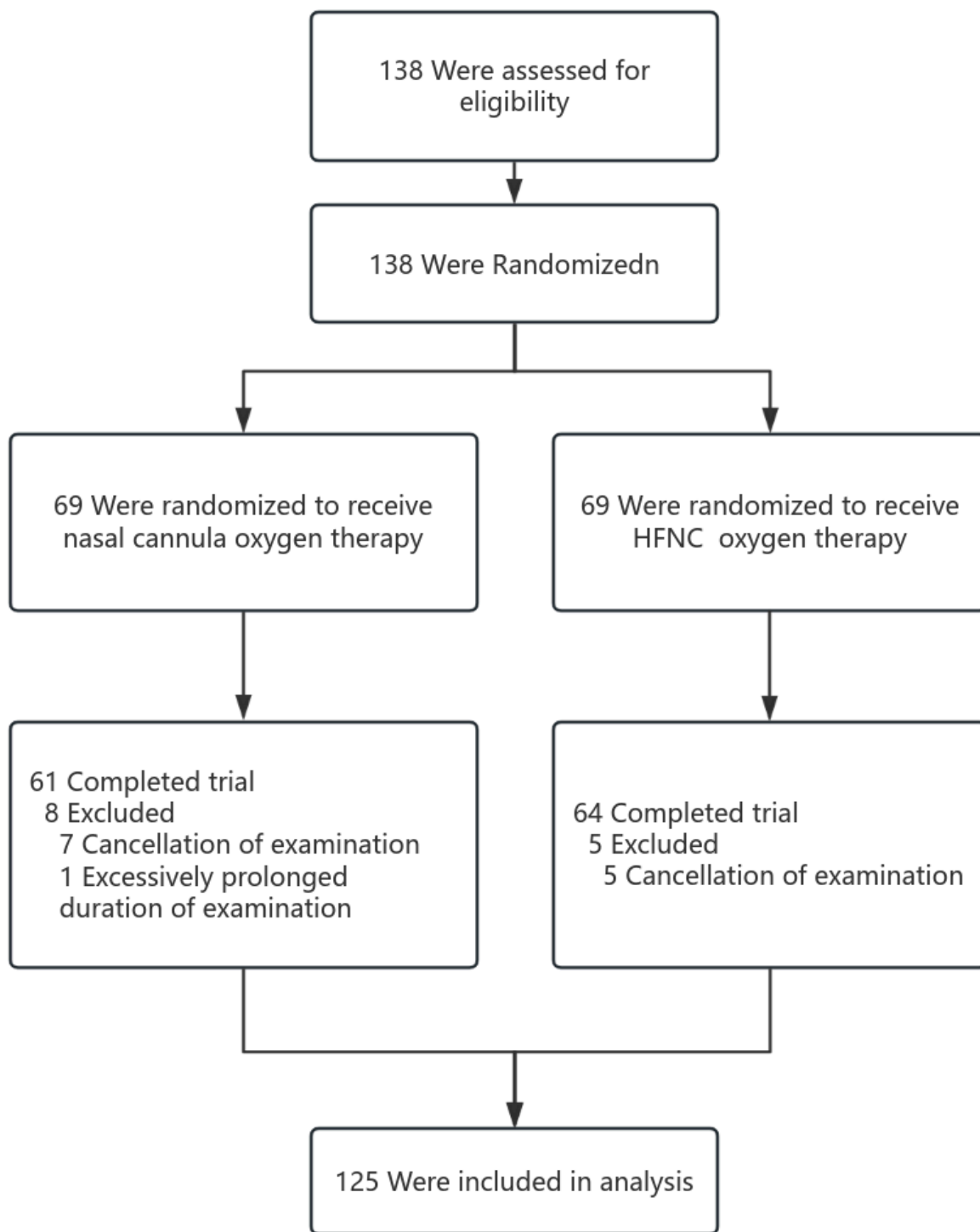


Figure 1

CONSORT flowchart.