Effect of lateral versus supine positioning on hypoxaemia in sedated adults: multicentre randomised controlled trial

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ABSTRACT

OBJECTIVES

To evaluate the effect of lateral versus supine positioning on incidence of hypoxaemia in sedated patients and to provide evidence based recommendations for respiratory strategies.

DESIGN

Prospective, multicentre, randomised controlled trial.

SETTING

14 tertiary hospitals in China, July to November 2024.

PARTICIPANTS

2159 adults (≥18 years) who underwent sedation.

INTERVENTIONS

Sedated patients were randomly assigned (1:1) to receive either lateral positioning or conventional supine positioning, stratified by study centres.

MAIN OUTCOME MEASURES

The primary outcome was incidence of hypoxaemia (peripheral oxygen saturation (SpO_2) ≤90%) within the first 10 minutes after positioning. Secondary outcomes included airway rescue interventions, incidence of severe hypoxaemia (SpO_2 ≤85%), lowest oxygen saturation recorded, length of stay in the post-anaesthesia care unit, and safety measures (eg, bradycardia, tachycardia, hypotension, new onset arrhythmia). Analyses were performed on an intention-to-treat basis.

RESULTS

Of 2159 patients randomised, 2143 were included in the primary analysis. The mean age of the patients was 53.1 years, mean body mass index was 23.9, and 53.7% (1150/2143) were women. The incidence of hypoxaemia was significantly lower in the lateral group compared with supine group (5.4% (58/1073) *v* 15.0% (161/1070); adjusted risk ratio 0.36, 95% confidence interval (CI) 0.27 to 0.49; P<0.001). Compared with patients in the supine group, patients in the lateral group required fewer airway rescue interventions (6.3% (68/1073) *v* 13.8% (148/1070); adjusted risk ratio 0.46, 0.34 to 0.61; P<0.001), had a lower incidence of severe hypoxaemia (0.7% (8/1073) *v* 4.8% (51/1070); adjusted risk ratio 0.16, 0.07 to 0.33; P<0.001), and had a higher mean lowest SpO_2 level (96.9% *v* 95.7%, absolute adjusted mean difference 1.20%, 95% CI 0.87% to 1.54%; P<0.001). Additionally, length of stay in the post-anaesthesia care unit was shorter in the lateral group (38.2 *v* 40.5 minutes; absolute adjusted mean difference −2.22 minutes; 95% CI −3.63 to −0.80; P=0.002). Safety outcomes were comparable between the groups, but tachycardia was less frequent in the lateral group.

CONCLUSIONS

Placing sedated adults in the lateral position significantly reduces the incidence and severity of hypoxaemia and decreases the need for airway rescue interventions without compromising safety. Given its simplicity and low cost, lateral positioning could offer advantages in remote or resource constrained clinical settings. Further replication studies targeting patients with advanced age and high body mass index are needed to improve the generalisability of the findings.

TRIAL REGISTRATION

ClinicalTrials.gov NCT06459167.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Hypoxaemia is a common and potentially life threatening complication in sedated patients

Delays in intervention, owing to a shortage of skilled respiratory clinicians, can increase morbidity and mortality

Although lateral positioning is widely recommended as a first aid manoeuvre for unresponsive patients with spontaneous breathing, its role in preventing or mitigating hypoxaemia in sedated patients remains unclear

WHAT THIS STUDY ADDS

In this large, multicentre, randomised controlled trial, lateral positioning significantly reduced both the incidence and the severity of hypoxaemia in sedated adults in the post-anaesthesia care unit

These findings support the use of lateral positioning as a simple, low cost, and effective respiratory management strategy for sedated adults, especially in resource constrained settings where access to specialised respiratory care is limited

Introduction

Hypoxaemia is a critical and potentially life threatening complication in sedated patients, with incidence rates ranging from 4% to 71%.[1-6] It can occur across a wide range of settings, including the emergency department and during endoscopy and inpatient and outpatient procedures.[7-9] It is also troublesome in palliative sedation, with a high

proportion of patients experiencing dyspnoea.[10] Hypoxaemia can lead to adverse outcomes, such as arrhythmias, haemodynamic decompensation, and hypoxic brain injury. Further prolonged oxygen deprivation can precipitate life threatening events like cardiac arrest or persistent vegetative state.[11] Therefore, less burdensome respiratory strategies are needed, regardless of oxygen delivery or the use of artificial airways. Hypoxaemia frequently occurs in sedated patients due to sedative induced respiratory depression and upper airway obstruction.[12-14] Conventional management typically involves oxygen supplementation and airway rescue manoeuvre. Delays in intervention, however, such as a shortage of skilled airway management clinicians, can worsen patient outcomes, and can also increase healthcare costs.[1 7 11] Therefore, optimising strategies to prevent hypoxaemia in sedated patients is imperative.

Conventional supine positioning of patients has been broadly reported to exacerbate gravitational displacement of soft tissues in the pharyngeal airway, increasing the likelihood of obstruction, especially during sedation.[15-18] Although alternative positions, such as semi-recumbent or prone, can enhance ventilation-perfusion matching, they do not deal directly with upper airway obstruction.[19-22] Lateral positioning theoretically mitigates these gravitational effects, but evidence supporting its application in routine clinical care is limited, derived mainly from small studies or in the context of specific procedures. Some smaller scale studies indicate that lateral positioning may alleviate airway collapse and improve oxygenation by reducing gravitational forces that compromise airway patency.[15 23-25] Other studies also found that the lateral position, compared with supine position, was associated with lower rates of apnoea during different procedures.[26 27] Additionally, such positional adjustments are already routinely recommended as a first aid measure for non-fasted patients and unresponsive patients with spontaneous breathing to reduce aspiration risk.[28-30]

Despite these promising observations, the effect of lateral positioning on prevention of hypoxaemia in sedated adults remains unclear. In this multicentre randomised controlled trial with a large sample of participants, we aimed to address this gap in knowledge.

Methods

Study design

This trial was an investigator initiated, multicentre, open label, nationwide, randomised controlled trial conducted across 14 centres in China from July to November 2024 (see supplementary table 1).

The trial compared lateral positioning with supine positioning in sedated adults in the post-anaesthesia care unit. The protocol was approved by the institutional review board of the First Affiliated Hospital, School of Medicine, Zhejiang University and corresponding ethics committees at each participating centre before commencement of the study. The protocol adhered to the Declaration of Helsinki. All participants provided written informed consent preoperatively. No substantive changes were made to the protocol after the initiation of patient enrolment. Owing to the translation from Chinese to English, however, some discrepancies between the registered trial protocol on ClinicalTrials.gov and this manuscript exist. We have clarified these further in the supplementary material and enclosed the original Chinese trial protocol and a certified English translation for transparency. An independent data and safety monitoring board supervised the conduct of the trial and patient wellbeing throughout.

Participants

Eligible participants were consecutively enrolled adults (≥18 years) undergoing general anaesthesia with intubation intraoperatively. On admission to the post-anaesthesia care unit, the patients were extubated under the supervision of a consultant anaesthetist following predefined criteria (see supplementary table 2). One minute after extubation, patients' sedation levels were assessed using the Ramsay sedation scale; those scoring 2 to 4 were considered eligible (score 1, restless; 2, completely awake, quiet, and cooperative; 3, drowsy but responding to verbal commands; 4, lightly asleep but responding to touch or pain; 5, asleep but slowly responding to touch or pain; and 6, deeply asleep and does not respond). Our broad inclusion criteria intentionally encompassed patients from diverse surgical procedures (including high risk procedures, such as thoracic, lung, major abdominal surgeries, and emergency procedures), different sedation regimens, and different durations of procedure to enhance the generalisability and applicability of our results across varied clinical practices. Exclusion criteria included pre-existing hypotension (systolic blood pressure <80 mm Hg) or bradycardia (heart rate <50 beats/min); pre-existing hypoxaemia (defined as hypoxaemia before surgery, regardless of supplemental oxygen use); anatomical variations (eg, spinal deformity) or procedures prohibiting change of position; coexisting conditions, such as severe cardiovascular or cerebrovascular diseases, severe pulmonary diseases, and intracranial hypertension; and coagulation disorders or a tendency for nose bleeding (see supplementary table 3 for details).

Randomisation and masking

After confirmation of participants' eligibility, they were randomly assigned in a 1:1 ratio to receive either lateral positioning or supine positioning using permuted blocks of four, stratified by study centre. An independent statistician not involved in study implementation provided randomisation sequences using computer generated codes. Allocation concealment was maintained through sequentially numbered, opaque, sealed envelopes opened immediately before implementation of the intervention. Blinding was not feasible owing to the

nature of the intervention; however, outcomes were objectively assessed to minimise bias.

Procedures

The patients were monitored with the Bispectral index, maintaining values between 40 and 60 during procedures and anaesthesia. After the procedures, patients were transferred to the post-anaesthesia care unit[31 32] while still intubated (see supplementary table 4) and continuously monitored, including electrocardiography, blood pressure, respiratory rate, and peripheral oxygen saturation (SpO_2) by monitor (see supplementary table 5 for list of manufacturers by study site). The pulse oximeter probe was applied to the arm with intravenous access and the non-invasive blood pressure cuff to the other arm. The consultant anaesthetist in the post-anaesthesia care unit decided on timing of extubation, administration of reversal agent, and discharge (see supplementary tables 2 and 6). After extubation, supplemental oxygen was administered at a flow rate of 2 L/min through a nasal cannula. An investigator assessed sedation levels using the Ramsay sedation scale; patients with a score between 2 and 4 were immediately randomised to receive either lateral or supine positioning. Those outside this range were reassessed with the Ramsay sedation scale and on reaching a score of 2-4 were promptly randomised and positioned. Before enrolment in our study, all patients remained in the supine position (0° head-of-bed elevation) (see supplementary figure 1).

Intervention

Patients allocated to lateral positioning were placed at 90° on a horizontal bed, supported with a pillow to maintain neutral alignment of the spine and avoid hyperextension or forward flexion of the neck. No preference was specified for left or right lateral decubitus positioning, allowing flexibility based on patient comfort and surgical requirements. Patients allocated to supine positioning were placed flat without head elevation or pillows (0° head-of-bed elevation) (see supplementary figure 2).

Clinicians were required to remain silent and avoid touching the patient to minimise environmental stimuli. To ensure strict adherence to the intervention, an independent investigator continuously monitored and periodically verified positioning of the patient. Immediate corrective action was mandated only for important deviations, such as lateral tilting to less than 45° or unintentional turning of patients. Minor deviations deemed unimportant were deliberately left uncorrected to minimise environmental factors that might influence outcomes. Patients with SpO_2 >90% were continuously monitored for 10 minutes after positioning. If SpO_2 decreased to ≤90% during the 10 minutes of observation, airway rescue interventions were initiated in accordance with the airway rescue protocol, aiming to restore SpO_2 to ≥98% for a sustained period of at least five minutes.

The airway rescue protocol was initiated when SpO_2 decreased to ≤90%. If hypoxaemia was detected, nurses would notify the consultant anaesthetist and initiate predefined airway interventions according to protocol, unless oxygen saturation spontaneously returned to 90% before intervention. The predefined protocol for transient desaturation (SpO_2 75-90% for <60 seconds) was increased oxygen flow to 10 L/min and simultaneous jaw thrust manoeuvre. For serious desaturation (SpO_2 75-90% for ≥60 seconds, or SpO_2 <75% for any duration), the consultant anaesthetist provided mask ventilation and placed oropharyngeal or nasopharyngeal airways as necessary. Emergency tracheal intubation was performed when required. Airway interventions were proactively initiated based on the consultant anaesthetist's judgment, particularly in patients at risk of rapid deterioration, such as airway spasm. Proactive initiation of airway interventions reflected the understanding that SpO_2 measurements may lag behind actual physiological changes, prompting pre-emptive action, in alignment with established clinical practices.[33-35]

Outcomes and data collection

We recorded the patients' baseline data, including personal characteristics, American Society of Anesthesiologists' health status, chronic comorbidities, preoperative vital signs, and relevant information during procedures or surgery. Airway examination included Mallampati class[36 37] (see supplementary figure 3), neck circumference,[38] cervical mobility, thyromental distance, and retrognathia or mouth opening of ≤3.5 cm. Adverse events were recorded during and after the intervention procedure in the post-anaesthesia care unit. After intervention, the patients' pain score was assessed with a visual analogue scale.

The primary outcome was incidence of hypoxaemia, defined as any occurrence of oxygen saturation (SpO_2) ≤90% for at least five seconds during the initial 10 minute period after positioning,[39-44] meanwhile receiving standardised oxygen supplementation (2 L/min through nasal cannula, about 28-30% fractional inspired oxygen).

Secondary outcomes included frequency of airway rescue interventions (eg, increased oxygen flow, jaw thrust manoeuvre, mask ventilation), incidence of severe hypoxaemia (≤85%), lowest oxygen saturation (defined as the oxygenation nadir during 10 minutes of continuous measurement), and duration of stay in the post-anaesthesia care unit until standard criteria for discharge were met.

Safety outcomes assessed were tachycardia (heart rate >100 beats/min), bradycardia (heart rate <50 beats/min), hypotension (systolic blood pressure <80 mm Hg), new onset arrhythmia, cough, nausea or vomiting, reflux, and aspiration.

Sample size estimation

We estimated the required study sample size with 90% power at a two sided significance level of 5% to detect a 50% difference in incidence of hypoxaemia (8% in

supine group and 4% in lateral group).[45 46] With an allocation ratio of 1:1, we determined that we needed 1576 patients (788 patients in each group). Assuming a 10% drop out rate, we estimated a final sample size of 1752 patients. Although the planned sample size was 1752, a total of 2143 participants were enrolled owing to delayed reporting of recruitment status across study sites. This unintentional over-enrolment occurred without access to outcome data and in the absence of any interim analysis.

Statistical analysis

Primary and secondary outcomes were analysed on an intention-to-treat basis, including all patients who underwent randomisation and had available outcome data.

Continuous variables are presented as means and standard deviations (SDs) and categorical variables as counts and percentages, overall and by study arms. No formal statistical analysis was conducted in accordance with established reporting guidelines.

For the primary outcome, we used a Poisson regression model adjusting for study sites to estimate risk ratios and corresponding 95% confidence intervals (CIs). Similar models were used for other secondary outcomes (eg, airway rescue, incidence of severe hypoxaemia). We used a binary regression model with identity link to report the absolute risk difference for the primary outcome. A linear regression model was used for two continuous secondary outcomes (lowest SpO_2 and length of stay in the post-anaesthesia care unit). All the models were adjusted for study sites. We further adjusted the baseline values of SpO_2 for the lowest SpO_2 analysis to address regression towards the mean. Prespecified subgroup analyses were conducted to explore any heterogeneous effects on the primary outcome across various patient subgroups, including age, sex, body mass index (BMI), current smoker, neck circumference, Mallampati class, haemoglobin level, Ramsay sedation scale score, visual analogue scale pain score, use of neuromuscular reversal agent, procedure duration, procedure category (eg, abdominal, orthopaedic), and morphine milligram equivalents.[47] These analyses were undertaken using the same regression model as was used for the primary outcome, with Poisson regression models adjusting for study sites and interaction between these variables and the intervention arms. The number needed to treat[48] (NNT) was estimated from the absolute risk difference and calculated for the primary outcome incidence of hypoxaemia and airway rescue.

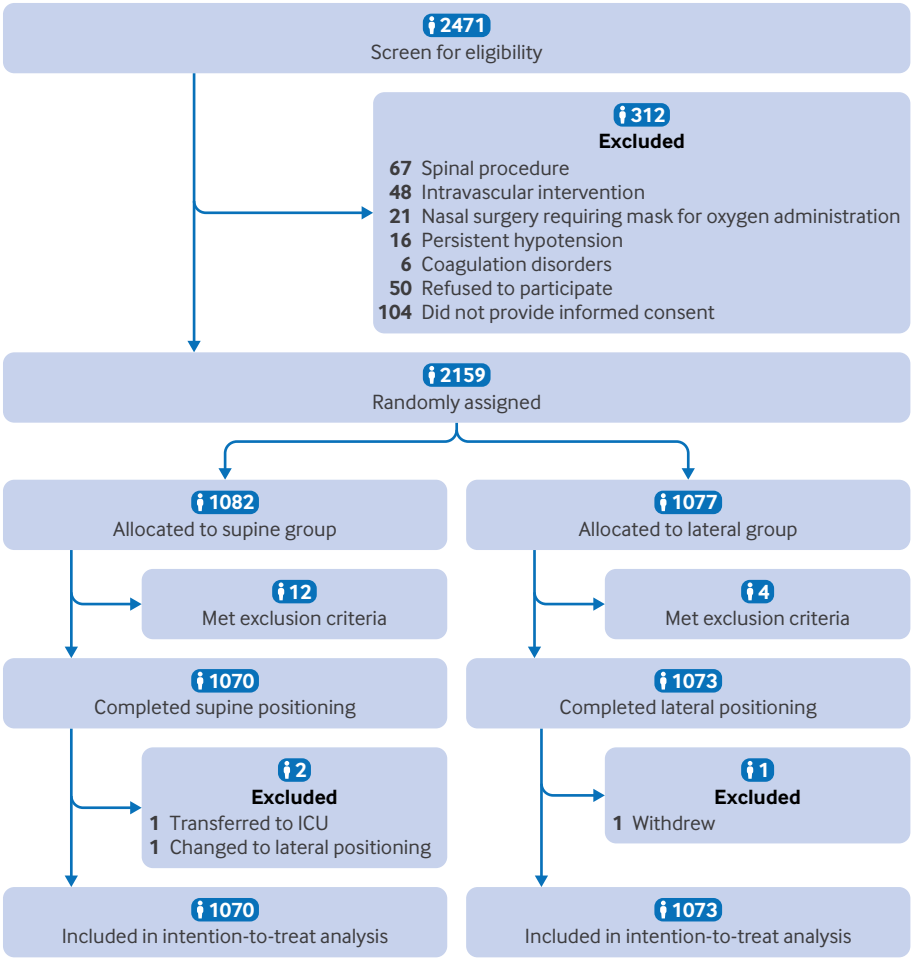


Fig 1 | Flow of participants through trial. ICU=intensive care unit

Table 1 | Baseline characteristics of sedated adults assigned to receive lateral or supine position. Values are number (percentage) unless stated otherwise

Characteristics	Total (n=2143)	Lateral group (n=1073)	Supine group (n=1070)
Mean (SD) age (years)	53.1 (14.9)	52.7 (14.9)	53.5 (15.0)
Sex:			
Women	1150 (53.7)	567 (52.8)	583 (54.5)
Men	993 (46.3)	506 (47.2)	487 (45.5)
Mean (SD) weight (kg)	63.5 (11.4)	63.8 (11.9)	63.2 (11.0)
Mean (SD) height (cm)	162.8 (8.2)	163.0 (8.2)	162.5 (8.1)
Mean (SD) body mass index	23.9 (3.4)	23.9 (3.5)	23.9 (3.4)
Mean (SD) neck circumference* (cm)	38.0 (3.7)	38.0 (3.7)	37.9 (3.7)
Current smoker	216 (10.1)	100 (9.3)	116 (10.8)
Alcohol misuse	149 (7.0)	66 (6.2)	83 (7.8)
ASA health status:			
1	114 (5.3)	65 (6.1)	49 (4.6)
2	1920 (89.6)	948 (88.4)	972 (90.8)
3	109 (5.1)	60 (5.6)	49 (4.6)
Mallampati class:			
1	781 (36.4)	384 (35.8)	397 (37.1)
2	1063 (49.6)	528 (49.2)	535 (50.0)
3	245 (11.4)	129 (12.0)	116 (10.8)
4	54 (2.5)	32 (3.0)	22 (2.1)
Comorbidities complicating airway	305 (14.2)	153 (14.3)	152 (14.2)
Thyromental distance ≤65 mm	81 (3.8)	37 (3.4)	44 (4.1)
Mouth opening ≤3.5 cm	14 (0.7)	8 (0.7)	6 (0.6)
Neck circumference ≥43 cm in men, 41 cm in women	227 (10.6)	117 (10.9)	110 (10.3)
Oxygen supplementation pre-enrolment:			
None	2107 (98.3)	1054 (98.2)	1053 (98.4)
Nasal cannula	31 (1.4)	16 (1.5)	15 (1.4)
Other	5 (0.2)	3 (0.3)	2 (0.2)
Gastric tube	21 (1.0)	10 (0.9)	11 (1.0)
Mean (SD) haemoglobin (g/L)	134.0 (17.6)	134.9 (17.6)	133.0 (17.5)
Chronic conditions	654 (30.5)	315 (29.4)	339 (31.7)
Hypertension	514 (24.0)	254 (23.7)	260 (24.3)
Diabetes	153 (7.1)	80 (7.5)	73 (6.8)
Cardiac disease	42 (2.0)	25 (2.3)	17 (1.6)
Stroke	27 (1.3)	12 (1.1)	15 (1.4)
COPD	30 (1.4)	12 (1.1)	18 (1.7)
Asthma	4 (0.2)	3 (0.3)	1 (0.1)
OSAS	4 (0.2)	2 (0.2)	2 (0.2)
Previous pulmonary infection	29 (1.4)	11 (1.0)	18 (1.7)
Vital signs:			
Mean (SD) SpO_2 (%)	99.1 (1.8)	99.1 (1.8)	99.1 (1.8)
Mean (SD) respiratory rate (breaths/min)	15.1 (3.5)	15.2 (3.5)	15.0 (3.6)
Mean (SD) mean arterial pressure (mm Hg)	99.2 (14.8)	99.1 (14.2)	99.3 (15.4)
Mean (SD) heart rate (beats/min)	79.1 (15.7)	78.6 (15.1)	79.5 (16.4)
Median (IQR) Ramsay sedation scale score†	3 (2-3)	3 (2-3)	3 (2-3)
Minimally invasive procedure‡	1273 (59.4)	660 (61.5)	613 (57.3)
Procedure category:			
Respiratory	161 (7.5)	80 (7.5)	81 (7.6)
Abdominal	983 (45.9)	516 (48.1)	467 (43.6)
Orthopaedic	334 (15.6)	150 (14.0)	184 (17.2)
Gynaecological	192 (9.0)	104 (9.7)	88 (8.2)
Otorhinolaryngology head and neck	274 (12.8)	133 (12.4)	141 (13.2)
Other	199 (9.3)	90 (8.4)	109 (10.2)
Admission category:			
Elective	1575 (73.5)	797 (74.3)	778 (72.7)
Scheduled	530 (24.7)	254 (23.7)	276 (25.8)
Emergency	38 (1.8)	22 (2.1)	16 (1.5)
Mean (SD) procedure duration (mins)	90.9 (65.0)	89.3 (62.3)	92.4 (67.6)
Mean (SD) opioid use, MME§ (mg)	130.9 (69.1)	129.3 (68.7)	132.5 (69.4)
Neuromuscular reversal agent	550 (25.7)	272 (25.3)	278 (26.0)
Median (IQR) fluid administration (mL)	1000 (600-1200)	1000 (600-1200)	1000 (600-1200)
Median (IQR) blood loss (mL)	10 (5-30)	10 (5-20)	10 (5-30)
Blood transfusion	57 (2.7)	28 (2.6)	29 (2.7)

ASA=American Society of Anesthesiologists; COPD=chronic obstructive pulmonary disease; IQR=interquartile range; MME=morphine milligram equivalents; OSAS=obstructive sleep apnoea syndrome; SD=standard deviation; SpO_2=pulse oximetry reading.
*Measured at upper margin of laryngeal prominence horizontally using inelastic tape.
†1=restless; 2=completely awake, quiet, and cooperative; 3=drowsy but responding to verbal commands; 4=lightly asleep but responding to touch or pain; 5=asleep but slowly responding to touch or pain; 6=deeply asleep and does not respond.
‡Procedures utilising endoscopic surgical techniques, such as thoracoscopy, laparoscopy, or arthroscopy.
§MME doses were estimated for comparison of opioid consumption.

Table 2 | Primary and secondary outcomes in sedated adults assigned to receive lateral or supine positioning. Values are number (percentage) unless stated otherwise

	Total (n=2143)	Lateral group (n=1073)	Supine group (n=1070)	Effect estimate (95% CI)*	P value	NNT (95% CI)†
Primary outcome						
Incidence of hypoxaemia‡:	219 (10.2)	58 (5.4)	161 (15.0)			
Risk ratio (95% CI)				0.36 (0.27 to 0.49)	<0.001	
Risk difference (95% CI) (%)				−9.15 (−11.65 to −6.65)	<0.001	11 (9 to 16)
Secondary outcomes						
Airway rescue:						
Yes	216 (10.1)	68 (6.3)	148 (13.8)			
No	1927 (89.9)	1005 (93.7)	922 (86.2)			
Risk ratio (95% CI)				0.46 (0.34 to 0.61)	<0.001	
Risk difference (95% CI) (%)				−6.96 (−9.38 to −4.55)	<0.001	15 (11 to 22)
Length of stay in PACU (mins):						
Mean (SD)	39.4 (18.5)	38.2 (18.0)	40.5 (19.0)	MD −2.22 (−3.63 to −0.80)	0.002	
Severe hypoxaemia§	59 (2.8)	8 (0.7)	51 (4.8)			
Risk ratio (95% CI)				0.16 (0.07 to 0.33)	<0.001	
Lowest SpO_2 (%):						
Mean (SD)	96.3 (4.2)	96.9 (3.1)	95.7 (5.1)	MD 1.20 (0.87 to 1.54)	<0.001	
Exploratory safety outcomes						
Tachycardia¶:	183 (8.5)	72 (6.7)	111 (10.4)			
Risk ratio (95% CI)				0.65 (0.48 to 0.87)	0.004	
Bradycardia**:	103 (4.8)	51 (4.8)	52 (4.9)			
Risk ratio (95% CI)				0.98 (0.67 to 1.45)	0.93	
Hypotension††:	20 (0.9)	11 (1.0)	9 (0.8)			
Risk ratio (95% CI)				1.26 (0.52 to 3.04)	0.61	
New onset arrhythmia:	17 (0.8)	9 (0.8)	8 (0.7)			
Risk ratio (95% CI)				1.12 (0.43 to 2.91)	0.81	
Cough:	210 (9.8)	102 (9.5)	108 (10.1)			
Risk ratio (95% CI)				0.94 (0.71 to 1.23)	0.64	
Nausea or vomiting:	41 (1.9)	18 (1.7)	23 (2.1)			
Risk ratio (95% CI)				0.78 (0.42 to 1.44)	0.42	
Reflux and aspiration	1 (0)	0 (0)	1 (0.1)	NA		

CI=confidence interval; MD=mean difference; NA=not applicable; NNT=number needed to treat; SD=standard deviation; PACU=post-anaesthesia care unit; SpO_2=pulse oximetry reading.
*Adjusted for study sites.
†Derived from absolute risk difference and given only for incidence of hypoxaemia and airway rescue.
‡Any occurrence of oxygen saturation (SpO_2) ≤90% lasting for at least five seconds.
§Any occurrence of oxygen saturation (SpO_2) ≤85% lasting for at least five seconds.
¶Heart rate >100 beats/min.
**Heart rate <50 beats/min.
††Systolic blood pressure <80 mm Hg.

Statistical analyses were conducted using STATA/MP version 16.0 (StataCorp).

Patient and public involvement

We appreciate the immense importance of patient and public involvement in research, but we did not have funding or resources available to support this activity. Thus, patients and members of the public were not directly involved in the design or conduct of the study owing to resource constraints.

Results

Patient characteristics and study intervention

Between July and November 2024 across the study sites, 2471 patients were screened for eligibility and 2159 were randomised equally to either lateral positioning or conventional supine positioning for 10 minutes. Among them, 16 patients (four in intervention arm and 12 in control arm) were later found to be ineligible (see supplementary table 7), and therefore 2143 patients were analysed: 1073 in the lateral group and 1070 in the supine group, all of whom were included in the intention-to-treat analysis. The recruited sample size was higher than originally estimated because study sites continued to recruit patients without knowledge of the number of patients recruited in the other study sites. We analysed all patients who were randomised. Three patients did not complete follow-up (fig 1).

The mean age of the patients was 53.1 years (SD 14.9) years, mean BMI was 23.9 (SD 3.4), and 53.7% (1150/2143) were women. A total of 43.4% (930/2143) of patients had a Ramsay sedation scale score of 2, 47.7% (1023/2143) had a score of 3, and the remainder had a score of 4 (8.9%, 190/2143). The mean respiratory rate was 15.1 (SD 3.5) breaths/min, without any ventilation support. Baseline characteristics were similar between the two groups (table 1, supplementary tables 8 and 9). The details of general anaesthesia and duration from sedation assessment to positioning were also similar between the two groups (see supplementary tables 10 and 11).

Primary outcomes

The incidence of hypoxaemia was significantly lower in the lateral group (SpO_2 ≤90% at least once) compared with supine group (5.4% (58/1073) *v* 15.0% (161/1070); adjusted risk ratio 0.36, 95% CI 0.27 to 0.49; P<0.001). The absolute adjusted risk difference

between the two groups was −9.15%, 95% CI −11.65% to −6.65%; P<0.001 (table 2 and supplementary figure 4). The NNT to prevent one episode of hypoxaemia using lateral instead of supine positioning was 11 (95% CI 9 to 16).

Secondary outcomes

Table 2, supplementary figure 4, and supplementary table 12 summarise the secondary outcomes. The airway rescue interventions—including increased oxygen flow, open airway manoeuvres such as jaw thrust and mask ventilation—were significantly lower in the lateral group compared with supine group (6.3% (68/1073) *v* 13.8% (148/1070); adjusted risk ratio 0.46, 95% CI 0.34 to 0.61; P<0.001). During the entire study period, no patient required the placement of oropharyngeal or nasopharyngeal airways or emergency tracheal intubation. The NNT to avoid any airway intervention (increased oxygen flow, jaw thrust, or mask ventilation) through lateral positioning was 15 (95% CI 11 to 22).

The mean length of stay in the post-anaesthesia care unit was shorter in the lateral group compared with supine group (38.2 *v* 40.5 minutes; absolute adjusted mean difference −2.22, 95% CI −3.63 to −0.80; P=0.002). The incidence of severe hypoxaemia was significantly lower in the lateral group compared with supine group (0.7% (8/1073) *v* 4.8% (51/1070); adjusted risk ratio 0.16, 95% CI 0.07 to 0.33; P<0.001) (table 2 and supplementary figure 4). Additionally, the lateral group had a higher mean lowest SpO_2 level compared with the supine group (96.9% *v* 95.7%; absolute adjusted mean difference 1.20%, 95% CI 0.87% to 1.54%; P<0.001) (table 2 and supplementary figure 5).

Oxygenation outcomes

Oxygen saturation <80% occurred in no patients in the lateral group compared with nine patients in the supine group. Oxygen saturation <70% occurred in no patients in the lateral group compared with three patients in the supine group. Mean decrease in oxygen saturation from baseline was 2.0% in the lateral group and 3.2% in the supine group. A decrease in oxygen saturation >3% occurred in 230 patients (21.4%) in the lateral group and 317 patients (29.6%) in the supine group. Supplementary table 13 describes the oxygenation outcomes.

Safety outcomes

Baseline vital signs were similar overall in both groups (table 1). During intervention, tachycardia was less common in the lateral group (6.7% (72/1073) *v* 10.4% (111/1070); adjusted risk ratio 0.65, 95% CI 0.48 to 0.87; P=0.004). Bradycardia, hypotension, arrhythmias, nausea or vomiting, and aspiration did not differ significantly between the two groups (P>0.05 for all comparisons) (table 2). Mean arterial pressure was lower in the lateral group compared with supine group. Patients in the lateral group had a lower heart rate immediately after positioning, compared with patients in the supine group. The mean respiratory rate of the two groups was similar across different time points (see supplementary figure 6).

Adverse respiratory events after positioning were documented. Only five patients (one in lateral group and four in supine group) experienced hypoxaemia post-intervention (see supplementary table 14).

Sensitivity analysis (composite outcome)

Sensitivity analysis of the composite outcome (either occurrence of hypoxaemia or any airway intervention) consistently showed a significantly lower incidence in the lateral group compared with supine group (77/1073 (7.2%) *v* 173/1070 (16.2%); adjusted risk ratio 0.45, 95% CI 0.34 to 0.58; P<0.001), reinforcing the robustness of the main results (see supplementary table 15).

Subgroup analyses

Figure 2 shows results of the subgroup analyses for the effect of lateral positioning on incidence of hypoxaemia in sedated patients. The median intraoperative opioid dose was established at 130 morphine milligram equivalents as a standard reference.[47] The interaction tests did not reach statistical significance in prespecified subgroups defined by age, BMI, smoking status, large neck circumference, Mallampati class, haemoglobin level, Ramsay sedation scale score, visual analogue scale pain score, use of neuromuscular reversal agent, procedure duration, procedure category, and intraoperative opioid dosages (fig 2), suggesting consistency in the effect across subgroups from a statistical perspective, even though individual subgroup results varied numerically. Lateral positioning was not favourable for the subgroups of patients with current smoking status, Mallampati class 3 or 4, visual analogue scale score ≥3, otorhinolaryngology head and neck procedure, and gynaecological procedure. A significant interaction by sex was noted (P=0.04 for interaction), with a stronger protective effect of lateral positioning in men; however, the lateral position remained beneficial in both men and women. The post hoc subgroup analyses further supported the primary findings, showing consistent reductions in incidence of hypoxaemia across varying analgesic types, postoperative opioid use in the post-anaesthesia care unit, and different types of anaesthetic (see supplementary figure 7).

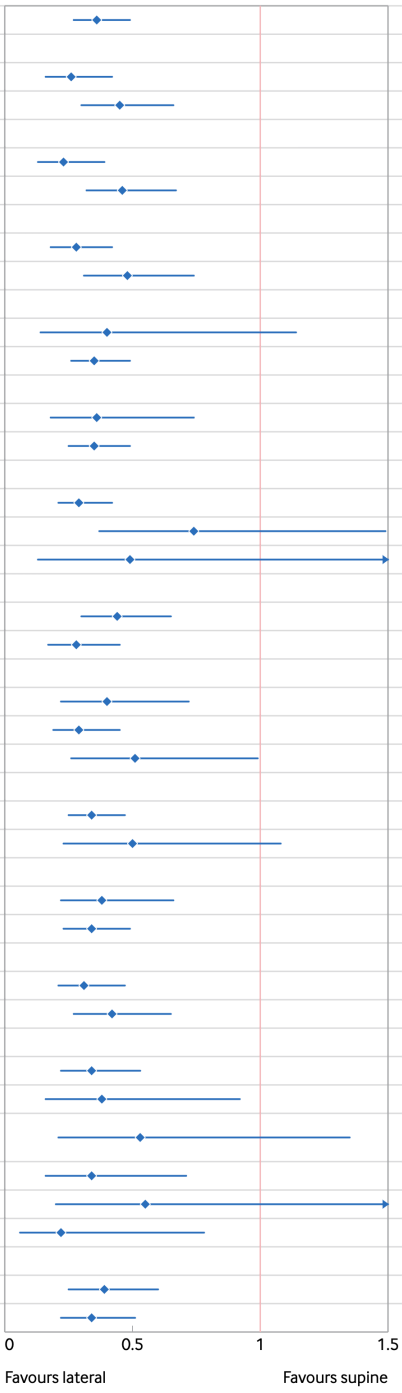
Discussion

In this large multicentre, randomised controlled trial including more than 2100 sedated adults in the post-anaesthesia care unit, we found that lateral positioning substantially decreased the incidence and severity of hypoxaemia compared with conventional supine positioning. The primary outcome—hypoxaemia within 10 minutes of positioning—occurred in only 5.4% of patients in the lateral group compared with 15.0% in the supine group (relative risk 0.36). This finding translated into a substantial absolute risk reduction of nearly 10%, exceeding our initial expectations. Lateral positioning also halved the need for airway rescue

Subgroup analyses of primary outcome

Effect of lateral versus supine positioning on incidence of hypoxaemia in sedated adults

Subgroup	No of events/No of participants (%) - lateral	No of events/No of participants (%) - supine	Risk ratio (95% CI)	P for interaction
Overall	58/1073 (5.4)	161/1070 (15.0)	0.36 (0.27 to 0.49)	
Age group (years)				0.09
<60	21/676 (3.1)	77/654 (11.8)	0.26 (0.16 to 0.42)	
≥60	37/397 (9.3)	84/416 (20.2)	0.45 (0.30 to 0.66)	
Sex				0.04
Men	16/506 (3.2)	67/487 (13.8)	0.23 (0.13 to 0.39)	
Women	42/567 (7.4)	94/583 (16.1)	0.46 (0.32 to 0.67)	
Body mass index				0.08
<25	27/714 (3.8)	101/732 (13.8)	0.28 (0.18 to 0.42)	
≥25	31/359 (8.6)	60/338 (17.8)	0.48 (0.31 to 0.74)	
Current smoker				0.76
Yes	5/100 (5.0)	14/116 (12.1)	0.40 (0.14 to 1.14)	
No	53/973 (5.4)	147/954 (15.4)	0.35 (0.26 to 0.49)	
Large neck circumference				0.81
Yes	11/117 (9.4)	26/110 (23.6)	0.36 (0.18 to 0.74)	
No	47/956 (4.9)	135/960 (14.1)	0.35 (0.25 to 0.49)	
Mallampati class				0.07
1 or 2	39/912 (4.3)	136/932 (14.6)	0.29 (0.21 to 0.42)	
3	15/129 (11.6)	19/116 (16.4)	0.74 (0.37 to 1.49)	
4	4/32 (12.5)	6/22 (27.3)	0.49 (0.13 to 1.83)	
Haemoglobin (g/L)				0.15
<135	36/508 (7.1)	91/568 (16.0)	0.44 (0.30 to 0.65)	
≥135	22/565 (3.9)	70/502 (13.9)	0.28 (0.17 to 0.45)	
Ramsay sedation scale score				0.3
2	16/472 (3.4)	40/458 (8.7)	0.40 (0.22 to 0.72)	
3	26/507 (5.1)	91/516 (17.6)	0.29 (0.19 to 0.45)	
4	16/94 (17.0)	30/96 (31.2)	0.51 (0.26 to 0.99)	
Visual analogue scale pain score				0.38
<3	48/928 (5.2)	141/930 (15.2)	0.34 (0.25 to 0.47)	
≥3	10/145 (6.9)	20/140 (14.3)	0.50 (0.23 to 1.08)	
Neuromuscular reversal agent				0.54
Yes	19/272 (7.0)	47/278 (16.9)	0.38 (0.22 to 0.66)	
No	39/801 (4.9)	114/792 (14.4)	0.34 (0.23 to 0.49)	
Procedure duration (mins)				0.36
<90	30/653 (4.6)	95/651 (14.6)	0.31 (0.21 to 0.47)	
≥90	28/420 (6.7)	66/419 (15.8)	0.42 (0.27 to 0.65)	
Procedure category				0.84
Abdominal	26/516 (5.0)	68/467 (14.6)	0.34 (0.22 to 0.53)	
Thoracic	7/80 (8.8)	18/81 (22.2)	0.38 (0.16 to 0.92)	
Otorhinolaryngology head and neck	7/133 (5.3)	14/141 (9.9)	0.53 (0.21 to 1.35)	
Orthopaedic	9/150 (6.0)	34/184 (18.5)	0.34 (0.16 to 0.71)	
Gynaecological	6/104 (5.8)	10/88 (11.4)	0.55 (0.20 to 1.53)	
Other	3/90 (3.3)	17/109 (15.6)	0.22 (0.06 to 0.78)	
MME received intraoperatively (mg)				0.63
<130	29/498 (5.8)	70/455 (15.4)	0.39 (0.25 to 0.60)	
≥130	29/575 (5.0)	91/615 (14.8)	0.34 (0.22 to 0.51)	



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MME=morphine milligram equivalents

Fig 2 | Subgroup analyses of primary outcome. Effect of lateral versus supine positioning on incidence of hypoxaemia in sedated adults. MME=morphine milligram equivalents. An interactive version of this graphic is available at https://public.flourish.studio/visualisation/24069525/

interventions (6.3% *v* 13.8%) and greatly decreased severe hypoxaemia events (SpO_2 ≤85%: 0.7% *v* 4.8%). Notably, these benefits were achieved without any compromise in safety—the incidence of adverse events was low and similar between groups, and tachycardia was even less frequent with lateral positioning. These findings underscore the potential of a simple, low cost, and effective intervention to improve respiratory outcomes in sedated patients. Such results merit further consideration of lateral positioning as a recommended respiratory management strategy for this population.

Comparison with other studies

Our results are both built upon and differ from those reported in previous studies. Earlier studies implemented in the post-anaesthesia care unit suggested a roughly 8% incidence of hypoxaemia in sedated patients managed in the supine position.[45 49] Accordingly, we hypothesised that lateral positioning might noticeably reduce this risk (to ~4%), based on evidence from procedures requiring sedation where lateral positioning reduced hypoxaemia by about 50% relative to supine positioning.[26] In our trial, incidence in the supine group was higher (15.0%), and in the lateral group (5.4%) it exceeded initial projections. This discrepancy is likely explained by the broader range of surgical patients and risk factors included in our study. We enrolled patients undergoing high risk procedures that are known independent contributors to respiratory complications—notably thoracic, lung, and major abdominal surgeries,[50 51] as well as emergency procedures.[52] In contrast, the literature informing our power calculation mostly examined elective, lower risk populations (excluding thoracic surgery, otorhinolaryngological surgery, and patients with difficult airways). As a result, the inclusion of higher risk surgeries and patients in our trial increased the overall incidence of hypoxaemia compared with previous reports. Importantly, despite the higher baseline risk, lateral positioning consistently showed benefit, reaffirming findings from smaller studies that found lateral positioning improved oxygenation during deep sedation.[23-27]

These results also complement existing knowledge on optimal positioning after extubation. Experts often encourage semi-recumbent or lateral positioning during emergence to increase functional residual capacity and reduce airway obstruction, especially in patients with obesity.[53 54] Our trial extends this evidence by rigorously comparing lateral positioning with supine positioning. The significant advantage observed with lateral positioning aligns with physiological studies showing that lateral postures can enlarge the upper airway and mitigate collapse during sedation.[23 24 27 55] Thus, our findings provide high level clinical evidence that validates longstanding clinical teaching: positioning matters in the prevention of immediate hypoxaemia in sedated patients.

Possible mechanisms

Our subgroup analyses provide further insights into the robustness and generalisability of lateral positioning. Firstly, the benefit of lateral positioning was consistent across different adult age groups, showing no significant interaction effect with age. The average age of participants was 53.1 years, which reflects a relatively younger patient population compared with typical western surgical cohorts, which generally report higher mean ages (about 56-59 years).[50-58] Older patients (≥60 years) experienced comparable reductions in hypoxaemia to younger individuals, reinforcing the clinical utility of lateral positioning irrespective of a patient's age. This finding is reassuring, as older patients typically represent a higher risk group owing to age related declines in respiratory reserve and airway protective reflexes.

Interestingly, although it might be anticipated that patients in the overweight category[59] (BMI ≥25) would gain greater benefit from lateral positioning, our results showed otherwise. Although lateral positioning still significantly reduced the rate of hypoxaemia among such patients, the relative magnitude of this benefit was not greater compared with individuals in lower weight categories. This somewhat counterintuitive observation may be explained by the multifactorial mechanisms underlying hypoxaemia in patients in the overweight category. These individuals (patients with higher BMI) often experience reduced lung volumes, decreased functional residual capacity, and increased airway collapsibility.[60 61] Such physiological challenges may limit the ability of lateral positioning alone to fully counteract airway obstruction and improve oxygenation, thus attenuating its relative effectiveness in this subgroup. This result is consistent when BMI is dichotomised at the threshold of 28, which is the average BMI of people in western countries.[58]

Considering the influence of factors,[12-14] we further analysed intraoperative drugs and sedation level as well as opioids administered in the post-anaesthesia care unit. No significant differences were found between the two study groups for type of intravenous anaesthetics, combination of anaesthetics, inhalational anaesthetics, analgesics, use of muscle relaxant antagonists, analgesic regimens, sedation level (Ramsay sedation scale), or opioid use in the post-anaesthesia care unit. Furthermore, post hoc analyses also showed consistent advantages. These results indicate that the benefits of lateral positioning observed in our main analyses remain significant irrespective of anaesthetic factors.

We also explored other subgroups, including procedure duration and type. Overall, lateral positioning provided consistent benefits across these varied clinical contexts, with no significant interactions detected. However, a notable finding was the absence of clear benefit among current smokers. This may relate to the small sample size or predominantly the characteristics of intrapulmonary disease in smokers, such as small airway disease and emphysema—conditions less responsive to positional interventions targeting upper airway obstruction.[62-65]

Finally, it might be hypothesised that patients with higher Mallampati scores (3 or 4), indicative

of increased anatomical risk for airway obstruction, would derive greater benefit from positional strategies. Contrary to this expectation, our data showed that patients with lower Mallampati scores (1 or 2) benefited significantly more. Anatomically, higher Mallampati scores reflect increased tongue volume and crowding of oropharyngeal structures, creating complex, multilevel obstruction patterns that may not respond effectively to simple positional adjustments.[66 67] Conversely, lower Mallampati scores are associated primarily with tongue base obstruction, a scenario more readily alleviated by lateral positioning.[61 68 69]

In summary, lateral positioning broadly reduced hypoxaemia in sedated adults across diverse subgroups. The nuanced findings, however, especially for obesity and Mallampati classification, underscore the importance of understanding the underlying mechanisms of airway obstruction to optimise positioning strategies in clinical practice.

Implication of findings

The findings of this trial have immediate and practical clinical implications. Lateral positioning is a simple intervention that can be implemented at minimal cost, requiring no specialised equipment beyond staff training and diligence, and thus it is feasible even in resource limited settings.[70] With a NNT of only 11 to prevent one hypoxaemia event and 15 to avoid an airway intervention, the routine adoption of lateral positioning could substantially reduce airway complications. This reduction in hypoxaemia might also decrease downstream events such as cardiac stress or unplanned intensive care admissions—outcomes warranting further exploration.

Strengths and limitations of this study

The strengths of this study enhance confidence in its clinical applicability. Foremost, the trial was large (>2100 patients) and multicentre, spanning 14 hospitals, which improves the generalisability of the results. We intentionally selected participants to ensure a heterogeneous patient population, including a wide variety of surgical types and patient characteristics reflecting real world case mix in the post-anaesthesia care unit. The consistency of the benefit across these diverse subgroups shows the intervention's robustness and broad relevance. Additionally, the study was conducted under routine care conditions (eg, standard monitoring, usual oxygen supplementation), improving its external validity. The intervention itself—turning a patient into the lateral position—is inherently pragmatic; by showing it is effective under everyday clinical circumstances increased the likelihood that our findings can be translated directly into practice. Another notable strength is that all outcomes were analysed on an intention-to-treat basis across multiple centres with stratified randomisation, which together ensured a balanced comparison and minimised bias. Finally, this large randomised controlled trial to compare lateral positioning with supine positioning in post-anaesthesia care fills a critical knowledge gap and provides a high level of evidence to support what has largely been a commonsense but unproven practice.

This trial has several limitations. Firstly, the open label design could introduce observer or performance bias. Although independent consultant anaesthetists made key clinical decisions, including discharge of patients, some residual bias remains possible. However, the primary endpoint of hypoxaemia was objectively recorded by pulse oximetry, mitigating this risk.

Secondly, our observation window was the initial 10 minutes after positioning in the early period of post-extubation. This period was chosen because it carries the highest risk of hypoxaemia events due to residual anaesthesia effects, and indeed previous studies indicated that most desaturation episodes occurred in those initial minutes.[71 72] Focusing on this critical window allowed us to capture the intervention's immediate impact, but it also meant we could not ascertain whether lateral positioning confers benefits (or risks) beyond this timeframe. We did note that hypoxaemia diminished after 10 minutes in both groups (only ~0.3% of patients had any episode beyond the intervention period), suggesting that the lack of later observation may not have missed important events in the post-anaesthesia care unit. However, we cannot ascertain long term respiratory outcomes, such as later pulmonary complications. Future studies with extended follow-up could clarify these longer term effects.

Thirdly, compared with typical surgical populations in western countries, our patient population was younger and with a lower average BMI, potentially limiting generalisability.[50 56-58] Nevertheless, subgroup analyses confirmed consistent benefits across older and overweight subpopulations, partially mitigating these concerns. Further trials in higher BMI or elderly cohorts would strengthen external validity.

Fourthly, although our trial found that lateral (90°) positioning significantly reduces hypoxaemia compared with supine (0°) positioning, we did not include a semi-recumbent (head elevated 30°) comparator. Many centres routinely position sedated patients with the head of the bed elevated to about 30°, which increases functional residual capacity but does not fully address gravitational collapse of the tongue base.[16 21 71] In the current trial our control arm remained in the supine position, therefore we could not definitively determine whether lateral positioning confers an advantage over semi-recumbent positioning. Future studies should include a semi-recumbent group to establish whether lateral positioning provides incremental benefit beyond that achieved by head elevation alone.

Fifthly, physiological measurements, including lateral side selection, utilised pragmatic, non-standardised limb selections for placement of the pulse oximetry probe and different pulse oximeter devices[73] across centres. This could introduce minor variability in measurements, or bias. However, randomisation was stratified by study centre to minimise such

effects, reflecting real world practice and enhancing generalisability.

Lastly, granular details on intraoperative ventilation (such as positive end expiratory pressure levels and reversal of neuromuscular blockade) were not systematically recorded, limiting detailed analysis of intraoperative influences on oxygenation. Our findings apply specifically to modest supplemental oxygen (2 L/min through nasal cannula) and extubation practices in the post-anaesthesia care unit.

Despite these limitations, our study provides compelling, robust evidence supporting lateral positioning to significantly reduce hypoxaemia in sedated adults, emphasising its strong clinical utility, simplicity, and safety for widespread implementation.

Conclusion

The findings of this multicentre, randomised clinical trial suggest that lateral positioning reduces the incidence and severity of hypoxaemia and the need for airway rescue interventions without compromising patient safety in sedated adults in the post-anaesthesia care unit. As a simple, low cost, and easily implementable intervention, lateral positioning represents a promising respiratory management strategy for preventing hypoxaemia in sedated adults, which could offer advantages in remote or resource constrained clinical settings. Further validation in more diverse populations—such as older patients or those with morbid obesity—is advisable before widespread recommendation.

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Contributors: HY and L-HC contributed equally to the study and are joint first authors. NI and X-MF contributed equally to the work as the senior supervising authors. HY, L-HC, G-HX, P-LW, HL, S-JW, S-WS, PC, and X-MF conceived and designed the study. HY, L-HC, G-HX, Y-JH, YL, Q-HW, Z-XX, M-YT, B-DW, H-YH, JY, TY, H-YW, YW, Z-JY, X-FB, M-CW, L-YC, X-XW, X-BZ, C-SH, JW, Y-PL, F-QL,WZ, C-GW, HC, W-JL, JL, Y-QW, R-RL, DW, L-QH, LS, JZ, KW, XP, RZ, Q-QY, and P-LW executed the study. HY, L-HC, Y-JH, YL, Q-HW, Z-XX, M-YT, and B-DW contributed to the collection of data. HY, L-HC, NI, and X-MF conducted the data analyses. HY, L-HC, G-HX, LS, NI, and X-MF contributed to the acquisition, analyses, or interpretation of data. HY, G-HX, and X-MF obtained the funding. X-MF provided administrative, technical, or material support. NI and X-MF supervised the study. HY, L-HC, G-HX, NI, and X-MF drafted the manuscript. All authors critically reviewed the manuscript for important intellectual content. HY, NI, and X-MF had full access to all the data. HY and X-MF take responsibility for the integrity of the data. X-MF is the guarantor. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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Ethical approval: This trial was approved by the institutional review board of The First Affiliated Hospital, School of Medicine, Zhejiang University (approval No 2024-043) and other participating centres.

Data sharing: The codes used to analyse the data can be found in the supplementary files and GitHub (https://github.com/Huiye272/2025-hypoxaemia). The data underlying the findings of this paper are available in Synapse (https://doi.org/10.7303/syn66534226). If you encounter problems accessing the data, please contact the corresponding author. Access is governed by a data use agreement to ensure appropriate use and privacy protection. For additional inquiries about data use, potential collaborations, or related projects, interested researchers are encouraged to contact the principal investigator of the study.

Transparency: The lead author (X-MF) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as originally planned have been explained.

Dissemination to participants and related patient and public communities: As personal identifying information was removed from the study dataset, it is not possible to send the results of this study to participants. We will, however, work with patient advocacy groups and public media channels to disseminate our findings with accessible lay summary and blogs. Study findings will be shared with clinicians and patients through national and international conferences and press releases.

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Supplementary information: Supplementary appendix