

RESEARCH

Open Access



The impact of semi-upright position on severity of sleep disordered breathing in patients with obstructive sleep apnea: a two-arm, prospective, randomized controlled trial

Gincy A. Lukachan¹, Azadeh Yadollahi², Dennis Auckley³, Bojan Gavrilovic², John Matelski⁴, Frances Chung^{5†} and Mandeep Singh^{5*†}

Abstract

Background The severity of sleep-disordered breathing is known to worsen postoperatively and is associated with increased cardio-pulmonary complications and increased resource implications. In the general population, the semi-upright position has been used in the management of OSA. We hypothesized that the use of a semi-upright position versus a non-elevated position will reduce postoperative worsening of OSA in patients undergoing non-cardiac surgeries.

Methods This study was conducted as a prospective randomized controlled trial of perioperative patients, undergoing elective non-cardiac inpatient surgeries. Patients underwent a preoperative sleep study using a portable polysomnography device. Patients with OSA (apnea hypopnea index (AHI) > 5 events/hr), underwent a sleep study on postoperative night 2 (N2) after being randomized into an intervention group (Group I): semi-upright position (30 to 45 degrees incline), or a control group (Group C) (zero degrees from horizontal). The primary outcome was postoperative AHI on N2. The secondary outcomes were obstructive apnea index (OAI), central apnea index (CAI), hypopnea index (HI), obstructive apnea hypopnea index (OAHI) and oxygenation parameters.

Results Thirty-five patients were included. Twenty-one patients were assigned to the Group 1 (females-14 (67%); mean age 65 ± 12) while there were fourteen patients in the Group C (females-5 (36%); mean age 63 ± 10). The semi-upright position resulted in a significant reduction in OAI in the intervention arm (Group C vs Group I postop AHI: 16.6 ± 19.0 vs 8.6 ± 11.2 events/hr; overall $p = 0.01$), but there were no significant differences in the overall AHI or other parameters between the two groups. Subgroup analysis of patients with "supine related OSA" revealed a decreasing trend in postoperative AHI with semi-upright position, but the sample size was too small to evaluate statistical significance.

[†]Frances Chung and Mandeep Singh are shared senior authorship for this study.

*Correspondence:

Mandeep Singh

mandeep.singh@uhn.ca

Full list of author information is available at the end of the article



Conclusion In patients with newly diagnosed OSA, the semi-upright position resulted in improvement in obstructive apnea, but not the overall AHI.

Trial registration This trial was retrospectively registered in clinicaltrials.gov NCT02152202 on 02/06/2014.

Keywords Obstructive sleep apnea, Supine-related OSA, Surgery, Elevated position, Positional therapy

Introduction

Obstructive sleep apnea (OSA) is a common sleep-related breathing disorder, associated with increased morbidity and mortality in the general and surgical population [1, 2] in the perioperative period [3]. It is an independent risk-factor for post-operative cardiac and respiratory complications [4–7] resulting in increased utilization of health care resources [8].

The screening and treatment of OSA is found to be cost effective on the lifetime horizon [9]. According to the current guidelines adult patients at risk of OSA should be screened preoperatively using validated tools such as STOP-Bang, P-SAP, Berlin, and ASA Check List [10]. The American Society of Anesthesiology (ASA) practice guidelines on the perioperative management of OSA advise to consider the initiation of continuous positive airway pressure (CPAP) therapy preoperatively in patients with newly detected severe OSA. [11], Despite improvement in OSA severity and oxygenation with CPAP, poor patient compliance has been a hurdle to their use in the perioperative period [12, 13]. Other alternatives to OSA treatment, such as weight reduction, [14] custom-made orthodontic appliances [15], and surgery (orthodontic surgery, [16] uvulopalatopharyngoplasty, [17] tonsillectomy, [18] or bariatric surgery [19]) are not feasible in the preoperative period. There is a need for alternative approaches for the management of OSA in surgical patients.

Positional therapy could be a useful intervention in surgical patients with OSA in the perioperative period [20]. This option may be more feasible in the postoperative setting as it is cost-effective, easy to administer, and can be adjusted to allow patient comfort. In the general population, sleeping in the non-supine and elevated posture was found to be effective in reducing OSA severity [21–23]. The utility of positional therapy may be greater in patients with supine-related OSA. Supine-related OSA is defined as Apnea–hypopnea index (AHI) > 5 events/hr, and where the supine AHI was more than twice the AHI of the non-supine AHI, and the non-supine AHI was less than 5 events/hr [24, 25].

The American Society of Anesthesiology practice guidelines on the perioperative management of OSA recognized that positional therapy may improve the AHI in patients with OSA, but acknowledged that the literature was “insufficient to evaluate the effects of

positioning adult OSA patients in the postoperative setting” [11]. We hypothesized that the use of a semi-upright position versus a supine position will prevent postoperative worsening of OSA in patients undergoing non-cardiac surgeries. The objective of the study was to determine whether a semi-upright versus supine position while asleep helps decrease the postoperative worsening of AHI in surgical patients with newly diagnosed OSA. The secondary objective was to study the impact of the semi-upright position in a subgroup of patients with supine-related OSA.

Methods

Study design

This was a two-arm, prospective, randomized controlled, proof of concept trial. The intervention was patient positioning in a semi-upright position (Group I: intervention, head-end elevation 30 to 45 degrees from horizontal), compared to supine position (Group C: control).

Study setting

This study was conducted at Toronto Western Hospital and Mount Sinai Hospital in Toronto, over a period of seven months. Institutional Review Board approval was obtained from both hospitals prior to start of this study (University Health Network 11-0056AE and Mount Sinai Hospital 11–0021-E). This trial was registered at www.clinicaltrials.gov (NCT02152202).

The inclusion criteria of patients were adult patients, American Society of Anesthesiologists (ASA) physical status I to IV, undergoing elective inpatient non-cardiac surgery with newly diagnosed OSA. The exclusion criteria were: patients with OSA on treatment (continuous positive airway pressure (CPAP), oral appliance, or previous OSA surgery); known cervical, shoulder, spine abnormalities, and/or chronic pain predisposing to difficulty in maintaining a sitting position and specific types of surgery, such as hip or spine, where a sitting position would be contraindicated postoperatively. Patients were screened by using the STOP-Bang questionnaire [26]. Patients identified as high risk of OSA (STOP-Bang score of three or greater) were consented to undergo a home portable polysomnography (PSG) and OSA status was confirmed by an AHI over 5 events per hour.

Patient recruitment, intervention and follow-up

Portable PSG was performed using a 10-channel portable PSG device (Embletta X100; Embla, Broomfield, CO). The PSG was obtained preoperatively (preop) at home and on postoperatively (postop) on N 2 [27]. The Embletta X100 is a level 2 diagnostic tool for OSA and has been validated against laboratory PSG [27]. The PSG recording montage comprised two electroencephalographic channels (C3 and C4), left or right electro-oculogram, chin muscle electromyogram, nasal cannula (pressure), thoracic and abdominal respiratory effort bands, body-position sensor, and pulse oximetry. At bedtime, the portable PSG device was connected to the patient by a PSG technician at their home. Patients were taught how to disconnect the device, which was picked up by the same sleep technician the following morning. The portable PSG recording was scored by a certified PSG technologist who was supervised by a sleep physician.

Apneas were defined as a reduction in airflow from intranasal pressure of at least 90% for 10 s or longer, and hypopneas as reduction in flow of at least 30% for 10 s or longer, associated with $\geq 4\%$ oxygen desaturation [28]. Apneas and hypopneas were classified as either obstructive (presence of breathing effort) or central (absence of breathing effort) events. Mixed apneas were classified for events that began as central for at least 10 s and ended as obstructive, with a minimum of three obstructive efforts. AHI was the average number of apnea and hypopnea episodes per hour of recording. Apnea index was calculated as the average number of apnea episodes per hour. Hypopnea index was the average number of hypopnea episodes per hour. The secondary outcomes were obstructive apnea index (OAI), calculated as the total number of obstructive apneas divided total sleep time (TST); central apnea index (CAI) calculated as the total number of central apneas per hour; obstructive apnea hypopnea index (OAHI), calculated as the total number of obstructive apneas and hypopneas per hour; oxygen desaturation index (ODI), number of events with oxygen desaturation below 4% threshold per hour, and CT90, cumulative percentage of sleep duration with oxygen desaturation less than 90%.

Randomization and allocation concealment

Patients with OSA (defined as AHI > 5 events/hr), were randomized into two groups: Control or Intervention groups (computer generated blocks of 8) by the research analyst, who was not involved in group allocation or data collection during the study. Group allocation was concealed using sealed, opaque envelopes, and patients were assigned to their group following surgery. In the Control group (Group C), there was no bed elevation, and

patients were positioned at bedtime with no head elevation or bed angle to zero degrees from the horizontal. In the Intervention group (Group I), patients were positioned at bedtime in a semi-upright position with bed elevated to 30 to 45 degrees from horizontal. The bed angle was measured by a research assistant using an in-built bed angle monitor, or a goniometer, wherever applicable. The bed angle measurements were performed at night and in the morning to monitor compliance with the allocated bed position. Patients had the option to request changing the bed angle to facilitate recovery from surgery in view of pain and discomfort.

Perioperative anesthetic care and postoperative pain management

A standardized balanced anesthetic technique was used in all patients per routine care. In general anesthesia (GA), patients received an induction dose of propofol, opioid (fentanyl and/or hydromorphone), an inhalational agent (sevoflurane or desflurane), and a muscle relaxant (rocuronium). The muscle relaxant was reversed with neostigmine and atropine. In regional anesthesia (RA), patients received spinal anesthetic and sedation using midazolam, fentanyl and a propofol infusion (20–150 mcg/kg/min). Use of intrathecal opioid (100 mcg preservative free morphine) was at the discretion of the anesthesiologist. Both groups received intravenous or oral narcotics in the postoperative period guided by the Acute Pain Service team, as per our institutional standard of care. Pain was evaluated on a score of 0–10, with 0 as no pain and 10 as the most excruciating pain. Intravenous morphine by patient-controlled analgesia was initiated when the verbal pain score was 4 or higher. The research assistant visited patients daily to assist them with application and removal of the portable PSG, collect data, and document adverse events during the hospital stay.

Target sample size

The primary outcome of our study was AHI on postop N2. There was no previous research from the perioperative setting evaluating the impact of body positioning. Previous studies in the general population found that the mean change in AHI between the upright position (6 ± 12 events/hr), and no head elevation (29 ± 6 events/hr), respectively [23, 29]. The original sample size calculated in the protocol was 28 in each arm calculated after taking a minimal clinically significant difference (MCSD) of an effect size (change in AHI) of at least 10 events per hour from baseline, a power of 0.9 and a standard deviation of 10, after adjusting for an estimated drop-out, and loss of follow up to a total of 20%. However, the study was terminated early due to concerns with funding, and

a final sample size of 32 patients was obtained, which had sufficient power of 0.8, with type 1 error of 0.05. It was decided to proceed with analysis of the data by the senior authors.

Statistical analysis

Analyses were performed using the SAS 9.2 statistical software for Windows (SAS Institute, Cary, NC) or R (version 3.1.1) [30]. The analysis was blinded to allocation until the completion of data accrual period. Because of patient preference and deviation from assignment of intervention, a per-protocol analysis was performed for this study, where patients were analyzed based on the bed angle monitor reading noted in the morning following their PSG to show no deviation from protocol. An intention-to-treat analysis was performed as sensitivity analysis, meaning that all participants were analyzed in the group to which they were randomized.

Baseline demographic variables are summarized for the entire study population and by treatment group using standard bivariate methods, as implemented in R package tableone [31]. For each variable we include

a standardized mean difference, along with a p-value against the null hypothesis of equality between groups.

Continuous variables were compared using two-tailed, paired t-tests for variables with normally distributed data and Wilcoxon signed rank test for variables with non-normally distributed data.

Pre-defined linear regression was performed for the primary and secondary outcomes, with preop AHI and supine-related OSA as covariates. Supine-related OSA was defined as AHI > 5 events/hr, and where the supine AHI was more than twice the AHI of the non-supine AHI, and the non-supine AHI was less than 5 events/hr [24]. A two-sided p value < 0.05 was considered significant and controlled for repeated observations, wherever applicable.

Results

Study population

Patient recruitment and flow is summarized in Fig. 1, based on the CONSORT recommendations. A total of 635 patients were screened preoperatively, with 164 patients giving consent, of which 135 patients completed

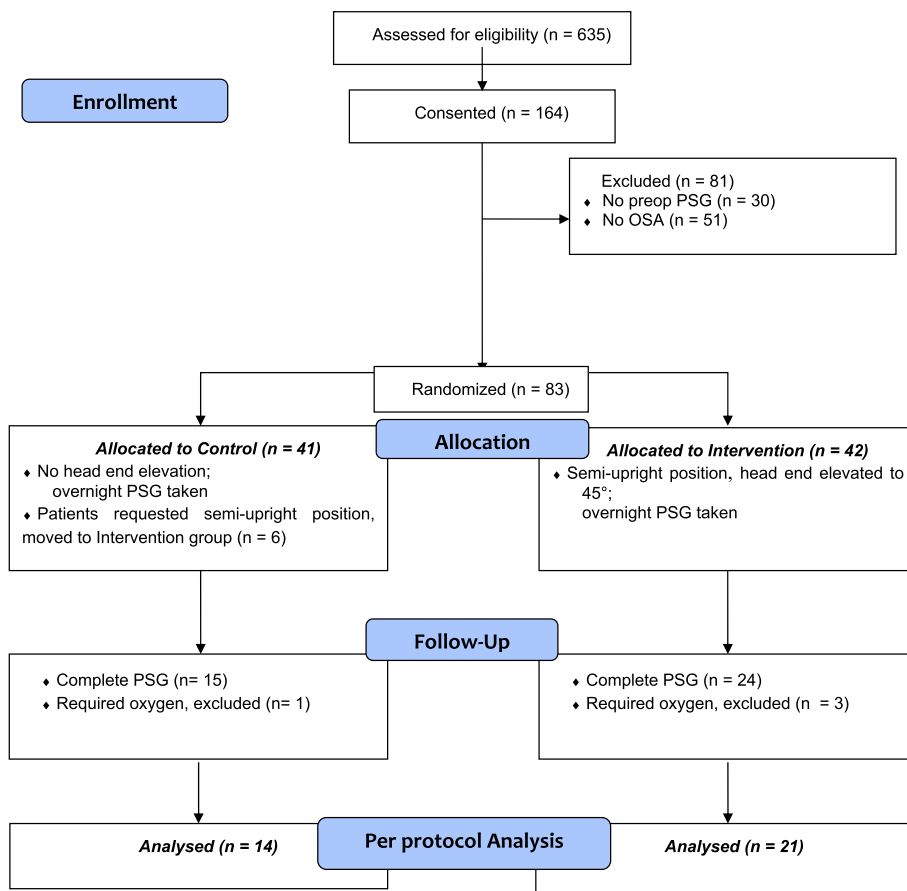


Fig. 1 Participant flow in the study

home PSG study. Eighty-three patients with OSA (AHI > 5 events/hr) were randomized, Group C: 41 and Group I: 42. During the study, six patients in Group C requested to change position to semi-upright position and were allocated to Group I. Complete postoperative N2 PSG data were obtained from 15 and 24 patients for Group C and I, respectively. This was partly because of patient refusal to undergo the PSG postoperatively while recovering from surgery, primarily due to postoperative pain and discomfort. Four patients were excluded as they required oxygen supplementation. Per protocol analysis was done for 14 patients in Group C and 21 patients in Group I. The baseline characteristics for PP and ITT analysis are presented in Table 1, and Supplementary table 1, respectively. While randomization led to a more balanced distribution of baseline demographic variables, deviation of protocol resulted in disturbances for the PP analysis where control group had higher neck circumference and lower OAI and CT 90 values (SMD > 0.8). The preop PSG (Table 1) data showed no difference in AHI, OAHl, HI between Group C and Group I. The baseline OAI was significantly higher (11.7 ± 9.2 vs. 6.0 ± 3.6 events per hour; $p=0.01$) while CAI was significantly lower (0.7 ± 1.4 vs. 3.7 ± 9.5 ; $p=0.04$) in Group I than Group C. The CT90 was significantly higher (3.8 (0.4–6.1) % vs. 0.7 (0.1–1.2) %; $p=0.04$) and the lowest SaO₂ was significantly lower ($79.1 \pm 6.1\%$ vs. $83.2 \pm 5.0\%$; $p=0.04$) in Group I vs Group C.

Primary outcome

Comparing postop N2 vs preop baseline, the AHI increased in Group C while it decreased in Group I (Table 2). The differences were not significant within the groups or between groups. (Group C: postop AHI vs preop AHI: 28.4 ± 28.1 vs 18.1 ± 13.3 events/hr, $p=0.33$; Group I: postop AHI vs preop AHI: 20.8 ± 23.8 vs 21.4 ± 13.1 ; $p=0.36$); overall $p=0.15$. (Fig. 2A).

Comparing postop N2 vs preop parameters, the changes in OAI within the two groups were not significant but there was an overall significant change between the two groups (Group C vs Group I: postop AHI 16.6 ± 19.0 vs 8.6 ± 11.2 events/hr); (overall $p=0.01$) (Fig. 2B). There were no significant differences in CAI, HI, OAHl within the two groups and between groups (Table 2).

Among the oxygenation parameters, CT90 (Supplementary Fig. 3) significantly increased postoperatively in both groups (Group C: postop CT90 vs preop: $4.4 \pm 4.9\%$ vs $1.3 \pm 2.0\%$, $p=0.003$; Group I: postop CT90 vs preop: $15.7 \pm 19.8\%$ vs $4.4 \pm 4.9\%$; $p=0.04$), and the average SaO₂ were significantly decreased in the postoperative period for both groups (Group C: postop average SaO₂ vs preop: $90.0 \pm 3.6\%$ vs $93.4 \pm 1.3\%$, $p=0.01$; Group I:

postop average SaO₂ vs preop: $90.3 \pm 3.8\%$ vs $93.1 \pm 2.4\%$, $p=0.002$). However, between group comparison did not show a significant difference (Table 2).

The other parameters were not significantly different from preop to postop and between the two groups (Table 2).

Subgroup analysis

The impact of body position was examined in patients classified as “supine-related OSA” ($n=8$; Group C: 5 patients, and Group I: 3 patients). There was greater reduction in mean AHI in Group I (postop AHI vs preop AHI: 6.0 ± 3.0 vs 24.3 ± 13.9 events/hr) than in Group C (Fig. 3), but the sample size was too small to evaluate statistical significance.

Discussion

This is a novel study in the perioperative setting to evaluate the efficacy of semi-upright position postoperatively for management of newly diagnosed OSA. We found that it is feasible to institute positional therapy in the form of semi-upright position in the postoperative period for OSA patients. The elevated position resulted in a significant reduction in OAI by eight events per hour, but not the AHI, CAI, HI, and OAHl. The lack of positive results in AHI may be because the patients in the intervention group had significantly worse OAI, lower SaO₂, and higher CT 90 preoperatively. Nevertheless, in the surgical patients with supine-related OSA, we were able to demonstrate the effectiveness of semi-upright position as the mean AHI decreased by 18 events per hour.

Although positive airway pressure (PAP) is the mainstay of treatment for moderate to severe OSA, perioperative adherence has been poor as studies have demonstrated only 34% CPAP adherence [13] and 45% auto-titrated CPAP adherence [12] in patients with newly diagnosed OSA treated with PAP therapy before surgery. This suggests a need for alternative therapies for these patients. We found that positional therapy is a feasible alternative treatment option for OSA patients in the perioperative setting especially in those with supine related OSA. These findings could be explained by the close association of upper airway collapsibility with body, head, and neck positioning [24].

Previous work has suggested that the semi-upright position significantly enlarges the upper airway dimensions [32, 33]. The mean upper airway volume was greater with 44° head elevation compared to supine position [33]. Mild elevations of the head of the bed by 7.5° were associated with reductions in the AHI and improvements in oxygen parameters [34]. In a randomized crossover study of 30 postpartum women with OSA in the post-anesthesia care unit, 45° elevation

Table 1 Patient demographics across the two groups (Per-protocol)

	Control (n = 14)	Intervention (n = 21)	P value	Standardized Mean Difference
Age (years)	63 ± 10	65 ± 12	0.60	0.188
BMI (kg/m ²)	32.8 ± 4	35.2 ± 7	0.26	0.420
Neck Circumference (cm)	43.3 ± 3	41.0 ± 3	0.04	0.752
Gender F/M	5/9	14/7	0.09	0.651
STOP-Bang score	4.5 ± 1	4.5 ± 1	0.95	0.020
Co-morbidity				
Hypertension	7	12	0.74	0.144
Gastroesophageal reflux	2	7	0.26	0.459
Diabetes Mellitus	1	6	0.20	0.583
Smoker	2	2	1.00	0.147
Asthma	1	3	0.64	0.232
COPD	1	1	1.00	0.101
CAD	3	0	0.06	0.739
Type of surgery			0.65	0.707
Orthopedic	8	12		
General	5	6		
Gynecology	0	2		
Urology	1	0		
Type of Anesthesia			1.00	0.048
General	7	10		
Spinal	7	11		
ASA Status			0.16	0.589
II	8	7		
III	5	14		
Total amount of opioids (in mg IV morphine equivalents)				
1 st 24 h	10.3 [5.3—19.8]	11.0 [5.—20]	0.84	0.080
1 st 48 h	21.4 [13.3—44.4]	33.4 [15.0—55.0]	0.45	0.186
1 st 72 h	25.8 [14.2—60.50]	41.4 [25.0—81.5]	0.29	0.259
Preoperative sleep study data between the two groups				
AHI	18.1 ± 13.3	21.4 ± 13.1	0.48	0.246
OAI	6.1 ± 3.7	11.7 ± 9.2	0.04	0.807
OAHl	14.6 ± 7.2	20.7 ± 12.6	0.11	0.593
CAI	3.7 ± 9.5	0.7 ± 1.4	0.16	0.444
HI	8.6 ± 5.2	9.0 ± 7.3	0.84	0.071
ODI	15.5 [13.5—23.7]	17.9 [12.1—39.1]	0.57	0.281
CT90	0.7 [0.1—1.2]	3.8 [0.4—6.1]	0.04	0.804
Average SaO ₂	93.4 ± 1.27	93.1 ± 2.4	0.71	0.137
Lowest SaO ₂	83.2 ± 5.0	79.1 ± 6.1	0.04	0.748

Data are expressed as mean (SD) or median (interquartile range IQR) where appropriate. Standardized Mean Difference was calculated using R package tableone

BMI body mass index, *COPD* chronic obstructive pulmonary disease, *CAD* coronary artery disease, *OR* operating room, *h* hours, *AHI* Apnea–Hypopnea Index, Apnea index average number of apnea episodes per hour, *Arousal Index* number of arousals × 60 / Total sleep time, *CAI* Central Apnea Index: total number of central apneas per hour, *CT90* cumulative percentage of Total sleep time with oxygen desaturation below 90%, *HI* Hypopnea index, average number of hypopnea episodes per hour, *OAHl* Obstructive Apnea Hypopnea Index, total number of obstructive apneas and hypopneas per hour, *OAI* Obstructive Apnea Index: total number of obstructive apneas divided by Total sleep time, *ODI* Oxygen Desaturation Index, number of events with oxygen desaturation below 4% threshold in one hour, *REM%* Time spent in rapid eye movement stage of sleep, *SaO₂* saturation of oxygen in hemoglobin

of the upper body caused a significant reduction in AHI compared to non-elevated position [35]. A recently published randomized crossover trial among

perioperative patients with moderate to severe OSA, compared high-flow nasal cannula (20 l/min with 40% oxygen concentration) with or without 30-degree

Table 2 Postoperative sleep-related outcomes in both groups

Variable	Control (n = 14)			Intervention (n = 21)			Between group comparison (ANCOVA) p-value
	Pre-op	Post-op	p-value	Pre-op	Post-op	p-value	
AHI	18.1 ± 13.3	28.4 ± 28.1	0.33	21.4 ± 13.1	20.8 ± 23.8	0.36	0.15
OAI	6.0 ± 3.6	16.6 ± 19.0	0.09	11.7 ± 9.2	8.6 ± 11.2	0.13	0.01*
CAI	3.7 ± 9.5	3.6 ± 4.9	0.35	0.7 ± 1.4	1.3 ± 3.5	0.79	0.11
HI	8.6 ± 5.2	8.6 ± 8.4	0.9	9.0 ± 7.3	11.3 ± 11.4	0.34	0.49
OAHl	14.6 ± 7.2	25.2 ± 24.2	0.14	20.7 ± 12.6	19.8 ± 21.5	0.54	0.09
ODI	19.3 ± 12.5	26.2 ± 24.7	0.39	23.1 ± 14.3	26.1 ± 27.1	0.66	0.55
CT90	1.3 ± 2.0	28.1 ± 35.4	0.003*	4.4 ± 4.9	15.7 ± 19.8	0.04*	0.11
Average SaO2	93.4 ± 1.3	90.0 ± 3.6	0.01*	93.1 ± 2.4	90.3 ± 3.8	0.002*	0.40
Lowest SaO2	83.2 ± 5.0	75.0 ± 21.2	0.26	79.0 ± 6.1	77.8 ± 9.9	0.79	0.91
Supine %	44.5 ± 30.3	86.8 ± 20.4	< 0.001	43.0 ± 35.6	66.2 ± 42.4	0.06	0.40

AHI Apnea–Hypopnea Index, Apnea index average number of apnea episodes per hour, CAI Central Apnea Index: total number of central apneas per hour, CT90 cumulative percentage of total sleep time with oxygen desaturation below 90%, HI Hypopnea index, average number of hypopnea episodes per hour, OAHl Obstructive Apnea Hypopnea Index, total number of obstructive apneas and hypopneas per hour, OAI Obstructive Apnea Index: total number of obstructive apneas divided sleep time, ODI Oxygen Desaturation Index, number of events with oxygen desaturation below 4% threshold in one hour, SaO₂ saturation of oxygen in hemoglobin. Statistically significant P values are indicated with an asterisk (*)

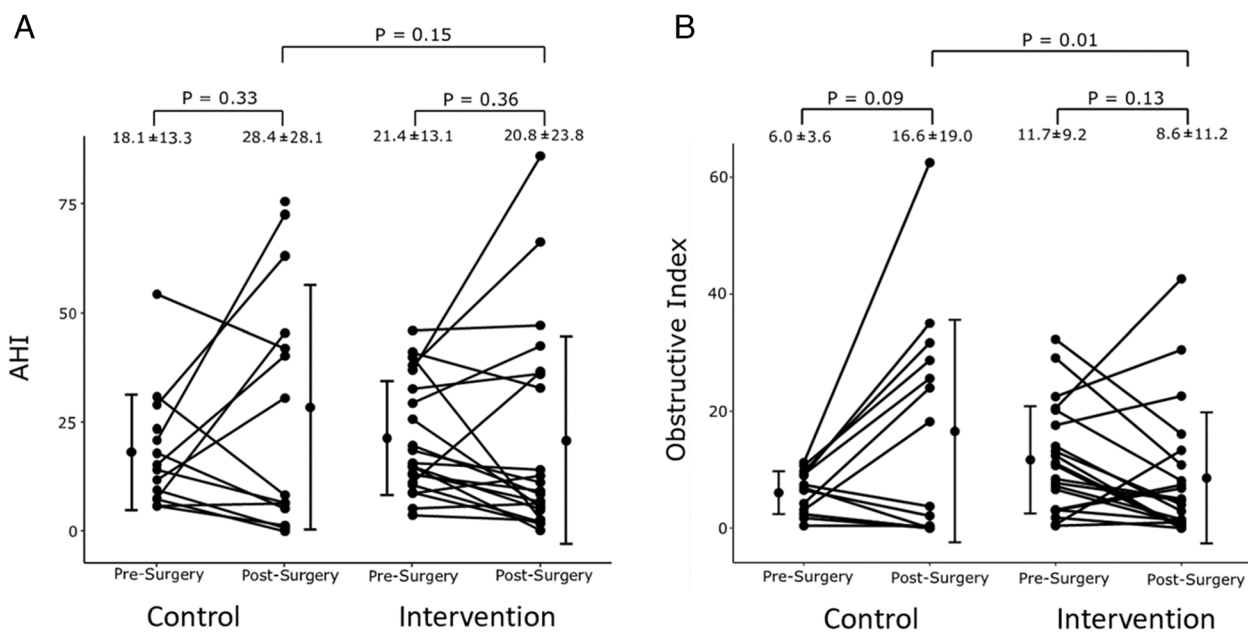


Fig. 2 A. The effect of semi-upright position on apnea–hypopnea index in the two groups per-protocol analysis. B. The effect of semi-upright position on obstructive index in the two groups per-protocol analysis

head-of-bed elevation [36]. Patients were assessed with modified apnea hypopnea index, based exclusively on the airflow signal without arterial oxygen saturation criteria. High-flow nasal cannula caused significant improvement in OSA independently, with an additive effect when combined with 30-degree head-of-bed elevation (compared to Control flow-based AHI reduced

by 10.9 (95% CI, 1 to 21) events · h⁻¹, P = 0.028; and 23 (95% CI, 13 to 32) events · h⁻¹, P < 0.001 respectively).

Body position may affect factors such as upper-airway passive collapsibility, airway dilator muscle activity, loop gain, and arousal threshold in patients with OSA [37]. These factors may play a role in how elevating the upper body can reduce OSA severity. In patients with

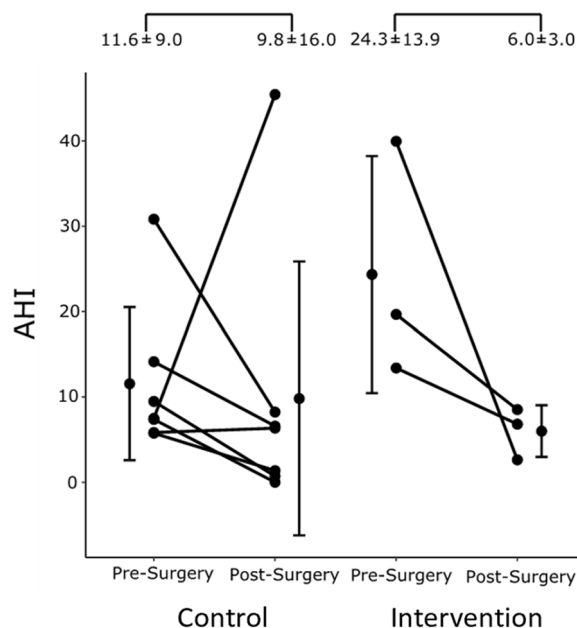


Fig. 3 The effect of semi-upright body position on the apnea-hypopnea index (AHI) in patients with supine-related OSA ($n = 10$)

OSA, pharyngeal critical closing pressure is higher in the supine position than lateral position [38] which may be related to reduction in functional residual capacity [39]. An increase in the diaphragmatic descent during the respiratory cycle leads to an increase in lung volume and thus an increase in longitudinal traction on the upper airway which increase upper airway caliber during sleep and anesthesia [40–42]. In addition, rostral fluid shift may worsen OSA severity and thus consolidate the effects of gravity on the propensity of OSA as demonstrated in healthy men [43, 44] and non-obese men [45].

A retrospective study on OSA patients with upper airway surgery found that the prevalence of positional OSA increased from 26 to 54% in those with persistent OSA at six months [46]. Among the non-responders to OSA surgery, almost 70% of patients were position dependent on preoperative PSG with no improvement at six months postoperatively [47]. This highlights the need to explore positional therapy, especially in those with positional OSA.

In a systematic review of positional therapy for OSA, CPAP was better than positional therapy to lower the AHI, while positional therapy was better than inactive controls to lower the AHI and improved daytime sleepiness [48]. Long term compliance and treatment benefit from positional therapy needs to be determined by longitudinal studies, and compared to other modalities such as CPAP.

In the general population, patients with supine-related OSA may be a suitable phenotype to benefit from positional therapy [24]. Good initial control of the OSA severity has been demonstrated but there is a lack of long-term compliance and outcome data [24]. The supine-related OSA phenotype can be easily identified on the preoperative sleep study. Though our data was limited, we found that patients with supine-related OSA benefit from postoperative semi-upright position with a reduction in AHI. Thus, we recommend the incorporation of semi-upright positioning as a practical adjunct to the perioperative management of OSA patients. It would be useful in those at high risk of OSA, newly diagnosed OSA or CPAP nonadherent patients. Further studies on custom-made pillows (to allow for elevated head position, or lateral position), tennis ball t-shirt, [21] or body position alarm devices [49] need to be done. Future studies aimed at localizing the site of obstruction by performing a drug induced sleep endoscopy or Point of care ultrasonography (POCUS) prior to randomization may also help to identify the subset of patients who will benefit with position therapy.

The limitations to our study were a small sample size with limited numbers in patients with supine-related OSA. Second, there can be variability in how the body position is reported and scored on the PSG. We used an accelerometer attached to the portable PSG which was placed on the patient's chest. In-built automatic position sensors define body position as a categorical variable rather than a continuous variable, and may not reflect the physiological impact of various body positions on the collapsibility of the upper airway [24]. Third, head and neck position can independently influence the AHI [50]. Recording trunk position does not account for the effect of head and neck on upper-airway collapsibility and the impact on OSA severity [51, 52]. However, we were able to show that the elevated position resulted in a significant reduction in OAI by eight events per hour. In those with supine-related OSA, we found a non-significant decrease in the mean AHI by 18 events per hour.

Conclusion

We found that the semi-upright position compared to supine position reduced postoperative OAI, indicating reduction in upper airway collapsibility and obstructive apneas. There was a decreasing trend in postoperative AHI in patients with supine-related OSA. Further studies on postoperative positional therapy are needed.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12871-023-02193-y>.

Additional file 1.

Acknowledgements

We acknowledge the help of Islam Sazzadual, MSc, Babak Amirshahi, MD, Hoda Fazel MD and Hisham Elsaid MD for conduct of the study. We thank Pu Liao MD for database management, Yuming Sun, MD for scoring polysomnography. We acknowledge the help of Colin Shapiro MD for the supervision of polysomnography scoring.

Authors' contributions

FC and MS conceptualized the study, acquired funding, designed the methodology, supervised and oversaw the trial, assisted with writing the original draft, reviewed and edited the final manuscript. GAL, AY, DA and JM assisted with data analysis, drafting and revising the article. BG assisted with data collection, data analysis, drafting and revising the article. The author(s) read and approved the final manuscript. Frances Chung and Mandeep Singh shared senior authorship for this study.

Funding

This study was supported by Departmental funds. Mandeep Singh is supported by a Canadian Anesthesiologists' Society Career Scientist Award and by the Merit Awards Program from the Department of Anesthesiology and Pain Medicine at the University of Toronto. Frances Chung reports having received research support from the University Health Network Foundation (Toronto, ON, Canada) and the Ontario Ministry of Health and Long-Term Care, royalties from UpToDate Inc., and consultant fees from the Takeda Pharmaceutical Company Limited. She is a developer of the STOP-Bang questionnaire (proprietary to the University Health Network).

Availability of data and materials

All data and materials in this manuscript are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Ethics approval for this study was provided by Research Ethics Board at Toronto Western Hospital (Approval no. 14–8710.0) and Mount Sinai Hospital (Approval no. 11–0021-E) on June 23, 2011 and June 22, 2011 respectively. The study was registered in clinicaltrials.gov NCT02152202 on 02/06/2014. The study was also done as per the declaration of Helsinki. The benefits and purposes of the study were explained to the patients, and each participant provided written, informed consent. Confidentiality was maintained at all levels of the study by avoiding identifiers and using codes to identify patients. Participants' involvement in the study was voluntary. Participants who did not wish to participate in the study or who wished to withdraw at any time were informed that they could do so without restriction.

Consent for publication

Not applicable.

Competing interests

Frances Chung holds the ResMed Research Chair of Anesthesia, sleep and perioperative medicine, consultant to Takeda Pharma. STOP-Bang questionnaire proprietary to University Health Network. Mandeep Singh (MS) currently holds the Canadian Anesthesiologists' Society Career Scientist Grant and a Merit award from the Department of Anesthesiology and Pain Medicine, University of Toronto (Toronto, Canada) to support academic time. MS also serves on the Medical Advisory Board of Hypersomnia Foundation (Atlanta, GA) on a voluntary basis. Gincy A Lukachan, Azadeh Yadollahi, Dennis Auckley, Bojan Gavrilovic, John Matelski: No competing interests.

Author details

¹Department of Anesthesia, Believers Church Medical College Hospital, Thiruvalla, Kerala, India. ²KITE - Toronto Rehabilitation Institute, University Health Network, University of Toronto, Toronto, ON, Canada. ³Division of Pulmonary, Critical Care and Sleep Medicine, MetroHealth Medical Center, Case Western Reserve University, Cleveland, OH, USA. ⁴Biostatistics Research Unit, University Health Network, Toronto, ON, Canada. ⁵Department of Anesthesia, Toronto Western Hospital, University Health Network, University of Toronto, 399 Bathurst Street, MCL 2-405, Toronto, ON M5T 2S8, Canada.

Received: 16 November 2022 Accepted: 30 June 2023

Published online: 13 July 2023

References

- Durán J, Esnaola S, Rubio R, Izuetza Á, Izuetza A, Izuetza Á. Obstructive sleep apnea-hypopnea and related clinical features in a population-based sample of subjects aged 30 to 70 yr. *Am J Respir Crit Care Med*. 2001;163(3 Pt 1):685–9.
- Redline S, Young T. Epidemiology and natural history of obstructive sleep apnea. *Ear Nose Throat J*. 1993;72(1):20–6.
- Opperer M, Cozowicz C, Bugada D, Mokhlesi B, Kaw R, Auckley D, et al. Does obstructive sleep apnea influence perioperative outcome? a qualitative systematic review for the society of anesthesia and sleep medicine task force on preoperative preparation of patients with sleep-disordered breathing. *Anesth Analg*. 2016;122:1321–34.
- Hai F, Porhomayon J, Vermont L, Frydrych L, Jaoude P, El-Solh AA. Post-operative complications in patients with obstructive sleep apnea: a meta-analysis. *J Clin Anesth*. 2014;26(8):591–600.
- Kaw R, Chung F, Pasupuleti V, Mehta J, Gay PC, Hernandez AV. Meta-analysis of the association between obstructive sleep apnoea and postoperative outcome. *Br J Anaesth*. 2012;109(6):897–906.
- Chan MTV, Wang CY, Seet E, Tam S, Lai HY, Chew EFF, et al. Association of unrecognized obstructive sleep apnea with postoperative cardiovascular events in patients undergoing major noncardiac surgery. *JAMA - Journal of the American Medical Association*. 2019;321(18):1788–98.
- Bolden N, Posner KL, Domino KB, Auckley D, Benumof JL, Herway ST, et al. Postoperative critical events associated with obstructive sleep apnea: results from the society of anesthesia and sleep medicine obstructive sleep apnea registry. *Anesth Analg*. 2020;131(4):1032–41.
- Memtsoudis SG, Stundner O, Rasul R, Chiu YLL, Sun X, Ramachandran SKK, et al. The impact of sleep apnea on postoperative utilization of resources and adverse outcomes. *Anesth Analg*. 2014;118(2):407–18.
- Sankar A, Dixon PR, Sivanathan L, Memtsoudis SG, De Almeida JR, Singh M. Cost-effectiveness analysis of preoperative screening strategies for obstructive sleep apnea among patients undergoing elective inpatient surgery. *Anesthesiology*. 2020;133:787–800.
- Chung F, Memtsoudis SG, Ramachandran SK, Nagappa M, Opperer M, Cozowicz C, et al. Society of anesthesia and sleep medicine guidelines on preoperative screening and assessment of adult patients with obstructive sleep apnea. *Anesth Analg*. 2016;123(2):452–73.
- Gross JAJ, et al. Practice guidelines for the perioperative management of patients with obstructive sleep apnea: an updated report by the american society of anesthesiologists task force on perioperative management of patients with obstructive sleep apnea. *Anesthesiology*. 2014;129(2):268–86.
- Liao P, Luo Q, Elsaid H, Kang W, Shapiro CM, Chung F. Perioperative auto-titrated continuous positive airway pressure treatment in surgical patients with obstructive sleep apnea: a randomized controlled trial. *Anesthesiology*. 2013;119(4):837–47.
- Guralnick AS, Pant M, Minhaj M, Sweitzer BJ, Mokhlesi B. CPAP adherence in patients with newly diagnosed obstructive sleep apnea prior to elective surgery. *J Clin Sleep Med*. 2012;8(5):501–6.
- Kajaste S, Brander PE, Telakivi T, Partinen M, Mustajoki P. A cognitive-behavioral weight reduction program in the treatment of obstructive sleep apnea syndrome with or without initial nasal CPAP: a randomized study. *Sleep Med*. 2004;5:125–31 (Netherlands LG-English PT-Journal: Article EM-200414).
- Fransson AM, Tegellberg A, Svenson BA, Lennartsson B, Isacson G. Influence of mandibular protruding device on airway passages and

- dentofacial characteristics in obstructive sleep apnea and snoring. *Am J Orthod Dentofacial Orthop.* 2002;122(4):371–9.
16. Waite PD, Wooten V, Lachner J, Guyette RF. Maxillomandibular advancement surgery in 23 patients with obstructive sleep apnea syndrome. *J Oral Maxillofac Surg.* 1989;47(12):1256–61.
 17. Senior BA, Rosenthal L, Lumley A, Gerhardstein R, Day R. Efficacy of uvulopalatopharyngoplasty in unselected patients with mild obstructive sleep apnea. *Otolaryngol Head Neck Surg.* 2000;123:179–82.
 18. Verse T, Kroker BA, Pirsig W, Brosch S. Tonsillectomy as a treatment of obstructive sleep apnea in adults with tonsillar hypertrophy. *Laryngoscope.* 2000;110:1556–9 (UNITED STATES PT-Journal Article LG-English).
 19. Rasheid S, Banasiak M, Gallagher SF, Lipska A, Kaba S, Ventimiglia D, et al. Gastric bypass is an effective treatment for obstructive sleep apnea in patients with clinically significant obesity. *Obes Surg.* 2003;13:58–61 (Canada PT-Journal Article LG-English).
 20. Ha SCN, Hirai HW, Tsoi KF. Comparison of positional therapy versus continuous positive airway pressure in patients with positional obstructive sleep apnea: a meta-analysis of randomized trials. *Sleep Med Rev.* 2014;18:19–24.
 21. Skinner MA, Kingshott RN, Filsell S, Taylor DR. Efficacy of the “tennis ball technique” versus nCPAP in the management of position-dependent obstructive sleep apnoea syndrome. *Respirology.* 2008;13(5):708–15.
 22. Skinner MA, Kingshott RN, Jones DR, Homan SDR, Taylor DR. Elevated posture for the management of obstructive sleep apnea. *Sleep Breathing.* 2004;8:193–200 (United States LG-English PT-Journal: Article EM-200507).
 23. McEvoy RD, Sharp DJ, Thornton AT. The effects of posture on obstructive sleep apnea. *Am Rev Respir Dis.* 1986;133(4):662–6.
 24. Joosten SA, O’Driscoll DM, Berger PJ, Hamilton GS. Supine position related obstructive sleep apnea in adults: pathogenesis and treatment. *Sleep Med Rev.* 2014;18:7–17.
 25. Subramani Y, Singh M, Wong J, Kushida CA, Malhotra A, Chung F. Understanding phenotypes of obstructive sleep apnea: applications in anaesthesia, surgery, and perioperative medicine. *Anesth Analg.* 2017;124:179–91.
 26. Chung F, Abdullah HR, Liao P. STOP-Bang Questionnaire: a practical approach to screen for obstructive sleep apnea. *Chest.* 2015;149(3):631–8.
 27. Chung F, Liao P, Sun Y, Amirshahi B, Fazel H, Shapiro CM, et al. Perioperative practical experiences in using a level 2 portable polysomnography. *Sleep Breath.* 2011;15(3):367–75.
 28. Iber C, Cheeson A, Quan SF. *A Israel S. The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology and Technical Specifications.* 1st ed. Westchester, IL, USA: American Academy of Sleep Medicine; 2007.
 29. Skinner MA, Kingshott RN, Jones DR, Homan SDR, Taylor DR. Elevated posture for the management of obstructive sleep apnea. *Sleep Breath.* 2004;8:193–200 (United States LG-English PT-Journal: Article EM-200507).
 30. RCoreTeam. *R: A Language and Environment for Statistical Computing.* R Foundation for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria; 2013.
 31. Yoshida Kazuki AB. *tableone: Create “Table 1” to Describe Baseline Characteristics with or without Propensity Score Weights.* R package version 0132. 2022;
 32. Battagel JM, Johal A, Smith AM, et al. Postural variation in oropharyngeal dimensions in subjects with sleep disordered breathing: a cephalometric study. *Eur J Orthod.* 2002;24:263–76.
 33. de Barros Souza FJF, Evangelista AR, Silva JV, Périco GV, Madeira K. Cervical computed tomography in patients with obstructive sleep apnea: influence of head elevation on the assessment of upper airway volume. *J Bras Pneumol.* 2016;42(1):55–60.
 34. Souza FJFB, Genta PR, de Souza Filho AJ, Wellman A, Lorenzi-Filho G. The influence of head-of-bed elevation in patients with obstructive sleep apnea. *Sleep Breath.* 2017;21(4):815–20.
 35. Zaremba S, Mueller N, Heisig AM, Shin CH, Jung S, Leffert LR, et al. Elevated upper body position improves pregnancy-related OSA without impairing sleep quality or sleep architecture early after delivery. *Chest.* 2015;148(4):936–44.
 36. Sakaguchi Y, Nozaki-Taguchi N, Hasegawa M, Ishibashi K, Sato Y, Isono S. Combination therapy of high-flow nasal cannula and upper-body elevation for postoperative sleep-disordered breathing: randomized crossover trial. *Anesthesiology.* 2022;137(1):15–27.
 37. Eckert DJ, White DP, Jordan AS, Malhotra A, Wellman A. Defining phenotypic causes of obstructive sleep apnea. Identification of novel therapeutic targets. *Am J Respir Crit Care Med.* 2013;188(8):996–1004.
 38. Penzel T, Möller M, Becker HF, Knaack L, Peter JH. Effect of sleep position and sleep stage on the collapsibility of the upper airways in patients with sleep apnea. *Sleep.* 2001;24(1):90–5.
 39. Joosten SA, Sands SA, Edwards BA, Hamza K, Turton A, Lau KK, et al. Evaluation of the role of lung volume and airway size and shape in supine-predominant obstructive sleep apnoea patients. *Respirology (Carlton, Vic).* 2015;20(5):819–27.
 40. Tagaito Y, Isono S, Tanaka A, Ishikawa T, Nishino T. Sitting posture decreases collapsibility of the passive pharynx in anesthetized paralyzed patients with obstructive sleep apnea. *Anesthesiology.* 2010;113(4):812–8.
 41. Walsh JH, Leigh MS, Paduch A, Maddison KJ, Armstrong JJ, Sampson DD, et al. Effect of body posture on pharyngeal shape and size in adults with and without obstructive sleep apnea. *Sleep.* 2008;31(11):1543–9.
 42. Isono S, Tanaka A, Ishikawa T, Tagaito Y, Nishino T. Sniffing position improves pharyngeal airway patency in anesthetized patients with obstructive sleep apnea. *Anesthesiology.* 2005;103:489–94 (United States PT-Journal Article LG-English).
 43. Redline S, Lewis EF. Gravitational influences and shifting propensity for sleep apnea: Another source of heterogeneity or a new intervention target? *Circulation.* 2010;121:1583–5.
 44. Su MC, Chiu KL, Ruttanaumpawan P, Shiota S, Yumino D, Redolfi S, et al. Difference in upper airway collapsibility during wakefulness between men and women in response to lower-body positive pressure. *Clin Sci.* 2009;116(9):713–20.
 45. Redolfi S, Yumino D, Ruttanaumpawan P, Yau B, Su MCC, Lam J, et al. Relationship between overnight rostral fluid shift and obstructive sleep apnea in nonobese men. *Am J Respir Crit Care Med.* 2009;179(3):241–6.
 46. Martínez Ruiz de Apodaca P, Carrasco Llatas M, Matarredona Quiles S, Dalmau Galofre J. Development of positional obstructive sleep apnea (POSA) after upper airway surgery in OSA patients. *Sleep Breath.* 2020;24(3):849–56.
 47. Lee YC, Eun YG, Shin SY, Kim SW. Change in position dependency in non-responders after multilevel surgery for obstructive sleep apnea: analysis of polysomnographic parameters. *Eur Arch Otorhinolaryngol.* 2014;271(5):1081–5.
 48. Srijithesh PR, Aghoram R, Goel A, Dhanya J. Positional therapy for obstructive sleep apnoea. *Cochrane Database of Systematic Reviews.* 2014;(2).
 49. Levendowski DJ, Seagraves S, Popovic D, Westbrook PR. Assessment of a neck-based treatment and monitoring device for positional obstructive sleep apnea. *J Clin Sleep Med.* 2014;10(8):863–71.
 50. van Kesteren ER, van Maanen JP, Hilgevoord AAJ, Laman DM, de Vries N. Quantitative effects of trunk and head position on the apnea hypopnea index in obstructive sleep apnea. *Sleep.* 2011;34(8):1075–81.
 51. Isono S, Tanaka A, Tagaito Y, Ishikawa T, Nishino T. Influences of head positions and bite opening on collapsibility of the passive pharynx. *J Appl Physiol.* 2004;97:339–46 (United States PT-Journal Article LG-English).
 52. Walsh JH, Maddison KJ, Platt PR, Hillman DR, Eastwood PR. Influence of head extension, flexion, and rotation on collapsibility of the passive upper airway. *Sleep.* 2008;31(10):1440–7.

Publisher’s Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.