

Changes in Site of Obstruction in Obstructive Sleep Apnea Patients According to Sleep Position

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Introduction

Obstructive sleep apnea (OSA) is a manifestation of upper airway instability during sleep. The unstable airway results from a combination of a structurally vulnerable upper airway and a physiologic loss of muscle tone that occurs during sleep. Adequate treatment of OSA is imperative considering its impact on quality of life and numerous complications this disease is associated with.

The severity of the disease varies and is determined by multiple factors that are still not completely understood. It is well known that sleep position affects the occurrence and severity of sleep apnea [1, 2]. OSA worsens in terms of apnea frequency, duration, desaturation, and duration of arousals in the supine position. Positional dependency defined as having a supine AHI two times greater than a non-supine AHI [3] can be seen in as many as 50–70 % of OSA patients [3, 4].

The mechanism responsible for worsening of OSA in the supine position is not clear. Most likely it relates to the effect of gravity on the size or shape of the upper airway [5]. A smaller pharyngeal airway in the supine posture making it more vulnerable to collapse is an intuitive explanation [6]. However, reports are inconsistent in this regard, with some studies reporting the pharynx to be smaller in the supine than in the lateral recumbent posture [5, 7, 8] and others reporting a similar pharyngeal size in the two postures [9–11]. Until now the effect of posture on the upper airway during sleep in OSA patients is largely unknown.

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Various efforts have been made to elucidate the effect of positional dependency using tools such as acoustic reflection [9, 11], lateral cephalometry [12–14], computed tomography [10], magnetic resonance imaging [15], and optical coherence tomography [16, 17]. However, these studies have limitations as they are performed while awake and/or during only the supine position.

In this chapter, we introduce a unique study in which we evaluated the changes of site and pattern of obstruction of the upper airway according to sleep position by the use of dynamic airway evaluation during drug-induced sleep.

Patient Characteristics

Eighty-five patients were included in this study. The inclusion criteria were patients who had performed full-night attended nocturnal polysomnography (PSG), patients who underwent drug-induced sleep endoscopy in the supine and lateral position, and patients with an AHI greater than 15. Patients with a previous history of upper airway surgery were excluded from this study.

Subgroup analysis was performed according to severity and lateral AHI. They were divided into two groups according to severity: moderate OSA (AHI=15–30) and severe OSA (AHI>30) groups. Among the 85 patients, 78 patients who had at least 30 min of lateral sleep were divided into two groups according to the lateral AHI (average of AHI in the left and right decubitus position): lateral obstructor group (LO, lateral AHI \geq 10) and lateral nonobstructor group (LNO, lateral AHI<10).

There were 61 males and 24 females with a mean age of 47.8 ± 6.7 years. Body mass index (BMI) was 26.9 ± 2.7 kg/m². Mean AHI, mean supine AHI, and mean lateral AHI (average of right and left lateral AHI) were 33.3 ± 16.0 , 44.3 ± 22.4 , and 21.3 ± 22.4 , respectively. The lowest oxygen saturation was 80.02 ± 13.8 %, and proportion of oxygen saturation below 90 % was 7.5 ± 13.1 % (Table 1).

Drug-Induced Sleep Endoscopy

Drug-induced sleep endoscopy (DISE) was performed in the following manner. The patient lied down comfortably in the supine position. Heart rate and oxygen saturation were monitored throughout the examination. Examination started in the awake state after unilateral nasal topical anesthesia and decongestion using cotton pledges placed at the middle meatus. Thereafter, sleep was induced by intravenous administration of midazolam (initial dose of 3 mg for adult patients over 50 kg; 0.06 mg/kg). After the patient fell asleep, endoscopy was performed through the same nostril. Desaturation events (drop of basal saturation during sleep of more than 3 %) were analyzed for obstruction level, structure, pattern, and degree and representative findings recorded. If there was no desaturation, changes during snoring were analyzed. Additional bolus of 0.5 mg of midazolam was administered in the

Table 1 Demographic and polysomnographic findings

PSG parameters	n=85
M:F	61:24
Age	47.8±6.7
BMI	26.9±2.7
AHI	33.3±16.0
Supine AHI	44.3±22.4
Lateral AHI	21.3±22.4
O ₂ saturation min	80.2±13.8
O ₂ saturation <90 %	7.5±13.1

BMI body mass index, *AHI* apnea-hypopnea index

event of awakenings. Target level of sedation was upper muscle relaxation producing obstruction (i.e., snoring or apnea) without respiratory depression. Level of sedation was maintained to a modified Ramsay score of 5 (sluggish response to a light glabellar tap or loud auditory stimulus) or 70–80 in selected patients in which BIS monitoring was used.

After observing the airway in the supine position, the patients were positioned in the right lateral decubitus position. Body and head was moved simultaneously so that axis of the body and the Frankfort plane of the head were perpendicular to the bed.

At least three obstructive events were observed in each position, and the most severe event was determined as the obstruction site of the patient. After the conclusion of the examination, 2 mg of flumazenil was administered intravenously as an antidote. The average examination time was 40 min.

Midazolam-induced sleep endoscopy (MISE) findings were classified according to obstruction structures (soft palate (SP), lateral wall (LW) including palatine tonsils, tongue base (TB), and larynx (LX) including epiglottis). The degree of obstruction was determined as 0, no obstruction; 1, partial obstruction (vibration with desaturation); and 2, complete obstruction (total collapse of airway with desaturation). For obstruction in the tongue base more than >50 % displacement compared to the awake state was determined as grade 1, while grade 2 obstruction was attributed for more than 75 % obstruction.

DISE Findings According to Sleep Position

In the supine position, the most common structure contributing to obstruction was the soft palate which was observed in 87.6 % of patients ($n=74$) followed by TB ($n=65$, 76.5 %), LW ($n=60$, 70.6 %), and LX ($n=18$, 21.2 %) (Table 2). When the patients were positioned in the lateral decubitus position, the most frequent anatomical structure contributing to obstruction changed from the SP to the LW which was seen in 51 patients (60 %), followed by SP ($n=19$, 22.3 %), TB ($n=6$, 7.1 %),

Table 2 Changes of obstruction site according to sleep position ($n=85$)

Obstruction site	Supine position, patient number (%)	Lateral position, patient number (%)
Soft palate		
Total ($n=85$)	74 (87.6)	19 (22.3)*
Mod OSA ($n=47$)	43 (91.5)	9 (19.1)*
Severe OSA ($n=38$)	31 (81.6)	10 (26.3)*
Lateral wall		
Total	60 (70.6)	51 (60.0)
Mod OSA	29 (61.7)	17 (36.2)*
Severe OSA	31 (81.6)	34 (89.5)
Tongue base		
Total	65 (76.5)	6 (7.1)*
Mod OSA	38 (80.1)	4 (8.5)*
Severe OSA	27 (71.1)	2 (5.0)*
Larynx		
Total	18 (21.2)	1 (1.2)*
Mod OSA	11 (23.4)	0 (0)*
Severe OSA	7 (18.4)	1 (2.6)*
No obstruction		
Total	0 (0)	21 (24.7)*
Mod OSA	0 (0)	14 (29.8)*
Severe OSA	0 (0)	2 (5.3)*

OSA obstructive sleep apnea

* p -value < 0.05

and LX ($n=1$, 1.4 %). A patent airway with no discernible site of obstruction was found in 25.3 % of patients in the lateral position. The degree of obstruction of the six patients who showed TB obstruction in the lateral position was all grade 1, indicating partial obstruction (Table 2). The prevalence of obstruction in the SP, TB, and LX showed statistically significant decrease when sleep position was changed from supine to lateral position ($p < 0.05$), while overall prevalence of LW obstruction was not affected by position change ($p > 0.05$).

Changes in Obstruction Site According to Severity of OSA

Among the 85 patients, 47 patients had moderate OSA (AHI=15–29) and 38 patients had severe OSA (AHI \geq 30). In moderate OSA patients, the prevalence of all the anatomic structures contributing to obstruction (SP, LW, TB, LX) showed significant improvement ($p < 0.05$) when position was changed from supine to lateral, with no airway obstruction in 29.8 % of patients (Table 2).

In severe OSA patients, the prevalence of obstruction in the SP, TB, and LX showed significant improvement (SP changed from 81.6 % to 26.3 %, TB from

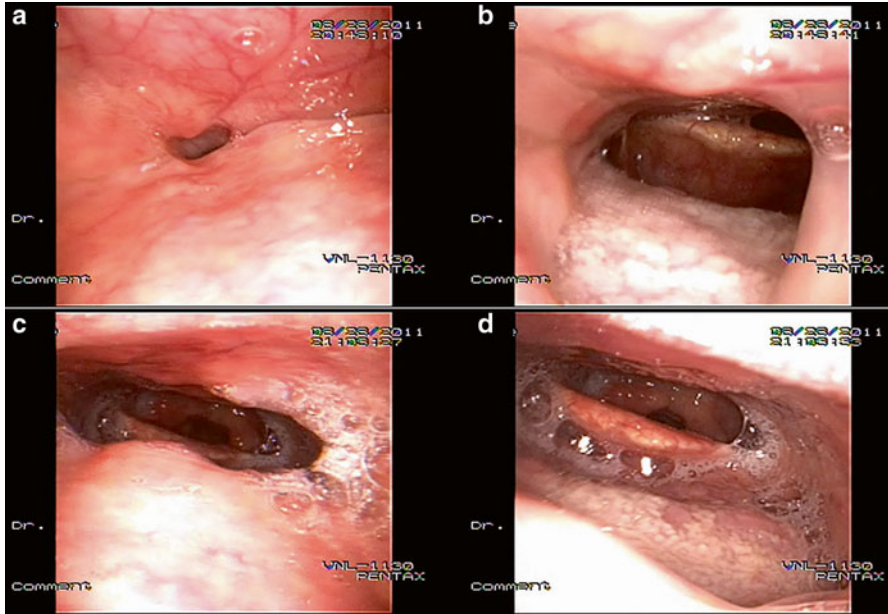


Fig. 1 Representative DISE findings from our series showing changes in site of obstruction according to sleep position. In the supine position (**a, b**), the patient shows obstruction at the soft palate (**a**) and tongue base resulting in secondary epiglottis obstruction (**b**). When the patient changed position to the lateral decubitus position (**c, d**) a patent airway was observed in the retropalatal and retroglottal airway. The AHI for this particular patient was 44.2 (total), 52.6 (supine), 7.4 (lateral). The patient was classified as lateral nonobstructor

71.1 % to 5.0 %, LX from 18.4 % to 2.6 %) after position is changed to the lateral position ($p < 0.05$). However, there was no change in the prevalence of obstruction in the LW. The incidence of LW obstruction in the lateral position was significantly higher in the severe OSA patients (89.5 %) compared to the moderate OSA patients (36.2 %) ($p < 0.05$).

Representative DISE findings in the supine and lateral positions are shown in Figs. 1 and 2.

Changes in Obstruction Site in Lateral Obstructors and Lateral Nonobstructors

Subgroup analysis was carried out in 78 patients whose sleep time spent in lateral position was greater than 30 min. Among them, 50 patients were position dependent (PD), while 28 were non-position dependent (NPD). Patients with a lateral AHI equal or below 10 were regarded as lateral nonobstructors (LNO), while those who had a lateral AHI equal or above 10 were regarded as lateral obstructors (LO). Characteristics of the two groups are summarized in Table 3.

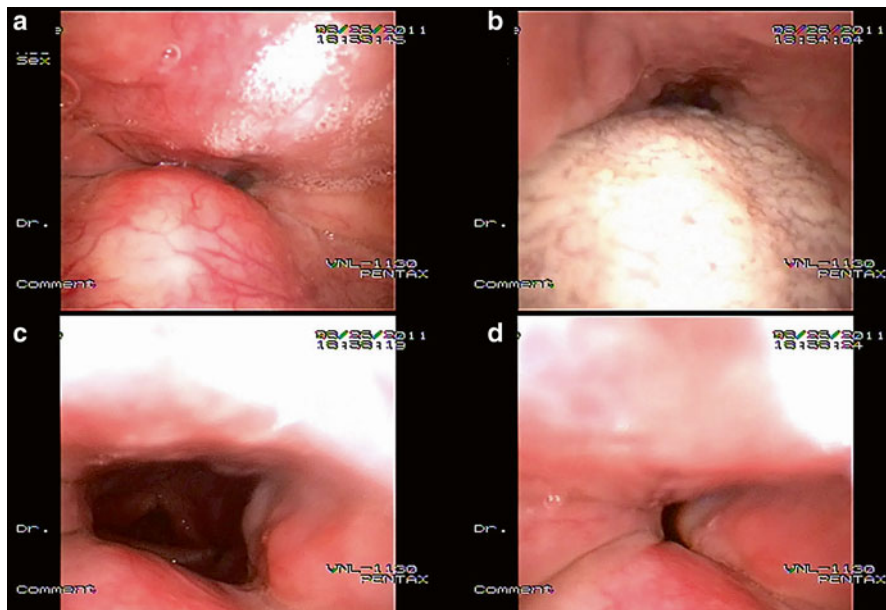


Fig. 2 Representative DISE findings from our series showing changes in site of obstruction according to sleep position. In the supine position (**a, b**), the patient shows obstruction at the soft palate (**a**), oropharyngeal lateral wall, and tongue base (**b**). When the patient changed position to the lateral decubitus position (**c, d**), there was no obstruction observed in the soft palate and tongue base (**c**); however, there was persistent obstruction in the lateral walls (**b**). The AHI for this particular patient was 63.8 (total), 89.7 (supine), and 32.2 (lateral). The patient was classified as lateral obstructor

Table 3 Demographic and polysomnographic findings of LO and LNO

	LO (n=42)	LNO (n=36)
M:F	34:8	25:11
Age	46.7±8.3	48.8±5.7
BMI	28.8±3.2	25.2±2.3*
AHI total	46.9±13.6	22.3±4.24*
Supine AHI	58.3±25.4	31.3±18.4*
Lateral AHI	29.4±19.7	7.8±5.3*
Position dependency	14 (33.3 %)	36 (100 %)*

LO lateral obstructor, LNO lateral nonobstructor

*p-value <0.05

According to this criteria, 42 patients (53.8 %) were classified as LO group. Mean age was 46.7±5.3 years, with 34 males and 8 females. Body mass index was 28.8±3.2 kg/m² and mean AHI was 46.9±13.6. Positional dependency was found in 33.3 % of patients. Changes in obstruction site are shown in Table 4. When position was changed from supine to lateral, prevalence of obstruction in the SP, TB,

Table 4 Changes of obstruction site according to sleep position in LO and LNO patients

Obstruction site	SP	LW	TB	LX	No
LO (<i>n</i> =42)					
Supine	35 (83.3)	36 (85.7)	30 (71.5)	11 (26.2)	0 (0)
Lateral	13 (31.0)*	35 (83.3) ^a	4 (9.5)*	1 (2.6) ^{b,*}	1 (2.4)
LNO (<i>n</i> =36)					
Supine	32 (88.9)	19 (52.8)	30 (83.3)	8 (22.2)	0
Lateral	6 (16.7)*	12 (33.3)	1 (2.8)*	0 (0)*	19 (52.8)*

Value represents number and (%); numbers are not mutually exclusive

LO Lateral obstructor, LNO lateral nonobstructor

**p*-value <0.05

^aSignificant difference between LO and LNO in the lateral position

^bDue to redundant arytenoid mucosa

and LX was significantly reduced ($p < 0.05$). However, LW obstruction showed no significant change (85.7 % in supine position to 83.3 % in lateral position).

Thirty-six patients (46.2 %) were classified as LNO group. Mean age was 48.8 ± 3.4 years, with 25 males and 11 females. Body mass index was 25.2 ± 2.3 kg/m² and mean AHI was 22.3 ± 4.24 . Positional dependency was found in all (100 %) patients. Changes in obstruction site are shown in Table 4. When position was changed from supine to lateral, 19 of 36 patients (52.8 %) showed a patent airway. Prevalence of obstruction in the SP, TB, and LX was significantly reduced ($p < 0.05$). LW obstruction also showed reduction (52.8 % in supine position to 33.3 % in lateral position) in LNO group, but it failed to show statistical significance. In the 12 patients who still showed obstruction in the LW in the lateral position, 6 patients showed only partial obstruction (grade 1). Only one patient showed TB obstruction in the lateral position and this was grade 1.

When the prevalence of obstruction in the lateral position was compared between the LO and LNO groups, only LW obstruction was significantly different between the LO and LNO groups.

Discussion

Airway obstruction during sleep which occurs in OSA patients is not a continuous and constant process attesting that the obstruction is dynamic. Among various factors, sleep position is a major determinant that affects severity of OSA [3].

The mechanism responsible for worsening of OSA in the supine position or improvement in the lateral position is not clear. Previous studies have suggested that the airway shape (a more elliptically shaped airway) may contribute to its propensity to collapse [15]. Shortcomings of these studies include limited number of patients, size (CSA) or shape of the airway evaluated using static images without information on the site, or anatomic structure contributing to obstruction. Furthermore, evaluation was performed while awake which can be a major limitation since upper airway muscle tone show marked differences when asleep.

Evaluating the upper airway of OSA patients has been an elusive task. Recent implementation of dynamic evaluation of the airway during sleep (DAES) techniques such as sleep videofluoroscopy (SVF) or DISE have greatly enhanced our knowledge of the dynamic changes which occurs in the upper airway during sleep. Numerous studies have shown that it is a safe, feasible, and valid tool for dynamic assessment of the upper airway [18–21]. Using sleep videofluoroscopy, we have already shown that position dependency can be associated with obstruction site [2]. However, previous SVF and DISE studies that evaluate the upper airway during sleep have only been performed in the supine position.

Our results show that in the supine position, the most prevalent obstruction site was the SP (87.6 %) followed by the TB (76.5 %) which is comparable to other reports [22–24]. When sleep posture was changed to the lateral recumbent position, obstruction at the SP, TB, and LX improved significantly, with 24.7 % ($n=21$) of patients showing no overall obstruction. Improvement of obstruction at the TB and LX was most prominent (TB 76.5–7.1 % and LX from 21.2 % to 1.2 %). This pattern of improvement was maintained when stratified according to severity of AHI. The one patient who showed persistent obstruction at the larynx in the lateral position was a patient whose redundant arytenoid mucosa was causing the obstruction at the laryngeal inlet irrespective of sleep posture.

Obstruction at the lateral walls (LW), on the other hand, did not show significant improvement after position change (70.6 % in supine vs. 60.0 % in lateral). When severity of AHI was taken into consideration, improvement was seen in the moderate OSA group (61.7–36.2 %), while there was no change in the severe OSA group (81.6–89.5 %). Lateral wall obstruction is considered to be the most dynamic structure of the upper airway and thus a major contributor of upper airway collapse in OSA patients. Soares and colleagues have shown that patients with lateral wall obstruction are associated with surgical failure [25]. Overall frequency of lateral wall collapse in our study was 70.6 % in the supine position which is higher than other reports with DISE (51.2 %) [18]. We believe that this is due to exclusion of mild OSA patients in our study. When the mild OSA patients are taken into account, the rate of LW obstruction was 48 % which is comparable to other reports. Our study shows that LW obstruction is prominent in severe OSA patients, and this finding is accentuated in the lateral sleep position.

Prevalence of TB obstruction in the supine position was 71.1 %. However, there was a dramatic decrease in frequency of TB obstruction in the lateral sleep position. Only 6 out of 85 patients (7.1 %) showed TB obstruction in the lateral position. Furthermore, all six patients showed partial (grade 1) obstruction. This finding of improvement in obstruction of the TB with position change was consistently seen irrespective of age, sex, BMI, and severity.

We have observed a dramatic change in the upper airway during sleep when sleep position is changed from supine to lateral. This change is mainly focused in the TB and LX. Most OSA patients show improvement in TB and LX obstruction, irrespective of severity. Therefore, we can think that LW collapsibility will determine if the patient will still have persistent obstruction in the lateral position. Severe OSA patients or patients with a high BMI tend to have increased LW collapsibility which will cause persistent obstruction in the lateral position. This is one of the

reasons why the number of position-dependent (PD) patients decrease with increasing severity [2]. In the same context, we can speculate that most PD patients are patients who have TB obstruction without severe LW collapse. In a previous study, we have shown that UP3 can change non-PD patients into PD patients rendering them candidates for positional therapy [26, 27]. This is in agreement with our current study because UP3 can reduce LW collapsibility and thus decrease the lateral AHI making these patients PD.

Positioning the patient laterally and evaluating the changes in the airway can give us additional useful clinical information. As shown in our study, in the lateral position, most of the TB and LX components can be nullified. Therefore, a more accurate assessment of the SP and LW collapsibility can be achieved. In the supine position, obstructions at the SP and LW are frequently influenced by obstruction at the TB. We can commonly encounter patients whose SP is posteriorly displaced secondarily due to a retrodisplaced tongue. Displacement of the TB can also alter LW tension and can cause secondary LW collapse. In the lateral position, primary LW collapse can be assessed because the influence of the TB has been taken away. In the case of primary LW collapse, treatment options should be determined accordingly. If surgery is planned, techniques targeting the LW collapse should be implemented for increased success.

Conclusion

The upper airway changes according to sleep posture, and this change accounts for the varying severity of apneic events in OSA patients. We have provided another insight into the upper airway mechanics involved in positional dependency of OSA patients. When sleep posture is changed from supine to lateral, obstruction due to structures such as the tongue base and larynx improves dramatically. Obstruction in lateral position is mostly due to obstruction at the oropharyngeal lateral walls. Therefore, position dependency is mostly determined by lateral wall collapsibility. Evaluating the changes of the upper airway according to sleep position can further characterize the upper airway collapsibility and can be used for tailored treatment planning.

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