Evaluation of Soft Palate Changes Using Sleep Videofluoroscopy in Patients With Obstructive Sleep Apnea

Chul Hee Lee, MD, PhD; Ji-Hun Mo, MD, PhD; Bong Jik Kim, MD; Il Gyu Kong, MD; In Young Yoon, MD, PhD; Seockhoon Chung, MD, PhD; Jae-Hyung Kim, MD; Jeong-Whun Kim, MD, PhD

Objective: To quantitatively evaluate the changes in the soft palate (SP) by sleep videofluoroscopy (SVF).

Design: Retrospective analysis.

Setting: Academic tertiary referral center.

Patients: A total of 63 consecutive patients with snoring or sleep apnea (53 with obstructive sleep apnea [OSA] and 10 simple snorers).

Interventions: All the subjects underwent SVF and nocturnal polysomnography. Sleep videofluoroscopy was performed before and after sleep induction by intravenous injection of low-dose midazolam (2 mg per person) and was recorded during 3 kinds of events: awake, normoxegenation sleep, and desaturation sleep events.

Main Outcome Measures: Changes in SP length and the angle between inspiratory and expiratory efforts in each group were evaluated according to sleep events; changes in the SP was assessed according to obstruction sites and severity of OSA.

Results: Desaturation sleep events were detected in all patients with OSA but not in simple snorers. In awake events, inspiratory efforts increased the length and angle of the SP in patients with OSA but not in simple snorers. Elongation and angulation were greatest during desaturation sleep events and least during awake events. In normoxegenation events, changes in the SP were significantly larger in patients with OSA than in simple snorers ($P < .01$ for SP length; $P = .03$ for SP angle). Elongation of the SP was the biggest in SP-type obstruction.

Conclusions: Sleep videofluoroscopy quantitatively showed that the SP was considerably elongated and angulated in patients with OSA even in an awake state. It is an easy way to measure the SP changes and may be a useful technique to differentiate OSA from simple snoring with short examination time.


Obstructive Sleep Apnea (OSA) is a common form of sleep-disordered breathing characterized by repetitive episodes of partial or complete upper airway obstruction. It usually causes sleep fragmentation, reduced blood oxygen levels, and excessive daytime somnolence. Cognitive deficits, impaired psychosocial well-being, reduced driving competence, cardiovascular morbidity, and mortality have been reported. Because the clinical significance of OSA is increasing, more exact diagnosis for successful treatment is required. It has been suggested that patients with OSA have narrower pharyngeal airways than normal persons because of fat infiltration, the weight of the soft tissue of the neck, and/or reduced pharyngeal muscle tone.

The identification of the obstruction site of upper airway in patients with OSA is essential in choosing the appropriate treatment, especially surgical intervention. Precise localization of the obstructive sites during sleep has been attempted by a variety of techniques, including nasopharyngoscopy, fluoroscopy, pressure measurements, computed tomographic (CT) scanning, or magnetic resonance imaging. However, there was no gold standard method until now.

Sleep videofluoroscopy (SVF) is a kind of localization technique combining fluoroscopy and video recording and enabling direct visualization of dynamic airway change. Sleep videofluoroscopy in OSA may have a role in the selection of candidates for uvulopalatopharyngoplasty (UPPP). Patients who have experienced airway collapse during apnea epi-
sodes above the midpoint plane of C2 have been thought to be good candidates for UPPP, and 80% of the patients showed good response after UPPP when the selection of patients was appropriate.6 Previous SVF studies showed that the soft palate (SP) acted as a plug in the oropharynx, that the airway closure began in the oropharynx and progressed to the lower levels,7 and that the SP was the main obstruction site (in 75% of patients).6 However, those studies are mainly descriptive and qualitative and lack quantitative results. This study is designed to evaluate dynamic changes in the SP during midazolam-induced sleep (2 mg per person) according to the respiratory phases quantitatively and to analyze the site of upper airway obstruction by SVF.

### METHODS

#### SUBJECTS

From September 2005 through January 2007, 63 consecutive subjects (50 men and 13 women, with a mean age of 46 years [range, 20-67 years]) who visited the sleep center at Seoul National University Bundang Hospital (Seoul, South Korea) for treatment of snoring or sleep apnea were retrospectively included in this study. All the subjects underwent full-night nocturnal polysomnography. Fifty-three patients were diagnosed as having OSA (43 men and 10 women, with a mean age of 47 years [range, 20-67 years]). Their mean (SD) body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) was 27.0 (2.63), the apnea/hypopnea index (AHI) was 38.9 (23.6), and lowest oxygen saturation was 79.3% (7.3%). Fifty-three patients were classified into mild (5 ≤ AHI < 15; n = 7), moderate (15 ≤ AHI < 30; n = 15), or severe (30 ≤ AHI; n = 31) OSA groups according to the severity of their OSA. Ten subjects were diagnosed as simple snorers with an AHI of less than 5 and served as control subjects without OSA (7 men and 3 women, with a mean age of 41 years [range, 22-53 years]). Their mean BMI was 26.3 (2.9). This study was approved by the internal review board of Seoul National University Bundang Hospital.

### SLEEP VIDEOFLUOROSCOPY

All the subjects underwent SVF. The subjects were placed on a C-arm table in supine position with the head on a pillow. They were instructed to breathe in and out naturally. Oxygen saturation was monitored throughout the examination. During the normal respiration before sedation, an awake event was recorded for 15 seconds. Thereafter, sleep was induced by intravenous administration with midazolam, 2 mg per person. After the patients fell asleep, the sleep time examination started. Although the oxygen saturation did not decrease, a 15-second respiratory event was recorded as a normoxgenation sleep event. When oxygen saturation dropped by 4% or more, two 15-second desaturation sleep events were recorded.

Upper airway obstruction was analyzed using the recorded data. The sites of airway obstruction were determined by 2 otolaryngologists (J.-W.K. and C.H.L.) and 1 radiologist (J.-H.K.). The obstruction sites were classified as the SP, tongue base, or both. The length of the SP was defined as the distance from the posterior nasal spine to the uvula tip. The angle of the SP was defined as the angle between the extension of the nasal floor and the uvula tip (Figure 1). Elongation and angulation of the SP were analyzed during 3 different events, respectively: awake event, normoxgenation sleep event, and desaturation sleep event. The percentage change in the SP length or elongation was calculated as follows:

\[
\text{SP Length (Inspiratory Effort)} - \text{SP Length (Expiratory Effort)} \times 100
\]

#### STATISTICAL ANALYSIS

The paired t test and the Mann-Whitney U test were used to compare the parameters according to the obstruction site and the severity of OSA. All parametric results were expressed as mean (SD). A statistical significance of \( P < .05 \) was assumed for all parameters.

### RESULTS

#### SVF FINDINGS IN PATIENTS WITH OSA AND SIMPLE SNORERS

In patients with OSA, all 3 events (awake, normoxgenation sleep, and desaturation sleep events) could be obtained during SVF examination. Two desaturation sleep events were consistent in all the patients with OSA. However, in simple snorers, desaturation sleep events were not observed. Adverse effects due to midazolam did not occur during or after SVF examination.

In awake events, inspiratory efforts increased the length and angle of the SP in patients with OSA but not in simple
Snorers. In patients with OSA, the increase of the SP length and angle was maximal during desaturation sleep events and minimal during awake events. In patients with OSA, the percentage change in the SP length between inspiratory and expiratory efforts was 7.2% (8.9%), 11.7% (14.0%), and 24.9% (21.0%) during awake, normoxygenation, and desaturation sleep events, respectively (P < .01). In contrast, in control subjects, the percentage change in the SP length was 0% and 3.5% (7.7%) during the awake and normoxygenation sleep events, respectively (Figure 2A). The percentage change in the SP length was related to the disease severity of OSA. The percentage change of SP length was 15.2% (7.5%), 17.4% (6.1%), and 26.6% (10.5%) in mild, moderate, and severe OSA, respectively, during desaturation sleep events (P < .05) (Figure 3). Age, BMI, and lowest oxygen saturation did not affect the change in the SP (data not shown).

Figure 2. Changes in the soft palate (SP). A, Changes in SP length, and B, in SP angle, in simple snorers and patients with obstructive sleep apnea (OSA) according to the sedation and oxygen saturation. Although all the patients with OSA showed desaturation sleep events, those events were not observed in simple snorers. In patients with OSA, the changes in the SP length and angle were greatest during the desaturation sleep event and least during the awake events.

Figure 3. Change in the soft palate (SP) length according to the obstruction sites. The change in the SP length was greater when the obstruction site was at the SP level than when it was at the tongue base level (TB) or both (mixed). Error bars indicate standard deviations.

Obstruction sites could be identified during desaturation sleep events of SVF. The mixed type (SP plus tongue base) was most common (23 [43.5%]), followed by SP type (18 [34.0%]) and tongue base type (12 [22.5%]). During desaturation sleep events, the percentage change in SP length was 34.5% (14.3%), 17.1% (9.2%), and 24.5% (16.5%) in SP, mixed, and tongue base types, respectively (P < .05) (Figure 3). The percentage change in the SP length was related to the disease severity of OSA. The percentage change of SP length was 15.2% (7.5%), 17.4% (6.1%), and 26.6% (10.5%) in mild, moderate, and severe OSA, respectively, during desaturation sleep events (P < .05) (Figure 4). Age, BMI, and lowest oxygen saturation did not affect the change in the SP (data not shown).

This study was designed to quantitatively evaluate the changes in the SP during low-dose midazolam-induced sleep using SVF. Although several studies have already reported the changes in the upper airway, most of them have limitations in that the studies were performed while the patients were awake or in that they used static images. However, SVF can provide dynamic images while the patients are asleep for a short period of time. Therefore, it can be useful in detecting dynamic airway obstruction sites during sleep. Furthermore, it easily shows what is happening in the anatomic structures outside the pharyngeal airway. For instance, movements of the cervical spine, downward motion of the

**COMMENT**

Snorers. In patients with OSA, the increase of the SP length and angle was maximal during desaturation sleep events and minimal during awake events. In patients with OSA, the percentage change in the SP length between inspiratory and expiratory efforts was 7.2% (8.9%), 11.7% (14.0%), and 24.9% (21.0%) during awake, normoxygenation, and desaturation sleep events, respectively (P < .01). In contrast, in control subjects, the percentage change in the SP length was 0% and 3.5% (7.7%) during the awake and normoxygenation sleep events, respectively (Figure 2A). The percentage change in the SP length was related to the disease severity of OSA. The percentage change of SP length was 15.2% (7.5%), 17.4% (6.1%), and 26.6% (10.5%) in mild, moderate, and severe OSA, respectively, during desaturation sleep events (P < .05) (Figure 3). Age, BMI, and lowest oxygen saturation did not affect the change in the SP (data not shown).
hyoid bone, and jaw movements can be directly observed.

Many investigators reported that the oropharyngeal level was the narrowest region of the upper airway and that this level was the most affected part of the pharynx in patients with OSA.\textsuperscript{3-5,\textsuperscript{10,\textsuperscript{14}}} One study showed that patients with OSA had the narrowest cross-sectional area at the level of the uvula,\textsuperscript{13} and some reported that a longer and thicker SP was commonly seen in patients with OSA.\textsuperscript{10,\textsuperscript{16,\textsuperscript{17}}} However, these studies were based on the static cephalometric analysis or CT scan, so they lack analysis of dynamic feature of upper airway obstruction in awake as well as sleep states.

Although a cephalometric study could not distinguish patients with OSA from normal controls,\textsuperscript{16} a CT scan study showed that the retropalatal cross-sectional area was narrower in patients with OSA than in controls.\textsuperscript{7} Considering the fact that all patients with OSA, not simple snorers, have desaturation sleep events in SVF, it can be used to differentiate simple snorers from patients with OSA. We could also obtain from SVF information on the severity of OSA and obstruction sites. In patients with OSA, the changes in the SP reflected the severity of OSA. Although it is not definite whether the obstruction sites identified in SVF for a short period of time can represent full-night events, a study\textsuperscript{6} using somnofluoroscopy suggested that upper airway dynamics seem to be consistent within a given patient.

In our study, a dynamic change in the SP was measured quantitatively. Several studies\textsuperscript{10,\textsuperscript{12,\textsuperscript{17}}} have shown absolute differences in the upper airway structures. Because there are individual differences in the baseline length or angle of the SP while the subjects are awake or asleep, absolute comparison of the characteristics of the SP could lead to wrong interpretation. That is why we focused on the changes in the SP according to the respiratory phase. This study showed that patients with OSA had significantly greater elongation of the SP during desaturation sleep events than awake events ($P < .01$). Interestingly, the change in the SP length was larger in normoxegenation sleep events than in awake events. This finding shows that the SP became more redundant or compliant during sleep without sleep-disordered breathing.

There were notable differences in the SP changes between controls and patients with OSA in awake or normoxegenation sleep events. One study also showed that the oropharyngeal airway of patients with OSA was more compliant than the airway of healthy volunteers during resting tidal breathing.\textsuperscript{11} These findings indicate that patients with OSA might have an irreversible anatomical change in the SP owing to OSA, or at least possess pre-disposing anatomical characteristics in the SP resulting in OSA.

Our results provide some useful information on the pathophysiologic characteristics of OSA. However, this study also has some limitations. Only some—not all—sleep events were selected for recording, sleep staging was not scored, and sleep was induced by drug administration. Whether midazolam-induced sleep can represent physiologic sleep is controversial.\textsuperscript{10} Drug-induced sleep has a shorter duration of rapid eye movement sleep and has only 1 supine body position. Another criticism is that 45% of normal subjects snore under sedation and that 10% of snorers do not snore under sedation.\textsuperscript{19} In contrast, a study\textsuperscript{20} that compared nocturnal polysomnography with diazepam-induced sleep monitored by polysomnography showed that there is no significant difference in type of apnea in terms of apnea index, desaturation index, or mean maximal esophageal pressure. This study tells us that there is some validity in the idea that drug-induced sleep represents normal sleep.

Nevertheless, information from SVF might be helpful to determine the obstruction sites and the treatment option, such as surgery, continuous positive airway pressure treatment, or oral appliances. And, if surgery is selected as a treatment, it might also be used for quantitative comparison between pretreatment and posttreatment states of the upper airway.

**CONCLUSIONS**

Sleep videofluoroscopy showed dynamic changes in the upper airway during either awake or asleep events. It can be performed for a short period of time and can provide useful information on the obstructive events of the upper airway. In patients with OSA, the SP was considerably elongated and angulated during sleep. The SP changes were observed even in normoxegenation sleep events as well as in desaturation sleep events. In contrast, desaturation sleep events were not observed in simple snorers. In addition, SP changes were most notable in patients with a severe degree of OSA and in patients with SP-type obstruction. Sleep videofluoroscopy is a complementary diagnostic tool that can be easily performed, especially for surgeons who need to know where and how the obstruction occurs.

Submitted for Publication: January 9, 2008; final revision received April 14, 2008; accepted May 12, 2008. Correspondence: Jeong-Whun Kim, MD, PhD, Department of Otorhinolaryngology, Seoul National University Hospital, Seoul, South Korea.
Author Contributions: All authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Drs Lee and Mo contributed equally to this work. Study concept and design: Lee, Yoon, and J.-W. Kim. Acquisition of data: Lee, Mo, Chung, J.-H. Kim, and J.-W. Kim. Analysis and interpretation of data: B. J. Kim and Kong. Drafting of the manuscript: Lee, Mo, and J.-W. Kim. Critical revision of the manuscript for important intellectual content: Lee, B. J. Kim, Kong, Yoon, Chung, and J.-H. Kim. Statistical analysis: Mo, Kong, and Chung. Obtained funding: Lee and J.-W. Kim. Administrative, technical, and material support: B. J. Kim and J.-H. Kim. Study supervision: Lee, Mo, Kong, Yoon, and J.-W. Kim.

Financial Disclosure: None reported.

REFERENCES


