ELSEVIER

Sleep Medicine 2 (2001) 309–315

SLEEP MEDICINE

www.elsevier.com/locate/sleep

Original article

Pattern of upper airway obstruction during sleep before and after uvulopalatopharyngoplasty in patients with obstructive sleep apnea

A.N. Boudewyns[a,*], W.A. De Backer[b], P.H. Van de Heyning[a]

[a]*Department of Otorhinolaryngology, Head and Neck Surgery, University Hospital Antwerp, Wilrijkstraat 10, 2650 Edegem, Belgium*
[b]*Department of Pulmonary Medicine, University of Antwerp, Antwerp, Belgium*

Received 21 June 2000; received in revised form 10 October 2000; accepted 14 October 2000

Abstract

Objective: To investigate the pre-and postoperative pattern of upper airway obstruction in obstructive sleep apnea (OSA) patients treated by uvulopalatopharyngoplasty (UPPP).

Background: The response rate to UPPP in unselected OSA patients is generally about 50%.

Methods: Intraluminal pressure measurements during sleep were employed to analyze the pattern of upper airway obstruction before and after surgery.

Results: Ten patients with mild to moderate OSA (respiratory disturbance index 19.7 (16.9–27.5) events/hr underwent a full night polysomnography before and 114 (6 1–138) days after UPPP. UPPP resulted in a significant improvement in subjective snoring and daytime sleepiness, but did not significantly alter the severity of sleep-disordered breathing. Preoperatively, the major site of obstruction was located at the oropharynx in nine patients, seven of them had additional minor obstruction sites outside the oropharynx. Complete relief of upper airway obstruction was only observed in those two patients with collapse confined to the oropharynx.

Conclusions: In unselected OSA patients, UPPP improved subjective snoring and daytime sleepiness but did not result in a significant improvement in RDI or sleep architecture. Our results emphasize the need for a pre-operative investigation of the upper airway during sleep to select patients with collapse confined to the oropharynx.

Keywords: Uvulopalatopharyngoplasty; Sleep apnea; Upper airway obstruction; Snoring; Daytime sleepiness

1. Introduction

The results of uvulopalatopharyngoplasty (UPPP) for the treatment of obstructive sleep apnea are often perceived to be disappointing. In unselected OSA patients, the success rate (defined as reduction of the respiratory disturbance index (RDI) by at least 50% and RDI <20 events/h) is generally around 50%.

There is increasing evidence that the site of upper airway obstruction is an important predictor of the success of uvulopalatopharyngoplasty in the treatment of obstructive sleep apnea. Nevertheless, the data from a meta-analysis by Sher et al. [l] indicate that only 50.2% of patients with retropalatal obstruction could be classified as responders. This implies that even among 'good surgical candidates'; about 50% of the patients are not appropriately treated by

* Corresponding author. Tel.: +32-3-821-33-85; fax: +32-3-821-05-36.

E-mail address: an.boudewijns@uza.uia.ac.be (A.N. Boudewyns).

1389-9457/01/$ - see front matter
PII: S1389-9457(00)00095-2

UPPP alone. It is now well accepted that dynamic studies during sleep should be employed to accurately determine the site of upper airway obstruction [2]. The papers included in the analysis by Sher et al. [1] utilized different techniques (during wakefulness or sleep) to determine the site of upper airway obstruction. This may be one possible explanation why only 50.2% of the patients with 'retropalatal' obstruction were effective responders. Another likely explanation may be the dependence of the site of obstruction on sleep stage or body position. We have previously demonstrated that the majority of patients with obstructive sleep apnea have more than one site of upper airway obstruction during sleep and that sleep stage influences the pattern of upper airway obstruction [3].

The aim of the present investigation was to provide an answer to the following question: what is the pre- and postoperative pattern of upper airway obstruction observed in OSA patients who do or do not respond to UPPP? Therefore, upper airway pressure measurements were made pre-and postoperatively in a group of OSA patients undergoing UPPP. UPPP was performed in these patients, irrespective of the preoperative site of obstruction.

2. Materials and methods

Ten consecutive OSA patients, scheduled for UPPP at the ENT department of the University Hospital Antwerp, Belgium underwent intraluminal pressure measurements during sleep to determine the site of upper airway obstruction. The sleep studies were performed at the Sleep Disorders Unit of the University Hospital Antwerp. Full night polysomnography with upper airway pressure measurements was performed as outlined previously [3]. In brief, continuous recordings were made of electro-encephalography (EEG) (C4/Al and C3/A2); electrooculography (EOG); electromyography (EMG) of anterior tibialis and chin muscles, cardiac frequency. Respiratory effort was measured by thoracoabdominal strain gauges and oxygen saturation by a finger probe connected to a pulse oximeter (Palco Laboratories, Santa Cruz, CA). Oronasal airflow was measured by means of a thermistor or pneumotachometer and snoring was detected by means of a microphone at suprasternal notch. This provides a qualitative signal, indicating the absence or presence of snoring. Pressures in the upper airway and esophagus were measured continuously by means of a pressure catheter (Response III, Medtronic Upper Airway, Minneapolis, MN) connected to a pressure transducer. Design and positioning of the catheter have been described previously [3]

Polysomnographic data were manually scored for sleep stage, respiratory events and site of upper airway obstruction. Sleep stages were scored as outlined by Rechtschaffen and Kales [4]. An apnea was defined as the complete absence of oronasal airflow for at least 10 s. Apneas were classified as obstructive, mixed or central according to standard criteria [5]. An hypopnea was scored when a $\geq$50% reduction of airflow persisted for a minimum of 10 s and was followed by a $\geq$4% drop in oxygen saturation and/or arousal. The respiratory disturbance index (RDI) was calculated as the total number of apneas + hypopneas/hour of sleep. Response to UPPP was defined as a post-operative reduction in RDI of at least 50%. The site of upper airway obstruction was determined for all obstructive and mixed apneas as outlined previously [3]. The following sites of upper airway obstruction were recognized: nasopharynx: between sensor N and P (NP), oropharynx: between sensor P and O (PO), tongue base: between sensor O and L (OL) (Fig. 1). The percentage of the total amount of apneas at a particular site of the upper airway was calculated. The major site of obstruction was defined as the upper airway segment at which collapse occurred for more than 50% of the apneas. A minor site of obstruction was defined as an upper airway segment at which upper airway obstruction occurred for less than 50% of the apneas. Snoring time refers to the total amount of time (minutes) a snoring signal was present during polysomnography.

Pre- and postoperatively, we administered a standard questionnaire to assess snoring (SN score) (Table 1) and the Epworth sleepiness score. In addition, body mass index was measured and lung function tests and arterial blood gas analysis were performed at both visits. UPPP was performed as described by Simmons et al. [6]. Anthropometric and polysomnographic data obtained before and after UPPP are compared by Wilcoxon Matched Pairs test. Data are presented as median (lower-upper quartile). Statistical analysis

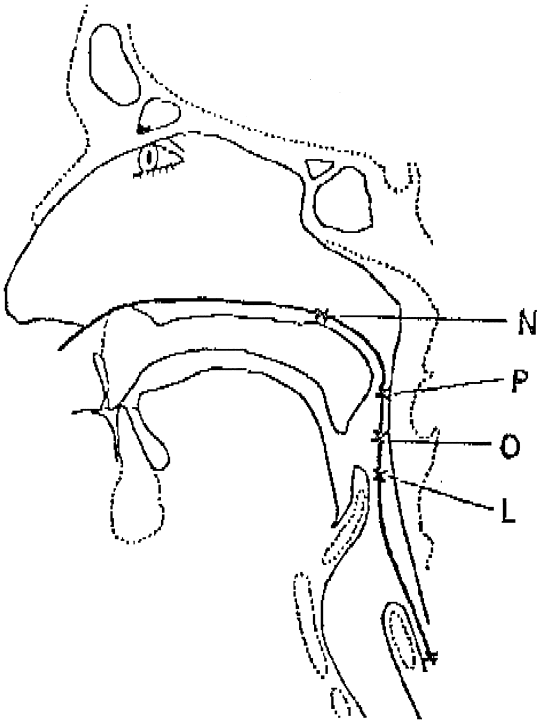

Fig. 1. Schematic respresentation of the positions of different sensors in the upper airway and oesophagus. Sensor N, at the posterior choanae; sensor P, at the inferior margin of the soft palate behind the uvula; sensor O, at the tongue base; sensor L, at the tip of the epiglottis, sensor

was performed with the StatSoft software package (1996, version 5, StatSoft Inc, Tulsa, OK).

3. Results

The baseline characteristics of the patients are presented in Table 2. As a group, the patients were middle aged, borderline obese and all but one complained of socially disturbing snoring (SN score = 4). Arterial blood gases were collected in nine patients. One of them was hypoxemic ($PaO_2 < 65$ mmHg) but none was hypercapnic ($PaCO_2 > 45$ mmHg) during the daytime. Baseline polysomnography revealed a mild to moderate OSA (median RDI 19.8 events/h).

The time between UPPP and the post-operative polysomnography was 114 (61–138) days. Body mass index, arterial blood gases and spirometric values remained unchanged (Table 3). The effect of UPPP on snoring, daytime somnolence and polysomnographic variables is displayed in Table 3. UPPP resulted in a significant improvement of both subjective snoring and snoring time. In two patients, socially disturbing snoring persisted after surgery (SN score = 4). All but one patient were found to snore during the post-operative polysomnography. Excessive daytime sleepiness significantly improved after UPPP. This was not accompanied by a significant improvement in sleep architecture. UPPP did not result in a significant improvement in the RDI. However, on an individual basis the RDI decreased by more than 50% of the pre-operative value in four patients who therefore may be classified as responders. The results of the pressure measurements are listed in Table 4 and graphically displayed in Fig. 2. Pre-operatively (Fig. 2A), eight patients were found to have a major site of obstruction at the oropharynx and in two of them this was the only site of upper airway obstruction. The other six patients had a major site at the oropharynx with minor sites of obstruction at the nasopharynx or tongue base. One patient had a major site at the nasopharynx and another at the base of the

Table 1
Question: do you snore?

Score 0 = never snoring
Score 1 = Snoring from time to time, only when lying on the back
Score 2 = continuous heavy snoring, only when lying on the back
Score 3 = heavy snoring in all positions
Score 4 = heavy snoring, socially disturbing

Table 2
Patient characteristics at baseline[a]

Parameter	Median (upper-lower quartile)
BMI (kg/m^2)	27.6 (25.0–30.1)
Age (years)	47.0 (44.0–51.0)
PaO2 (mmHg)	84.0 (8 1.0–88.0)
PaCO2 (mmHg)	37.0 (3 5.0–40.0)
FEV1 (% pred)	103.0 (101.0—108.0)
FVC (% pred)	103.0 (98.0—108.0)
SN score	4 (4–4)
ESS score	11.5 (7.0–17.0)

[a] BMI, body mass index; FEV1, forced expiratory volume in 1 s; FVC, vital capacity; SN score, snoring score; ESS score, Epworth sleepiness score.

Table 3
Results of UPPP[a]

Parameter	Before UPPP	After UPPP	*P* value
BMI (kg/m ^{2})	27.6 (25.1–30.1)	27.5 (25.3–30.0)	Ns
PaO_2 (mmHg)	84.0 (81.0–88.0)	85.0 (81.0–90.0)	Ns
$PaCO_2$ (mmHg)	37.0 (35.0–40.0)	37.5 (37.0–41.0)	Ns
SN score	4 (4–4)	1 (0–2)	0.007
ESS score	11.5 (7.0–17.0)	5.0 (3.0–8.0)	0.005
TST (min)	338.0 (300–375.5)	349.0 (326.0–376.5)	Ns
Wake (min)	154.7 (117.5–203.0)	115.2 (103.0–133.0)	Ns
NREM (min)	312. 7 (251.0–317.0)	300.5 (279.0–317.5)	Ns
REM (min)	54.7 (3 6.0–67.5)	63.0 (50.0–84.0)	Ns
Sleep efficiency (%)	67.8 (57.8–75.1)	73.7 (70.8–75.9)	Ns
ARI (n/h) ($n = 5$)	24.6 (19.1–42.1)	24.2 (21.5–29.8)	Ns
RDI (n/h)	19.8 (16.9–27.5)	17.5 (8.2–44.5)	Ns
Mean Saturation (%)	93.0 (91.0–95.0)	94.0 (93.0–94.0)	Ns
Snoring time (min)	109.2 (88.3–246.9)	32.8 (18.1–86.7)	0.01

[a] BMI, body mass index; SN score, snoring score; ESS score, Epworth Sleepiness score; TST, total sleep time; NREM, non-rapid eye movement sleep; REM, rapid eye movement sleep; ARI, arousal index; RDI, respiratory disturbance index.

tongue before surgery. Only those two patients with a major site at the oropharynx without minor sites of obstruction had a postoperative RDI <5 events/h and complete relief of upper airway obstruction. In all the other cases, obstructive apneas or hypopneas were found to persist. In four patients (VW, TH, JA, PI), the major site of obstruction was the same pre-and postoperatively. In others, the major site shifted towards a more upstream (NO, MO) or downstream segment of the upper airway (E, DE). The distribution of post-operative sites of obstruction is illustrated in Fig. 2B.

4. Discussion

We demonstrated that UPPP results in a significant improvement in subjective snoring and daytime somnolence in patients with mild to moderate obstructive sleep apnea. For the group of patients as a whole,

Table 4
Respiratory disturbance index and percentage of apneas with obstruction at the nasopharynx, oropharynx and base of the tongue OL before and after UPPP[a]

Case	Before UPPP				After UPPP			
	NP (%)	PO (%)	OL (%)	RDI	NP (%)	PO	OL	RDI
VW	**87**	13		16.6	**100**			21.5
RA		**100**		20.9				0.5
NO	24	**76**		29.8	**95**	5		44.5
TH	7.3	**91.7**	1.0	66.8	9.8	**61.8**	28.4	66.1
JA		93	7	18.5	5.7	**51.4**	42.8	47.1
VE	16.7	**83.3**		27.5	25	25	**50**	21.0
OP		**100**		16.9				0.6
MO		**86.8**	13.2	18.7	**54.8**	45.2		8.2
DE	10.9	**89.1**	0	27.5			**100**	11.5
PI		40.9	**59.1**	14.0			**100**	14.0

[a] NP, nasopharynx; PO, oropharynx; OL, base of the tongue. The major site of obstruction is indicated in bold.

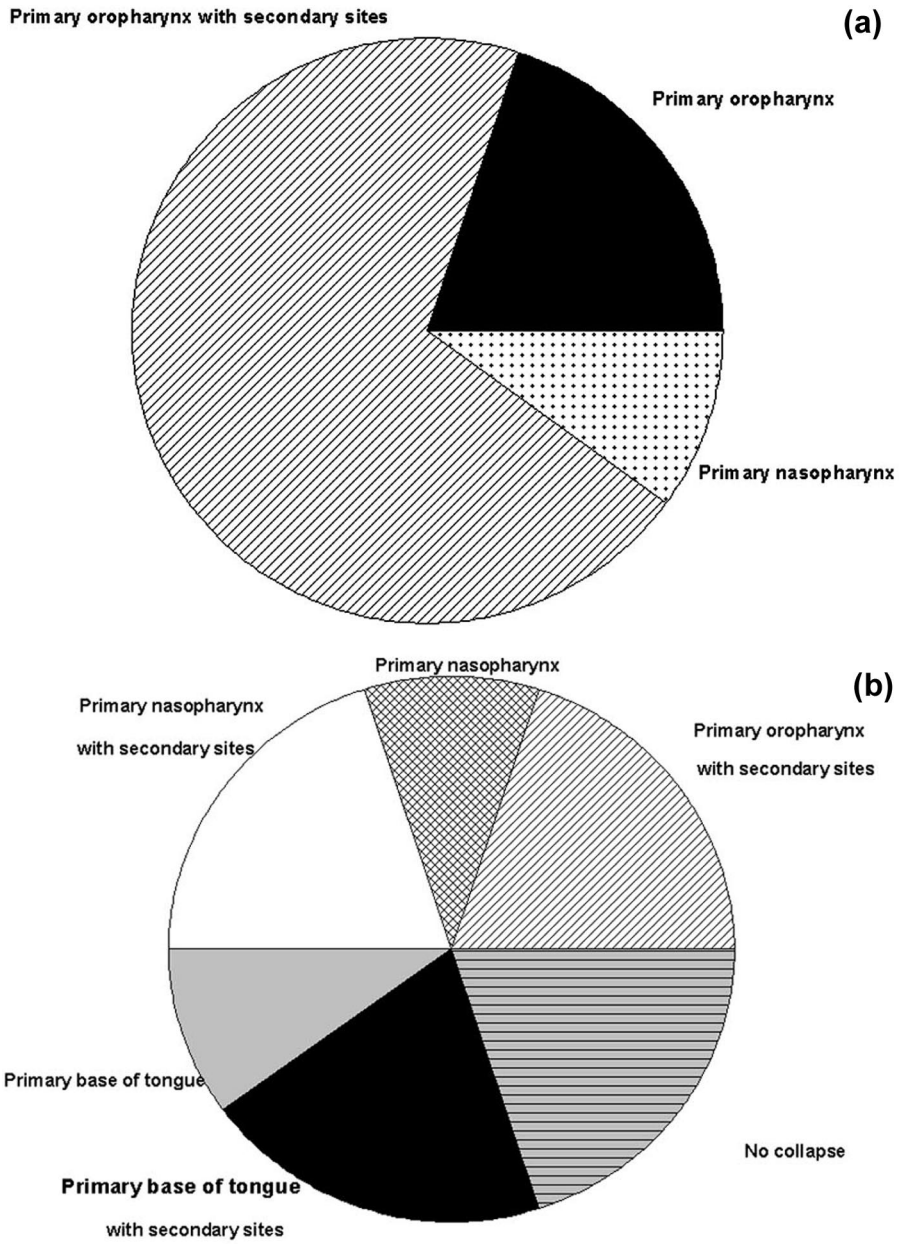

Fig. 2. Distribution of primary and secondary sites of obstruction (A) before; and (B) after UPPP.

no significant improvement in RDI could be documented. Data from intraluminal pressure measurements suggest that UPPP is successful in relieving upper airway obstruction in patients with a major and unique site of collapse at the oropharynx. In contrast, those patients with a major obstruction site outside the oropharynx or those with a major site at the oropharynx and minor sites of obstruction at other pharyngeal levels, tend to be insufficiently treated by UPPP alone. Additionally, failure of UPPP in OSA patients could be attributed to persistence of upper airway obstruction both in the oropharynx but also

at more proximal or distal levels of the pharynx (nasopharynx or base of the tongue, respectively).

In our OSA patients, a significant improvement in both subjective and objective snoring as well as in excessive daytime sleepiness was found after UPPP despite the lack of an improvement in RDI or sleep stage distribution. Several methodological difficulties exist for both the subjective and objective evaluation of snoring [7,8]. The validity of self-reported snoring is likely to vary by demographic, psychosocial and other factors such as age, sex, ethnicity, health status, and household composition [9]. In addition, although various techniques allow the objective measurement of snoring, there is as yet no standard and uniformly accepted technique available. Probably the most important drawback of all measurements is the lack of a biologic validation [10].

We found a significant improvement in daytime sleepiness without a major improvement in respiratory disturbance index. This is in line with previous studies, indicating that there is no close relationship between nocturnal measures of sleep-disordered breathing such as RDI or oxygen saturation, and daytime function [10]. We hypothesize that changes in arousals from autonomic variables or spectral EEG features may more closely correlate with the improvement in daytime sleepiness after UPPP in OSA patients.

The discrepancies between the improvement in subjective snoring and daytime sleepiness and the polysomnographic data on snoring, RDI and sleep architecture underscore the need for a postoperative polysomnography to objectively document the efficacy of the surgical procedure.

We previously demonstrated that the majority of OSA patients have multiple sites of upper airway obstruction during sleep [3]. Based on the present report, we could further document that only one of our patients with multiple sites of obstruction could be classified as a responder. These results are consistent with data published by Morrison et al. [11], Launois et al. [12] and Isono et al. [13].

Performing intraluminal pressure measurements after UPPP allowed us to investigate the possible explanation for failure with respect to the pattern of upper airway obstruction.

The post-operative data illustrated the persistence of a major obstruction site at the oropharynx in two patients and a shift towards a more proximal or distal site in two and three patients respectively. Five patients still had oropharyngeal collapse after surgery. Cephalometric studies have demonstrated that the remaining portion of the soft palate may become thickened with a bulbous appearance and that this may account for the persistence of retropalatal obstruction in UPPP failures [14]. Another attractive, yet unproven explanation, is that patients with multiple sites of upper airway obstruction have a more collapsible upper airway (higher closing pressure) and that the reduction in upper airway collapsibility that can be achieved with UPPP is insufficient to restore a normal breathing pattern in these subjects [15,16].

Our data illustrate the need for a pre-operative investigation of the upper airway to determine the site of obstruction, in each OSA patient considered for UPPP. Only in this way, can the outcome of this procedure be improved.

Intraluminal pressure measurements provide information about upper airway dynamics during sleep and are usually well tolerated. Previous investigators demonstrated that this technique induces only minor changes in sleep architecture which are unlikely to affect the conclusions drawn from this type of investigation [17,18]. Data can be recorded during the whole night, which allows one to investigate the effect of sleep stage and body position on the observed pressure pattern. Finally, this technique is less invasive and easier to perform than other dynamic studies such as the single breath technique described by Morrison et al. [11] and Launois et al. [12] and does not require general anesthesia as in the studies by Isono et al. [13]

Although the number of patients with obstructive sleep apnea in our study is small, our findings and data from the literature suggest that patients with multiple sites of upper airway obstruction and those with a single site of obstruction located outside the oropharynx are unlikely to benefit from UPPP as a single treatment procedure. Intraluminal pressure measurements may provide useful information on upper airway dynamics during sleep upon which appropriate treatment selection can be based. In addition, information may be gained about the pattern of upper airway obstruction in cases of UPPP failure and thus be helpful in the subsequent management of these patients.

Three months is a relatively short follow-up time after UPPP. In the literature, the results of UPPP have been investigated at variable time intervals. Scar tissue formation is thought to be complete after 3 months and therefore this was felt to be an appropriate follow-up time. Some authors advocate a 6 months follow-up time but there are no studies available validating this approach [19].

5. Conclusions

UPPP resulted in a significant improvement of snoring and excessive daytime sleepiness but not in sleep-disordered breathing in unselected OSA patients. Failure of UPPP could be attributed to the persistence of upper airway obstruction at different levels of the oropharynx. Our data suggest that persistence of sleep-disordered breathing in OSA patients may be attributed to multiple sites of upper airway obstruction and that patients with upper airway collapse restricted to the oropharynx are most likely to benefit from UPPP as a single treatment procedure.

References

[1] Sher AE, Schechtman KB, Piccirillo JF. The efficacy of surgical modifications of the upper airway in adults with obstructive sleep apnoea syndrome. Sleep 1996;19:156–177.
[2] Pépin JL, Ferretti G, Veale D, Romand P, Coulomb M, Brambilla C, Levy P. Somnofluoroscopy, computed tomography, and cephalometry in the assessment of the airway in obstructive sleep apnoea. Thorax 1992;47:150–156.
[3] Boudewyns A, Van de Heyning PH, De Backer WA. Site of upper airway obstruction in obstructive sleep apnoea and influence of sleep stage. Eur Respir J 1997;10:2566–2572.
[4] Rechtschaffen A, Kales A. A manual of standardized terminology, technique and scoring systems for sleep stages of human subjects. Los Angeles, CA, Brain Information 1968.
[5] Diagnostic Classification Steering Committee of the American Sleep Disorders Association. Sleep apnea syndrome. In: Thorpy MJC, editor. The international classification of sleep disorders. Diagnostic and coding manual, Lawrence, KS: Allen Press Inc, 1990. pp. 52–64.
[6] Simmons B, Guilleminault C, Miles CE. The palatopharyngoplasty operation for snoring and sleep apnea. Otolaryngol Head Neck Surg 1984;92:375–380.
[7] Miljeteig H, Mateika S, Haight JSJ, Cole P, Hoffstein V. Subjective and objective assessment of uvulopalatopharyngoplasty for treatment of snoring and obstructive sleep apnea. Am J Respir Crit Care Med 1994;150:1286–1290.
[8] Hoffstein V, Mateika S, Nasch S. Comparing perceptions and measurements of snoring. Sleep 1996;19:783–789.
[9] Young TB. Some methodologic and practical issues of reported snoring validity. Chest 1991;99:531–532.
[10] Kingshott RN, Engleman HM, Deary IJ, Douglas NJ. Does arousal frequency predict daytime function? Eur Respir J 1998;12:1264–1270.
[11] Morrison DL, Launois SH, Isono S, Feroah TR, Whitelaw WA, Remmers JE. Pharyngeal narrowing and closing pressures in patients with obstructive sleep apnea. Am Rev Respir Dis 1993;148:606–611.
[12] Launois SH, Feroah TR, Campbell WN, Issa FG, Morrison DL, Whitelaw WA, Isono S, Remmers JE. Site of pharyngeal narrowing predicts outcome of surgery for obstructive sleep apnea. Am Rev Respir Dis 1993;147:182–189.
[13] Isono S, Shimada A, Tanaka A, Tagaito Y, Utsugi M, Konno Y, Nishino T. Efficacy of endoscopic static pressure/area assessment of the passive pharynx in predicting uvulopalatopharyngoplasty outcomes. Laryngoscope 1999;109:769–774.
[14] Langin T, Pépin JL, Baranton-Cantin H, Righini G, Reyt E, Levy P. Upper airway in snorers and moderate sleep apnoea after uvulopalatopharyngoplasty (UPPP). Eur Respir J 1996;9:154s.
[15] Schwartz AR, Schubert NM, Rothman W, Godley F, Marsch B, Eisele DW, Nadeau J, Permutt L, Gleadhill IC, Smith PL. Effect of uvulopalatopharyngoplasty on upper airway collapsibility in obstructive sleep apnea. Am Rev Respir Dis 1992;145:527–532.
[16] McWhorter AJ, Rowley JA, Eisele DW, Smith PL, Schwartz AR. The effect of tensor veli palatini stimulation on upper airway patency. Arch Otolaryngol Head Neck Surg 1999;125:937–940.
[17] Chervin RD, Aldrich MS. Effects of oesophageal pressure monitoring on sleep architecture. Am J Respir Crit Care Med 1997;56:881–885.
[18] Skatvedt O, Akre H, Godtlibsen OB. Nocturnal polysomnography with and without continuous pharyngeal and oesophageal pressure measurements. Sleep 1996;19:485–489.
[19] Pépin JL, Veale D, Mayer D, Bettega G, Wuyam B, Levy P. Critical analysis of the results of surgery in the treatment of snoring, upper airway resistance syndrome (UARS), and obstructive sleep apnea (OSA). Sleep 1996;19:S90–S100.