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Assessment of Sleep Impairment in Persistent Allergic Rhinitis Patients Using Polysomnography

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Key Words
Persistent allergic rhinitis · Polysomnography · Sleep impairment · Peak nasal inspiratory flow

Abstract
Background: Although questionnaires have demonstrated an association between impairment of quality of sleep and symptoms in allergic rhinitis (AR) patients, to date there is no report of an objective assessment of sleep in patients with persistent allergic rhinitis (PER) as defined by ARIA guidelines. The aim of the present study was therefore to assess sleep disturbance in PER patients by polysomnography (PSG). ***Methods:*** Ninety-eight PER patients with moderate-to-severe nasal obstruction and 30 healthy volunteers were included in the study. All patients underwent PSG during nocturnal sleep to assess the presence and severity of sleep disorders. Peak nasal inspiratory flow (PNIF) was also measured to assess nasal resistance. ***Results:*** There were statistically significant, though clinically modest, differences between PER patients and healthy controls in most PSG parameters including sleep efficiency, arousal index, average SaO_2, lowest SaO_2, time spent with a saturation below 90%, and snoring time. Although the apnea-hypopnea index (AHI) was not significantly different between the 2 groups, 17 subjects (17.3%) in the PER group but none of the control subjects had an AHI >5. Patients with higher T5SS scores ($12 \leq T5SS \leq 15$) had a greater tendency to snore than did patients with lower scores ($8 \leq T5SS \leq 11$). Finally, PNIF in the PER group was significantly lower than in the control group. Weak correlations between the arousal index and PNIF, average SaO_2, and PNIF were found. ***Conclusion:*** PSG showed modest changes in PER patients versus control subjects.

Introduction

Allergic rhinitis (AR) is a global health problem that places a considerable burden both on individual patients and society. While earlier studies have estimated that the prevalence of AR in Europe ranges from 23 to 30% [1, 2], a recent study from China has indicated that the prevalence of AR across cities in mainland China ranges from 8.7 to 24.1% [3]. Although AR is not a life-threatening condition, the symptoms of nasal itching, sneezing, rhinorrhoea, and nasal congestion/obstruction are often

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bothersome and may significantly impair the quality of life of patients [4]. Moreover, a large number of AR patients experience daytime somnolence, fatigue, depression, and memory deficits, which may be related to sleep disturbance.

Indeed, several studies have indicated that that there may be an association between AR-induced nasal obstruction and snoring and daytime sleepiness [5–7]. More recently, Stull et al. [8] performed a prospective real-life study in 404 AR patients to assess the impact of nasal congestion and morning AR symptoms on patients' reports of sleep, daytime sleepiness, fatigue, and activity impairment using a battery of patient-reported outcomes. The authors demonstrated that nasal congestion significantly impacted patients' lives adversely and increased the likelihood of sleep problems, fatigue, shortness of breath, and daytime somnolence. In another cross-sectional study, Léger et al. [9] investigated the relationship between the severity/duration of AR and sleep disorders and sleep quality in 591 patients with AR in several centers across France using several self-administered questionnaires. These authors demonstrated that AR impaired all dimensions of sleep, with significantly greater impairments noted in patients with more severe AR than in patients with mild AR. The duration of AR (intermittent or persistent), however, did not affect sleep.

While questionnaires undoubtedly provide useful information on AR-associated sleep disorders, these may nevertheless be insufficient for the accurate assessment of specific aspects of sleep disorders as evaluated by polysomnography (PSG), the gold standard for the objective evaluation of sleep disorders. While PSG has been employed to assess sleep impairment in patients with seasonal AR [10] and perennial AR [11], to date no study has objectively assessed AR-induced sleep impairment/disturbances in patients with persistent allergic rhinitis (PER) defined according to ARIA guidelines [12]. The aim of the present study was therefore to assess sleep disturbance in symptomatic PER patients using PSG and to compare this with any sleep disturbance in nonrhinitic healthy individuals.

Methods

Subjects

The study was conducted at the Department of Otorhinolaryngology, West China Hospital, Sichuan University. Male and female subjects aged 18–60 years with a history of PER for at least 2 years, as defined according to ARIA guidelines [12], were enrolled into the study. The diagnosis of AR was further confirmed on the basis of a clinical physical examination and positive skin prick test (wheal ≥3 mm larger than the diluent control) to commercially available allergens (Allergopharma, Reinbek, Germany). All subjects were additionally required to demonstrate the presence of sufficiently severe symptoms, assessed according to a 4-point scale.

Healthy male and female subjects aged 18–60 years served as controls. They were recruited from among students of Sichuan University, the employees of West China Hospital, and their families.

Patients who had taken any medication which could significantly impact the symptoms of AR, or any medication which was not permitted during a washout period prior to entry into the study were excluded. Controls who had a positive skin prick test were excluded. Similarly, patients and controls with significant septal deviation, nasal polyps, acute or chronic rhinosinusitis, any clinically significant condition, or any other underlying pathology which might affect nasal breathing or nocturnal sleep, such as asthma or lower respiratory infection, were excluded; subjects with a history of alcohol abuse, pregnant or lactating women, and subjects who did not understand the study procedures were also excluded.

Study Design

Eligible PER patients scored the severity of 5 symptoms, i.e. nasal obstruction, rhinorrhoea, nasal itching, sneezing, and ocular complaints, on a scale of 0–3 [Total 5 Symptom Score (T5SS) [13, 14]; 0 = symptom not present; 1 = mild, symptom present but not bothersome; 2 = moderate, symptom bothersome but easily tolerated, and 3 = severe, symptom difficult to tolerate] at a clinical screening visit and each evening for a week. Patients with a screening and daily mean T5SS ≥8 (range 0–15) and a nasal obstruction score ≥2 (range 0–3) were assessed for the presence and severity of sleep disorders using PSG. PSG was performed and peak nasal inspiratory flow (PNIF) was measured within 1 week after the screening period.

The study was approved by the Ethics and Clinical Research Committee of West China Hospital, Sichuan University, and performed in accordance with ICH Good Clinical Practice regulations and the principles of the Declaration of Helsinki. All patients also provided their written informed consent to take part in the study.

Polysomnography

A PSG device (Alice 4, Respironics Co., USA) was used to measure and record PSG parameters according to the principles of the American Academy of Sleep Medicine [15, 16] during natural nocturnal sleep. Standard measurements were recorded, including electroencephalograms (EEG), bilateral electrooculograms (EOG), bipolar submental electromyograms (EMG), electrocardiograms (ECG), thoracoabdominal movements, oronasal airflow, and transcutaneous oximetry.

Sleep Impairment Measurements

Objective sleep impairment measurements were made by evaluating PSG and included (i) percentage of sleep efficiency (total sleep time divided by time in bed), (ii) arousal index (ArI; number of arousals per hour), (iii) apnea-hypopnea index (AHI; number of apneas and hypopneas per hour), (iv) mean oxygen saturation, (v) minimal oxygen saturation, (vi) time spent with an oxygen

Table 1. Baseline characteristics of PER and control subjects

	PER group (n = 98)	Control group (n = 30)	p
Males	53 (54.1%)	19 (63.3%)	0.407
Females	45 (45.9%)	11 (36.7%)	
Age	33.0 ± 9.9	32.7 ± 5.9	0.851
BMI	21.0 ± 2.3	21.5 ± 1.8	0.323

saturation below 90%, and (vii) snoring time in minutes. Arousals were scored as described by the American Sleep Disorders Association [17]. In addition, apnea was defined as a drop in the peak thermal sensor excursion by ≥90% of baseline for at least 10 s and at least 90% of the event's duration meeting the amplitude reduction criteria for apnea. Hypopnea was defined as a nasal pressure signal excursion drop of ≥30% of baseline for a period lasting at least 10 s with a ≥4% desaturation from preevent baseline. At least 90% of the event's duration must meet the amplitude reduction of criteria for hypopnea [18].

Peak Nasal Inspiratory Flow

Youlten peak flow meters (In-Check®; Clement Clarke, Harlow, UK) were used to assess nasal resistance after the PSG test. Studies have shown that PNIF is comparable to rhinomanometry [19] and has a good correlation with the sensation of nasal blockage [20–22]. According to the manufacturer's recommendation, participants used a face mask sealed around the nose and mouth, closed their mouth, and inhaled forcefully through the nose. For each assessment 3 measurements were performed, the maximal one of which was considered for evaluation.

Statistical Analysis

Statistical analyses were carried out using SPSS 11.0 software. An independent-samples t test was used for comparing 2 groups' data with a normal distribution. For variables that were not normally distributed, the Mann-Whitney U test was used. For correlation analysis, Pearson and Spearman correlation coefficients were used for normally and nonnormally distributed data, respectively. Two-sided exact p values were calculated to access differences between variables. Statistical significance was accepted at the 5% level.

Results

Description of the Study Population

Table 1 shows the main demographic characteristics of all of the evaluable subjects in the PER and control groups. A total of 100 participants fulfilling the ARIA criteria for PER were recruited, 98 of which completed the PSG test. The skin prick test was performed including house dust mites, animal dander, feathers, grasses, a weed mix, fungi, and trees; each PER patient showed at least 1 positive result and all of the controls were negative. All were asymptomatic for the lower airways and none had a history of asthma. There were no significant differences between the groups with regard to gender distribution, age, or body mass index (BMI).

Table 2. Sleep impairment in patients with PER and healthy controls measured according to PSG parameters

PSG parameter	PER (n = 98)	Control (n = 30)	p value
Sleep efficiency, %			0.044
Mean (SD)	87.86 (10.16)	90.97 (6.14)	
Range	52.9–100.0	75.2–98.6	
ArI			<0.001
Median (IQR)	24.90 (15.45)	15.15 (8.32)	
Range	9.2–86.8	7.8–38.8	
AHI			NS
Median (IQR)	1.80 (2.93)	2.03 (2.72)	
Range	0–42.7	0.3–4.2	
Average SaO_2, %			<0.001
Mean (SD)	94.10 (2.77)	96.13 (0.63)	
Range	85.0–98.0	95.0–97.0	
Lowest SaO_2, %			<0.001
Mean (SD)	88.48 (6.79)	92.20 (1.77)	
Range	62.0–96.0	89.0–95.0	
Time of SaO_2 <90%, min			0.001
Median (IQR)	0 (1.63)	0 (0)	
Range	0–141.0	0–0.5	
Snoring time, min			0.007
Median (IQR)	0 (0.1)	0 (0)	
Range	0–28.2	0–0.3	

Sleep Measurements

Table 2 shows the comparison of PSG parameters between patients with PER and healthy controls. The 2 groups were significantly different with respect to sleep efficiency (PER 87.86 ± 10.16% and control 90.97 ± 6.14%; p = 0.044). Assessment of the ArI demonstrated that subjects in the PER group were likely to have a significantly greater arousal than control subjects (PER 24.90 ± 15.45 and control 15.15 ± 8.97; $p < 0.001$) (table 2).

Analysis of respiratory events showed that 17 (17.3%) subjects in the PER group had an AHI >5; 16 of these subjects had an AHI between 5 and 15 and only 1 subject had an AHI ≥30. In contrast, all subjects in the control group had AHI values within the normal range (AHI <5) (table 3). However, the mean value of AHI between the 2 groups was not significantly different (PER 1.80 ± 2.93 and control: 2.03 ± 2.72; $p > 0.05$). Although there were significant differences between the 2 groups with regard to average oxygen saturation (PER 94.10 ± 2.77% and

Table 3. Severity of AHI in PER and control subjects

	PER (n = 98)	Control (n = 30)
AHI <5	81 (82.65%)	30 (100%)
5 ≤ AHI < 15	16 (16.33%)	0 (0%)
15 ≤AHI < 30	0 (0%)	0 (0%)
AHI ≥30	1 (1.02%)	0 (0%)

Table 4. Correlation between PNIF and PSG parameters

PSG parameters	r	p value
Sleep efficiency	–0.055	0.591
ArI	–0.201	0.047
AHI	–0.119	0.244
Average SaO_2	0.200	0.048
Lowest SaO_2	0.127	0.212
Time of SaO_2 <90%	–0.077	0.452
Snoring time	–0.039	0.701

control 96.13 ± 0.63%; $p < 0.001$) (table 2), the level of subjects with PER was still within the normal range, so the differences were not clinically relevant. A similar result was obtained for minimal oxygen saturation (PER 88.48 ± 6.79% and control 92.20 ± 1.77%; $p < 0.001$) (table 2); the difference observed was statistically significant but not clinically relevant. Forty-five subjects (45.92%) with PER had a saturation below 90% during sleep; in contrast only 2 (10%) subjects in the control group had a saturation below 90%, leading to a significantly longer time of SaO_2 below 90% in subjects with PER (range 0–141.0 min) compared with control subjects (range 0–0.5 min; $p = 0.001$) (table 2).

Similarly, 31 (31.6%) subjects in the PER group and only 1 (3.33%) subject in the control group snored during the sleep test, leading to a significantly longer snoring time in subjects with PER (range 0–28.2 min) compared with control subjects (range 0–0.3 min) ($p = 0.007$). Subgroup analysis of data on snoring PER subjects further indicated that subjects with higher symptom scores, i.e. 12 ≤ T5SS ≤ 15, had a greater tendency to snore than subjects with lower symptom scores, i.e. 8 ≤ T5SS ≤ 11 (37.9 vs. 18.8%, $p = 0.056$).

Peak Nasal Inspiratory Flow

PNIF was significantly lower in the PER group than in the control group (PER 67.42 ± 30.91 l/min and control 138.83 ± 51.97 l/min; $p < 0.001$). Weak correlations were found between the ArI and PNIF ($r = -0.201$, $p = 0.047$), average SaO_2, and PNIF ($r = 0.200$, $p = 0.048$) in the PER group (table 4).

Discussion

PSG has recently been employed to objectively assess sleep impairment/disturbances in subjects with a variety of upper respiratory tract conditions, including seasonal and perennial AR [10, 11], nonallergic and vasomotor rhinitis [23, 24], chronic rhinosinusitis [24], and polyposis [24, 25]. To our knowledge this is the first study to objectively assess AR-induced sleep impairment/disturbances in symptomatic patients with PER by PSG. ARIA guidelines suggest that: 'Although sleep apnea syndrome has been associated with nasal disturbance, it is unclear whether AR is associated with sleep apnea' [12]. Therefore, this topic has great clinical importance.

Studies investigating the impact of AR on the quality of life of affected individuals have demonstrated that AR adversely affects the patients' quality of sleep [26], with symptomatic subjects being more affected than nonsymptomatic subjects or non-AR subjects [27].

Two models have been proposed to explain why the quality of sleep may be impaired in AR. In the first model, an increasing body of evidence suggests that nasal congestion is likely to play a prominent role in AR-induced sleep impairment/disturbances [25]. There is evidence that nasal congestion in AR patients is associated with increased numbers of 'microarousals' from sleep [28], apnea episodes [29], and snoring [30]. A study evaluating the effect of obstructed nasal passages in 14 AR patients demonstrated that all individuals experienced disordered breathing in sleep, which was associated with characteristic microarousals from sleep [28]. The possible role of high nasal resistance in the pathogenesis of obstructive sleep apnea was examined in 7 patients with seasonal AR [29]. The study demonstrated that, during the symptomatic phase, an increase in the mean nasal resistance resulted in an increased rate (1.7 ± 0.3) of obstructive apneas, which decreased (0.7 ± 0.4) with decreasing nasal resistance during the nonsymptomatic phase. Although apneas were rarely associated with significant O_2 desaturation and were fewer in number than typically seen in a clinically significant sleep apnea syndrome, the authors concluded that nasal resistance might be a contributing factor in the pathogenesis of obstructive sleep apneas in general.

All subjects in the PER group were specifically required to have significant severe nasal obstruction, as indicated by a score ≥2 out of a maximum of 3, to be eligible for inclusion into the study. Objective assessment of the nasal airway obstruction using PNIF measurements verified that the PER group was indeed significantly obstructed and had a higher nasal resistance compared to controls. Overall, our study demonstrated a statistically significant influence of the subjects with PER on most sleep parameters; in particular, sleep efficiency was significantly decreased and ArI, time spent with a saturation below 90%, and snoring time were significantly increased. Approximately 17% of the subjects in the PER group only presented obstructive sleep apnea based on their AHI values; this suggests that PER is likely to result in OSAS in some but not all patients. Our finding of increased snoring in subjects with PER compared with healthy controls is also in accordance with the findings of a population-based study which demonstrated that nocturnal severe nasal congestion was associated with a 3-fold increase in the likelihood of habitual snoring [30]. Moreover, the present study demonstrated that patients with higher T5SS scores ($12 \leq T5SS \leq 15$) had a greater tendency to snore than patients with lower scores ($8 \leq T5SS \leq 11$). These findings support the notion that AR may be a risk factor for snoring or for sleep-disordered breathing. The correlation between PNIF and PSG parameters, including ArI and average SaO_2, manifested that increased nasal resistance might play an important role in the pathogenesis. However, we have to emphasize that the AHI of the PER group were not significantly different compared to those of the control group. Although the average and minimal oxygen saturations were statistically significantly decreased in PER subjects compared with healthy controls, the differences were only of a minor magnitude and hardly clinically relevant. Therefore, the deterioration of sleep quality in AR patients might not be fully explained by the sleep-disordered breathing caused by nasal blockage.

The poor correlation between sleep the quality and PSG parameters of AR patients has been reported before. In a prospective controlled clinical trial, Stuck et al. [10] investigated the impact of seasonal AR on subjective and objective sleep patterns. The authors concluded that seasonal AR leads to increased daytime sleepiness. While the objective measurements revealed a statistically significant influence of seasonal AR on selected sleep parameters, the changes were not of clinical relevance. Craig et al. [11] investigated the effect of nasal corticosteroids on objective sleep testing and the symptoms of sleep and daytime somnolence in perennial AR. The medication improved subjective sleep when compared with placebo; however, there was no difference in AHI between the 2 groups. It is possible that, besides the nasal blockage of AR, inflammatory cells and mediators involved in the pathophysiology of AR may also directly play a role in sleep impairment/disturbance which results in daytime symptoms and a decreased quality of life. For example, histamine is thought to be involved in the regulation of the sleep-wake cycle, arousal, cognition, and memory [31]; CysLTs may increase slow-wave sleep [32]; cytokines such as IL-1, IL-4, and IL-10 are correlated with a decreased sleep onset latency, an increased REM sleep latency, and a decreased duration of REM sleep [33], and substance P may increase REM latency and have an arousing effect [34]. However, whether these mediators are merely associated with or actually cause the sleep abnormalities observed in AR patients remains to be determined.

A major limitation of the current study is the lack of subjective assessments of the quality of sleep and daytime sleepiness, which would allow us to classify the severity of OSAS according to the recent manual of the American Academy of Sleep Medicine [16], and to define the relationship between subjective and objective sleep parameters. Another potential shortcoming of this study was that we preselected PER subjects with moderate-to-severe nasal blockage on the basis of a nasal obstruction score ≥2, which did not allow us to correlate the PSG data to nasal obstruction of a different magnitude.

Despite these limitations, this study is the first in AR subjects classified according to ARIA guidelines, and it included a large number of patients with a full PSG and PNIF evaluation. The study confirms that PER-induced nasal blockage does impact objective sleep parameters, though modestly, in the majority of patients; physicians should be aware of this consequence of PER and should consider evaluating and treating PER patients with moderate-to-severe nasal blockage accordingly. Further studies including the measurement of nasal blockage, quality of sleep, quality of life parameters, and PSG for AR patients should be carried out to better evaluate the correlation of AR-induced nasal blockage and sleep disturbance.

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References

1 Bauchau V, Durham SR: Prevalence and rate of diagnosis of allergic rhinitis in Europe. Eur Respir J 2004;24:758–764.
2 Bachert C, van Cauwenberge P, Olbrecht J, van Schoor J: Prevalence, classification and perception of allergic and nonallergic rhinitis in Belgium. Allergy 2006;61:693–698.
3 Zhang L, Han D, Huang D, Wu Y, Dong Z, Xu G, Kong W, Bachert C: Prevalence of self-reported allergic rhinitis in eleven major cities in China. Int Arch Allergy Immunol 2009;149:47–57.
4 Bousquet J, Bullinger M, Fayol C, Marquis P, Valentin B, Burtin B: Assessment of quality of life in patients with perennial allergic rhinitis with the French version of the SF-36 Health Status Questionnaire. J Allergy Clin Immunol 1994;94:182–188.
5 Muliol J, Maurer M, Bousquet J: Sleep and allergic rhinitis. J Investig Allergol Clin Immunol 2008;18:415–419.
6 Storms W: Allergic rhinitis-induced nasal congestion: its impact on sleep quality. Prim Care Respir J 2008;17:7–18.
7 Young T, Finn L, Kim H: Nasal obstruction as a risk factor for sleep-disordered breathing: the University of Wisconsin Sleep and Respiratory Research Group. J Allergy Clin Immunol 1997;99:S757–S762.
8 Stull DE, Roberts L, Frank L, Heithoff K: Relationship of nasal congestion with sleep, mood, and productivity. Curr Med Res Opin 2007;23:811–819.
9 Leger D, Annesi-Maesano I, Carat F, Rugina M, Chanal I, Pribil C, El Hasnaoui A, Bousquet J: Allergic rhinitis and its consequences on quality of sleep: an unexplored area. Arch Intern Med 2006;166:1744–1748.
10 Stuck BA, Czajkowski J, Hagner AE, Klimek L, Verse T, Hormann K, Maurer JT: Changes in daytime sleepiness, quality of life, and objective sleep patterns in seasonal allergic rhinitis: a controlled clinical trial. J Allergy Clin Immunol 2004;113:663–668.
11 Craig TJ, Mende C, Hughes K, Kakumanu S, Lehman EB, Chinchilli V: The effect of topical nasal fluticasone on objective sleep testing and the symptoms of rhinitis, sleep, and daytime somnolence in perennial allergic rhinitis. Allergy Asthma Proc 2003;24:53–58.
12 Bousquet J, Khaltaev N, Cruz AA, Denburg J, Fokkens WJ, Togias A, Zuberbier T, Baena-Cagnani CE, Canonica GW, van Weel C, Agache I, Ait-Khaled N, Bachert C, Blaiss MS, Bonini S, Boulet LP, Bousquet PJ, Camargos P, Carlsen KH, Chen Y, Custovic A, Dahl R, Demoly P, Douagui H, Durham SR, van Wijk RG, Kalayci O, Kaliner MA, Kim YY, Kowalski ML, Kuna P, Le LT, Lemiere C, Li J, Lockey RF, Mavale-Manuel S, Meltzer EO, Mohammad Y, Mullol J, Naclerio R, O'Hehir RE, Ohta K, Ouedraogo S, Palkonen S, Papadopoulos N, Passalacqua G, Pawankar R, Popov TA, Rabe KF, Rosado-Pinto J, Scadding GK, Simons FE, Toskala E, Valovirta E, van Cauwenberge P, Wang DY, Wickman M, Yawn BP, Yorgancioglu A, Yusuf OM, Zar H, Annesi-Maesano I, Bateman ED, Ben Kheder A, Boakye DA, Bouchard J, Burney P, Busse WW, Chan-Yeung M, Chavannes NH, Chuchalin A, Dolen WK, Emuzyte R, Grouse L, Humbert M, Jackson C, Johnston SL, Keith PK, Kemp JP, Klossek JM, Larenas-Linnemann D, Lipworth B, Malo JL, Marshall GD, Naspitz C, Nekam K, Niggemann B, Nizankowska-Mogilnicka E, Okamoto Y, Orru MP, Potter P, Price D, Stoloff SW, Vandenplas O, Viegi G, Williams D: Allergic Rhinitis and its Impact on Asthma (ARIA) 2008 update (in collaboration with the World Health Organization, GA(2)LEN and AllerGen). Allergy 2008;63(suppl 86):8–160.
13 Zuberbier T, Canonica G, Bachert C, Bousquet J: In subjects with persistent allergic rhinitis (PER) treated with desloratadine, improvements in total 5-symptom scores (T5SS) and rhinoconjunctivitis quality of life questionnaire-standardized (RQLQ-s) correlate with disease burden as measured using a simple visual analog scale (VAS). J Allergy Clin Immunol 2009;123:S131.
14 Segall N, Gawchik S, Georges G, Haeusler JM: Efficacy and safety of levocetirizine in improving symptoms and health-related quality of life in us adults with seasonal allergic rhinitis: a randomized, placebo-controlled study. Ann Allergy Asthma Immunol 2010;104:259–267.
15 Kushida CA, Littner MR, Morgenthaler T, Alessi CA, Bailey D, Coleman J Jr, Friedman L, Hirshkowitz M, Kapen S, Kramer M, Lee-Chiong T, Loube DL, Owens J, Pancer JP, Wise M: Practice parameters for the indications for polysomnography and related procedures: an update for 2005. Sleep 2005;28:499–521.
16 American Academy of Sleep Medicine: International Classification of Sleep disorders. Diagnostic and Coding Manual, ed 2. Westchester, American Academy of Sleep Medicine, 2005.
17 EEG arousals: scoring rules and examples: a preliminary report from the Sleep Disorders Atlas Task Force of the American Sleep Disorders Association. Sleep 1992;15:173–184.
18 Iber C, Ancoli-Israel S, Chesson A, Quan SF: The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology and Technical Specifications, ed 1. Westchester, American Academy of Sleep Medicine, 2007.
19 Holmstrom M, Scadding GK, Lund VJ, Darby YC: Assessment of nasal obstruction: a comparison between rhinomanometry and nasal inspiratory peak flow. Rhinology 1990;28:191–196.
20 Gomes Dde L, Camargos PA, Ibiapina Cda C, de Andrade CR: Nasal peak inspiratory flow and clinical score in children and adolescents with allergic rhinitis. Rhinology 2008;46:276–280.
21 Wilson A, Dempsey OJ, Sims EJ, Coutie WJ, Paterson MC, Lipworth BJ: Evaluation of treatment response in patients with seasonal allergic rhinitis using domiciliary nasal peak inspiratory flow. Clin Exp Allergy 2000;30:833–838.
22 Wilson AM, Dempsey OJ, Sims EJ, Lipworth BJ: Subjective and objective markers of treatment response in patients with seasonal allergic rhinitis. Ann Allergy Asthma Immunol 2000;85:111–114.
23 Kramer MF, de la Chaux R, Fintelmann R, Rasp G: NARES: a risk factor for obstructive sleep apnea? Am J Otolaryngol 2004;25:173–177.
24 Tosun F, Kemikli K, Yetkin S, Ozgen F, Durmaz A, Gerek M: Impact of endoscopic sinus surgery on sleep quality in patients with chronic nasal obstruction due to nasal polyposis. J Craniofac Surg 2009;20:446–449.
25 Craig TJ, Ferguson BJ, Krouse JH: Sleep impairment in allergic rhinitis, rhinosinusitis, and nasal polyposis. Am J Otolaryngol 2008;29:209–217.
26 Blaiss M, Reigel T, Philpot E: A study to determine the impact of rhinitis on sufferers' sleep and daily routine. J Allergy Clin Immunol 2005;115:S197.
27 Meltzer EO, Nathan R, Derebery J, Stang PE, Campbell UB, Yeh WS, Corrao M, Stanford R: Sleep, quality of life, and productivity impact of nasal symptoms in the United States: findings from the Burden of Rhinitis in America survey. Allergy Asthma Proc 2009;30:244–254.
28 Lavie P, Gertner R, Zomer J, Podoshin L: Breathing disorders in sleep associated with 'Microarousals' in patients with allergic rhinitis. Acta Otolaryngol 1981;92:529–533.
29 McNicholas WT, Tarlo S, Cole P, Zamel N, Rutherford R, Griffin D, Phillipson EA: Obstructive apneas during sleep in patients with seasonal allergic rhinitis. Am Rev Respir Dis 1982;126:625–628.
30 Young T, Finn L, Palta M: Chronic nasal congestion at night is a risk factor for snoring in a population-based cohort study. Arch Intern Med 2001;161:1514–1519.
31 Tashiro M, Mochizuki H, Iwabuchi K, Sakurada Y, Itoh M, Watanabe T, Yanai K: Roles of histamine in regulation of arousal and cognition: Functional neuroimaging of histamine h1 receptors in human brain. Life Sci 2002;72:409–414.
32 Sri Kantha S, Matsumura H, Kubo E, Kawase K, Takahata R, Serhan CN, Hayaishi O: Effects of prostaglandin d2, lipoxins and leukotrienes on sleep and brain temperature of rats. Prostaglandins Leukot Essent Fatty Acids 1994;51:87–93.
33 Krouse HJ, Davis JE, Krouse JH: Immune mediators in allergic rhinitis and sleep. Otolaryngol Head Neck Surg 2002;126:607–613.
34 Ferguson BJ: Influences of allergic rhinitis on sleep. Otolaryngol Head Neck Surg 2004;130:617–629.