

Novel Grading System for Quantifying Upper-Airway Obstruction on Sleep Endoscopy

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Received: 30 September 2011 / Accepted: 26 December 2011 / Published online: 20 January 2012
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Abstract

Background The aim of this study was to present a novel anatomically comprehensive and clinically applicable system for the quantification of sleep endoscopy findings in patients with obstructive sleep apnea/hypopnea syndrome (OSAHS).

Methods Fifty-five adult patients with a polysomnographic diagnosis of OSAHS were referred for midazolam-induced sleep endoscopy following failure of continuous positive airway pressure. Five anatomical sites of possible obstruction along the upper airway were documented: nose/nasopharynx (N), uvulopalatine plane (P), tongue base (T), larynx (L), and hypopharynx (H). Each involved site was assigned a severity grade of 1 (partial obstruction) or 2 (complete obstruction). The digits representing the obstruction pattern at each level were then added to yield a severity index (SI). The SI for each patient was determined by two independent observers. Findings were correlated with the respiratory disturbance index (RDI) and body mass index (BMI).

Results The SI was significantly correlated with the RDI ($R = 0.746$, Pearson; $P < 0.0001$) and predicted disease severity with 65% accuracy. There was no association with BMI. By site, the tongue base and hypopharynx were significantly correlated with obstruction severity; obstruction in the tongue base predicted disease severity with a sensitivity of 68.8 and sensitivity of 81.1.

Conclusion Our easy-to-use endoscopic grading system provides physicians with an accurate picture of the pattern of the upper-airway system obstruction in patients with obstructive sleep apnea/hypopnea syndrome. It is a promising tool for estimating the location and severity of upper airway disease and may have implications for treatment planning.

Keywords Sleep apnea · Grading system · Upper-airway obstruction · Sleep endoscopy

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Introduction

Obstructive sleep apnea/hypopnea syndrome (OSAHS) is one of a range of sleep-disordered breathing disturbances, which include also snoring and upper-airway resistance syndrome. The reported incidence of OSAHS is approximately 4% in men and 2% in women [1]. Cumulative evidence over the last two decades has linked OSAHS to excess mortality and morbidity, especially cardiovascular and cerebrovascular [2, 3].

Sleep endoscopy, introduced in 1991 by Croft and Pringle [4], to examine the upper airway during midazolam-induced sleep [5]. It has been applied in several studies of disordered sleep and found to be simple to use, safe, and cost-effective [4–9].

Our earlier experience with sleep endoscopy for the evaluation of surgical candidates with suspected OSAHS [10] yielded a considerable rate of supraglottic, laryngeal, and concentric hypopharyngeal obstructions (33% each). These findings suggested that the misdiagnosis of sleep-disordered breathing may explain at least part of the high surgical failure rate of uvulo-palatopharyngoplasty. Moreover, the results showed that the number of obstruction sites correlated with the respiratory distress index (RDI).

The evolution of sleep endoscopy techniques has led to the formulation of various grading systems. However, none provides a comprehensive and accurate classification reflecting the endoscopic findings in patients with sleep-disordered breathing, and there is to date no uniform nomenclature.

The aim of the present study was to present a novel endoscopic grading system that is anatomically comprehensive and clinically oriented and to evaluate its relationship with the RDI and with body mass index (BMI) in patients with OSAHS.

Patients and Method

A prospective study was conducted at a tertiary university-affiliated medical center. The study group consisted of 55 patients aged 18 years or older who were referred for sleep endoscopy from January 2004 to May 2006. All had complaints of daytime somnolence and were diagnosed with OSAHS by overnight polysomnography. All had previously failed treatment with continuous positive airway pressure and were seeking surgical intervention.

In all cases, polysomnography was performed in the sleep laboratory using the Compumedics e-Series, Profusion PSG device (version 1.01; Compumedics Ltd., Abbotsford, Victoria, Australia); sleep measurements were based on the criteria of the American Academy of Sleep Medicine [11].

Sleep Endoscopy Protocol

The patients underwent sleep endoscopy as part of the upper-airway assessment. The procedure was performed after a 6-h fast. Following a medical history and complete physical examination, the patients were asked to lie supine in a dark, quiet room. Heart rate, blood pressure, and arterial oxyhemoglobin saturation (pulse oximetry) were monitored throughout the procedure until after the patient awakened. The nasal cavity was lubricated with 5% Esra-caine gel, and sleep was induced by increasing doses of intravenous midazolam, titrating according to effect. The midazolam dose was administered in increments of 2 mg every 3–5 min; the total dosage ranged from 2 to 14 mg

(average = 6 mg). The five airway sites were visualized before onset of midazolam administration and again after every dose increment. A flexible nasopharyngoscope was gently introduced through the nasal cavity until it reached the larynx. It was then moved carefully for better inspection. Complete obstruction was defined clinically as complete blockage of the airway passage for at least 10 s, and partial obstruction as narrowing or intermittent collapse of the airway passage. Selected events were recorded on video and stills. Since the obstructive events during sleep apnea/hypopnea usually occur during inspiration, the images were generally taken in that phase. When the patients were fully awake, they were allowed to leave the hospital with an escort and advised to rest for the remainder of the day.

Sleep Endoscopy Grading System

Five anatomical sites of possible obstruction along the upper airway were documented during sleep-induced endoscopy, in addition to the severity of the pathophysiological process. The sites included the nose and nasopharynx (N), palatine plane, uvula, or tonsils (P), tongue base (T), larynx (L), and hypopharynx (H). The obstruction was categorized as partial (1) or complete (2), as defined above. These factors were then combined for a final grade (Table 1). For example, solitary partial obstruction of the palate (flutter) was graded P1, and partial obstruction of the palate combined with the tongue base falling backward and completely blocking the airway was graded PIT2. If, in the latter case, the hypopharyngeal walls were also collapsed circumferentially with complete obstruction, the final grade was P1T2H2. The endoscopy sleep index (SI) was then calculated by adding the digits representing the obstruction pattern at each level. For example, a patient with a grade of P2T2L2 was assigned a value of 6 (2 + 2 + 2). Since we identified five potential levels of obstruction, the total possible score of the grading system was 10 (N2P2T2L2H2). The score for each subject was determined independently during the sleep endoscopy

Table 1 Endoscopic upper-airway grading system for OSAHS

Staging	Staging index (SI)	Description
P1	1	Palatal partial obstruction = Palatal flutter
P2	2	Palatal obstruction
P2T2	4	Palatal and tongue obstruction
N2P2T2	6	Complete nasal, palatal, and tongue obstruction

N nose and nasopharynx, *P* palate, uvula, and/or tonsils, *T* tongue base, *L* larynx, *H* hypopharynx, *1* incomplete obstruction (flutter of the soft tissue); *2* complete obstruction

Anatomic level without obstruction is not labeled

procedure by two observers (GB and LE); discordant findings were discussed by a larger panel of observers.

To verify that our new grading system is indeed more correlative with sleep parameters than other existing systems, all patients were staged according to both our index and the well-documented system suggested by Pringle and Croft [7]. We then compared the scores of the two systems and their correlative power with the RDI and the BMI.

Statistical Analysis

Continuous variables were expressed as mean \pm standard deviation (SD), and categorical variables as percentages. Differences between groups were analyzed by χ^2 or Fisher exact test, as appropriate. The strength of the relationship between the SI and the RDI and the BMI was estimated by Pearson's correlation coefficient. A *P* value of less than 0.05 was considered significant.

Literature Review

The English-language medical literature was reviewed for current endoscopic grading systems and the different approaches were summarized and compared to our system.

Results

Endoscopic data were obtained from 53 of the 55 patients. In two patients, we did not achieve the adequate level of sedation for sleep endoscopy despite the administration of high-dose intravenous midazolam.

Forty-three patients (81%) were male and 10 female, with mean (\pm SD) age = 47 ± 13.4 years (range = 18–80), mean weight = 82.8 ± 9.2 kg (range = 50–122 kg), mean height = 172.9 ± 12.3 cm (range = 156–192 cm), and mean BMI = 27.6 ± 4 . The mean RDI was 33.7 (median = 28). Results for the Epworth Sleepiness Scale were available for 47 patients; the mean score was 13.6 (median = 13).

Obstructions were detected at all levels examined: nose, uvulopalatine plane, base of the tongue, larynx, and hypopharynx. The distribution of partial versus complete obstruction at each level is presented in Table 2. There was a positive, statistically significant correlation between the SI and the RDI ($R = 0.746$, $P < 0.0001$, Fig. 1). On regression analysis, SI predicted the disease severity (RDI) with 65% accuracy. Specifically, a score of 0–2 was associated with mild OSAHS (RDI < 20), a score of 3–4 with moderate OSAHS (RDI = 20–40), and a score of more than 4 with severe OSAHS (RDI > 40). There was also a strong correlation of the SI with the BMI ($R = 0.31$, $P = 0.024$).

Table 2 Distribution of partial versus complete obstruction by site ($N = 53$)

Obstruction Site	Partial	Complete	No obstruction
Nose	7 (63%)	4 (37%)	42
UP	16 (34%)	31 (66%)	6
Tongue	6 (33%)	12 (67%)	35
Larynx	7 (39%)	11 (61%)	35
Hypopharynx	8 (42%)	11 (58%)	34

UP uvulopalatine plane

Values are given as *n* (%)

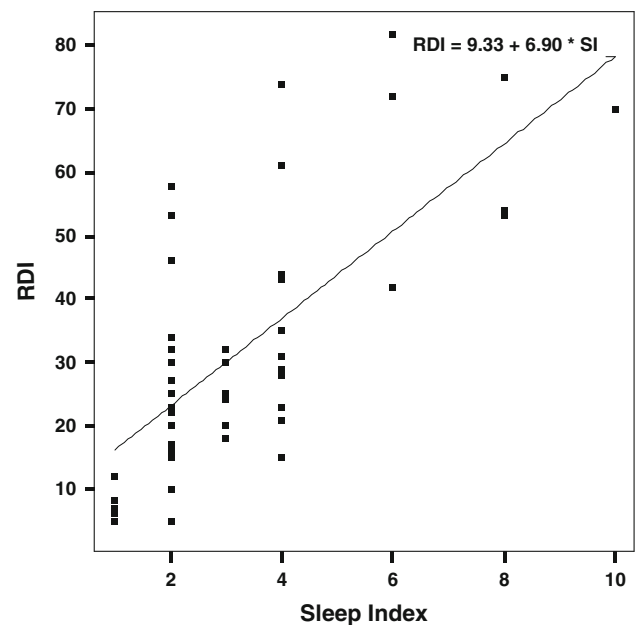


Fig. 1 Correlation between the SI and the RDI

When we applied the Pringle and Croft grading system to the study cohort, the mean score was 3.17 (range = 1–5). There was a moderately positive correlation between the Pringle and Croft score with the RDI ($r = 0.454$, $P < 0.001$). No correlation was found between the Pringle and Croft score and the BMI.

Correlative analysis yielded a significant association of obstruction in the tongue base and hypopharynx in patients with greater severity of obstruction (RDI > 40) (Table 3). The tongue base as the site of obstruction had a sensitivity of 68.8 and specificity of 81.1 in predicting the severity of obstruction.

Discussion

In patients with suspected OSAHS, polysomnography has little added value to the physical examination in identifying

Table 3 Distribution of site of obstruction by RDI

Site	<i>N</i>	RDI < 40 (<i>N</i> = 37) (%)	RDI > 40 (<i>N</i> = 16) (%)	<i>P</i>	Sensitivity	Specificity
Nose	11	8 (21.6)	3 (18.8)	NS	18.8	21.6
UP	46	31 (83.8)	15 (93.8)	NS	93.8	16.2
Tongue	18	7 (18.9)	11 (68.8)	0.0001	68.8	81.1
Larynx	17	11(19.7)	6 (37.5)	NS	37.5	70.3
Hypopharynx	19	10 (27)	9 (56.3)	0.042	56.3	73

RDI respiratory distress index, UP uvulopalatine plane

upper-airway obstruction. Therefore, sleep endoscopy is important in this setting. The present study introduces an endoscopic grading system that takes both the site involved (along the vertical axis of the upper airway) and the severity of the obstruction (partial or complete) into consideration. We found that our novel sleep endoscopy index (SI) was highly statistically correlated with both the RDI and the BMI. This technique may have therapeutic implications, because data on the number and severity of obstructions may influence the surgical approach.

The level of collapse of the upper airway varies among individuals owing to differences in the skeletal structure and the muscle tone of the pharyngeal walls [5]. In the first study of sleep endoscopy, Croft and Pringle [4] divided the patients into three groups: simple palatal snoring (defined by the observation of palatal vibration), single-level palatal obstruction, and multisegment involvement. Several authors, including Pringle and Croft [7], have since modified this site-oriented classification [9, 12, 13], as described in Table 4. However, all the systems lacked a comprehensive description of the upper-airway obstruction.

For example, they failed to quantify the narrowing at the different upper-airway levels.

To account for the different patterns of obstruction that may occur at any level of obstruction, Croft and Pringle [4] scored the approximate percentage decrease in a cross-sectional area as follows: minimal collapse, +1; up to 50% collapse, +2; more than 50% collapse, +3; 100% collapse (airway obliteration), +4. This technique was later applied by Sher et al. [14]. Others, however, raised concerns that the assessment was too subjective, placing it at risk of interobserver differences and inconsistencies. Quinn et al. [5] sought to better quantify the findings in an endoscopic study of the mechanisms underlying snoring in 54 adults. Their categorization of the various sites and patterns of obstruction is detailed in Table 5.

A better association with RDI was demonstrated in our study ($R = 0.746$, $P < 0.0001$, Fig. 1) than with the Pringle and Croft system ($r = 0.454$, $P < 0.001$). Pringle and Croft attempted to characterize the various obstruction patterns and locations in five stages. Our system offers more flexibility in describing the upper-airway pathology,

Table 4 Site-oriented classifications

Study	Grading system
Pringle and Croft [7]	Grade 1—Simple snoring Grade 2—Palatal obstruction Grade 3—Multisegment intermittent obstruction Grade 4—Sustained multisegment collapse Grade 5—Tongue base obstruction
Camilleri et al. [12]	Grade 1—Palatal snoring Grade 2—Palatal and base of tongue snorers Grade 3—Nonpalatal snoring
Sadaoka et al. [9]	Group A—Single-level palatal partial or complete obstruction Group B—Single-level tongue obstruction Group C—Multisegment involvement [uvulopalatine (UP) plane, tongue base, hypopharynx]
Iwanaga et al. [13]	Soft-palate obstruction Circumferential palatal obstruction Tonsillar-type obstruction Root-of-tongue obstruction Mixed-type (palatal and tongue) obstruction

Table 5 Classification of obstruction type

Study	Grading system
Higami et al. [15]	“Bilateral obstruction type” “Falling type” “All-around obstruction type”
Quinn et al. [5]	Palate Funnel-shaped aperture Transverse slit cross-sectional reduction Hypertrophic tonsil medialization Tongue Vibration against the pharyngeal wall Epiglottis Omega-shaped collapse Fall back onto and vibrate against the posterior pharyngeal wall
Iwanaga et al. [13]	Soft-palate-type obstruction Circumferential palatal-type obstruction Mixed-type (palatal tongue root) obstruction Tonsillar-type obstruction

including obstruction levels and additional information on the severity of the obstruction, thereby providing a better correlation with the actual clinical findings. In addition, the Pringle and Croft system does not focus specifically on obstructions of the nasal passages, larynx, and hypopharynx, which we found to be important contributors to the airway blockage in patients with OSAS.

It is difficult to translate the visual endoscopic findings into a sufficiently accurate and sensitive grading system. Ideally, the system should cover the entire upper airway, be both simple and practical, and provide a means to quantify the severity of the obstruction. Its use should also make it possible for physicians to compare results between and among centers and to summarize the results for the establishment of clinical guidelines and standardized treatment. Our novel grading system fulfills these criteria. It is dynamic, modular, and intuitive, much like the TNM staging system, so that it is easy for clinicians to implement. Importantly, the system can also be used to monitor disease progression, with restaging.

In the present study, the correlation of the SI, which takes into account both the site and the severity of obstruction in OSAHS, with the RDI and the BMI (Fig. 1) was even stronger than in our previous study of the association of the number of obstruction sites/sleep endoscopy examination and the RDI ($R = 0.44$, $P = 0.001$) [10]. This makes the SI an important parameter in the process of evaluation of suspected OSAHS. The grading system was found to be highly correlative with the BMI, which was missing in the Pringle and Croft system. The high predictive power of our grading system is attributable to its comprehensive description of all

potential sites of obstruction, which is not available in other grading systems.

Our analysis of the sites involved by degree of obstruction (mild-to-moderate versus severe) revealed a high incidence of severe tongue-base obstruction (Table 3). This finding suggests that surgeons should consider treating the tongue base in patients with an RDI > 40. At the same time, tongue base as well as laryngeal obstruction may occur secondary to upstream obstruction. Further studies are being planned to correlate the surgical results with the postoperative endoscopic examination.

This study has several limitations. First, a comparison of the sleep endoscopy results with patients without sleep apnea is lacking. Second, the analysis was confined to patients who failed CPAP, which may create some bias in the cohort analysis. Third, the feasibility of sleep endoscopy is not clear. It is time-consuming, and the administration of an IV sedative requires a setup that is not always available in the physician's office. Finally, the cohort was relatively limited, and further studies are needed to validate the grading system.

In conclusion, we present a new grading system for the interpretation of the visual findings obtained in sleep endoscopy. We found the system to be simple to use, practical, and clinically oriented, providing physicians with an accurate description of the pathophysiology of the upper airway in patients with OSAHS. The strong correlation between the SI and the RDI and the BMI makes it a good potential tool for estimating the location and severity of disease and for treatment planning.

Conflicts of Interest The authors have no conflicts of interest to disclose.

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