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with AHI or AI, they were strongly associated with the proportion of REM sleep (-0.553 , $p < 0.0001$) and slow wave sleep (-0.461 , $p < 0.0001$). OSA severity was strongly correlated with Mallampati grade, ($r = 0.389$, $p < 0.0001$), Friedman clinical staging, ($r = 0.331$, $p = 0.0007$), and Muller's grades of collapsibility, at all 3 levels, and the severity of OSA. Of significance, only 6.9% of patients with mild OSA had a >50% collapse of the base of tongue region, as compared to 65.9% of patients with severe OSA. Conclusion: There is good correlation between clinical examination parameters and the severity of OSA. An algorithm for surgical treatment of OSA should acknowledge both the site of obstruction and the severity of disease.

Key words: severity, obstructive sleep apnea, correlation, clinical parameters

Severity of Obstructive Sleep Apnea: Correlation with Clinical Examination and Patient Perception

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Abstract

Objective: The goal of this study was to evaluate the correlation of clinical history, patient self-perception of obstructive sleep apnea and physical examination with the severity of OSA. *Methods:* One hundred and two consecutive patients were prospectively enrolled in this study over a 6-month period. All patients underwent a comprehensive clinical examination, nasopharyngoscopy and an overnight-attended polysomnogram (Level I study). *Results:* There were 65 males and 37 females with a mean age of 50.2 ± 11.3 years (range from 24 to 76 years). The mean BMI was 32.9 ± 8.1 (range 17.7 to 74.6). The mean apnea-hypopnea index (AHI) was 37.9 ± 27.7 (range 0.7 to 111.2); the apnea index (AI) had a mean of 16.1 ± 17.7 (range 0.1 to 80.5). There was a strong correlation between patient self-perception of OSA severity and AHI ($r=0.499$, $p<0.0001$), and the correlation with AI was 0.577 ($p<0.0001$). There was also good correlation between self-perceived OSA severity and the arousal index, percentage oxygen desaturation, percentage of REM sleep and percentage of slow wave sleep. Although Epworth scores did not correlate with AHI or AI, they were strongly associated with the proportion of REM sleep (-0.553 , $p<0.0001$) and slow wave sleep (-0.461 , $p<0.0001$). OSA severity was strongly correlated with Mallampati grade, ($r=0.389$, $p<0.0001$), Friedman clinical staging, ($r=0.331$, $p=0.0007$), and Muller's grades of collapsibility, at all 3 levels, and the severity of OSA. Of significance, only 6.9% of patients with mild OSA had a $>50\%$ collapse of the base of tongue region, as compared to 65.9% of patients with severe OSA. *Conclusion:* There is good correlation between clinical examination parameters and the severity of OSA. An algorithm for surgical

treatment of OSA should acknowledge both the site of obstruction and the severity of disease.

Key words: severity, obstructive sleep apnea, correlation, clinical parameters

Introduction

Sleep-disordered breathing (SDB) is a common condition that ranges from simple snoring to upper airway resistance syndrome and obstructive sleep apnea (OSA). Young et al, studied 602 state employees with an overnight polysomnogram, and found that the incidence of SDB was 24% in men and 9% for women (1). However, many of these patients remain undiagnosed. It is estimated that up to 93% of females and 82% of males with moderate to severe OSA remain undiagnosed (2). The current method of diagnosing OSA is through clinical history, physical examination, imaging studies and polysomnography (3). Clinical symptoms of OSA include snoring, choking at night, witnessed apneic episodes, nocturia, frequent arousals, excessive daytime somnolence, poor concentration, poor memory, mood changes, and irritability. These symptoms are known to be non-specific for OSA. Snoring, for example, has been shown to have a specificity of only 72 - 87% (4,5,6). Apnea witnessed by the bed-partner is a better predictor of sleep apnea (5,7). Excessive daytime sleepiness is very sensitive but not specific for OSA, as sleep deprivation can also give rise to daytime somnolence and a high Epworth sleepiness scale score (EPW) (8,9). However, EPW scores have been shown to be higher in patients with OSA than normal controls (10). In general, clinical symptoms have limited predictive value in identifying patients with sleep apnea (7,11). Clinical examination has been shown to be useful in the prediction of OSA and its severity (12, 13, 14, 15). We sought to prospectively investigate the correlation between clinical examination, Friedman clinical staging, and the Muller's maneuver with the severity of OSA.

Methods and Materials

One hundred and two consecutive patients were prospectively enrolled in this study over a 6-month period. All patients underwent a comprehensive clinical examination, nasopharyngolaryngoscopy and an overnight attended polysomnogram (Level I study)

Clinical History

All patients completed the Epworth sleepiness scale (EPW) and a sleep questionnaire. The sleep questionnaire consisted of the following sleep symptoms: snoring, choking at night, observed pauses in breathing, tossing frequently, leg jerking, morning headaches, nocturnal palpitations, nocturia, and unrefreshed sleep. The questionnaire also had questions pertaining to reflux disease, hoarseness of voice, throat clearing, post-nasal drip, dysphagia, annoying cough, globus sensation and heartburn. These symptoms were divided into 4 main categories based on frequency: daily, often (more than 3 times per week), seldom (less than once per week) and never. Patients were also asked to rate their self-perceived level of severity of sleep apnea. They were asked to indicate his/her own perception of the severity of OSA by designating one of the 4 categories, “no OSA”, “mild OSA”, “moderate OSA” or “severe OSA”.

Physical Examination

Height, weight, body-mass index (BMI), and blood pressure were recorded. Oral cavity examination included documentation of the tonsil size, soft palatal redundancy, uvula length and thickness, tongue size, modified Mallampati index and jaw occlusion. Fiberoptic flexible nasopharyngoscopy was used to assess the anterior and posterior nasal space, the larynx and to perform the Muller maneuver. The Muller maneuver was graded

on a 5 point scale, 0 to 4 (23); we tabulated the Muller maneuver finding based on 3 levels, as previously described (16); soft palatal collapse, lateral pharyngeal wall collapse and base of tongue collapse. Laryngeal examination was also performed, assessing for any epiglottic abnormalities, vocal fold pathologies and signs suggestive of laryngo-pharyngeal reflux. Patients were then classified into Friedman's clinical staging for sleep-disordered breathing (17).

Polysomnography

All patients underwent an attended overnight polysomnogram (PSG) in the hospital. The polysomnogram systematically monitors electroencephalogram (EEG), electro-oculogram (EOG), electromyogram of the chin (EMG), electrocardiogram (EKG), body positions, nasal and oral airflow, thoracic and abdominal effort, limb movements, pulse oximetry and snoring sound level. Polysomnographic variables evaluated included, sleep latency, sleep time, sleep efficiency, complete sleep staging, REM and non-REM staging, arousals, respiratory events, oxygen desaturations, snoring level, body position and limb movements. An apnea was defined as cessation of oro-nasal airflow for >10 seconds. A hypopnea was defined as a reduction of oro-nasal airflow for >10 seconds, with at least a 30% reduction in thoraco-abdominal movement associated with at least 4% oxygen desaturation or the presence of an arousal. An arousal was defined as an increase in EEG activity, usually alpha, for more than 3 seconds on EEG in REM sleep and associated with increased EMG reading in NREM sleep. The AHI was calculated as the sum of the apneic and hypopneic events per hour of sleep. The polysomnograms were all scored by a sleep technologist and reviewed by a board-certified sleep physician.

Statistical Analysis

The Pearson and Spearman's correlation coefficients were used to explore the correlation between parametric and non-parametric data, respectively. Cohen's kappa was used to assess the strength of agreement between the patient self-perceived OSA severity and the polysomnographically-derived AHI, and an exact test (Proc Freq procedure in SAS) was used to determine whether these two measures showed significant agreement. The Proc Freq procedure in SAS was also used to calculate the frequency of base of tongue and lateral wall collapse in patients with severe OSA, as compared to mild OSA patients.

Results

The study group consisted of 102 patients. There were 65 males and 37 females. The age ranged from 24 to 76 years, with a mean of 50.2 ± 11.3 years. The mean BMI was 32.9 ± 8.1 , with a range of 17.7 to 74.6.

Symptomatology and Polysomnography

Seventy-four percent of the 102 patients complained of daily snoring, while 20.6% of patients snored “often”, more than 3 times per week (cumulative frequency of “daily” and “often” snorers was 94.6%). Among the patients who snored daily, 80.2% had an AHI > 5 . Thirty-four percent of patients complained of daily choking at night, while 44.1% had choking sensation at night for more than 3 times per week. Ninety-two percent of the patients who had daily choking at night had an AHI > 5 . Witnessed apneas by the bed-partner were present in 75.4% of patients, 3 times or more per week. Ninety-one percent of these patients with daily witnessed apneas had an AHI > 5 (Table 1), while only 89.7% of the patients who had daily unrefreshed sleep actually had OSA (AHI > 5). Epworth scores revealed a mean of 12.3 ± 4.6 , with a range of 1 to 22. The tabulated frequencies for each symptom are given in Table 2.

Analysis of the patient self-perception questionnaire revealed that 8% of the patients felt that they did not have OSA, 41.7% felt that they only had mild OSA, 33.3% felt that they had moderate OSA, and only 16.7% of the patients indicated that they could have severe OSA. Six patients indicated a “Don’t know” response. The mean self-perception reported was between mild and moderate OSA (1.58 ± 0.87).

The mean AHI was 37.9 ± 27.7 , with a range of 0.7 to 111.2. The apnea index (AI) had a mean of 16.1 ± 17.7 (range 0.1 to 80.5) (Table 3). Comparison of the patient

self-perception of their OSA severity and the AHI on the PSG revealed a correlation of 0.499 ($p < 0.0001$); the correlation with AI was 0.577 ($p < 0.0001$). There was also a strong correlation of the self-perceived OSA severity with the arousal index, percentage oxygen desaturation, REM percentage and slow wave sleep percentage (Table 4).

The EPW scores did not correlate with AHI or AI, with a correlation of 0.053 ($p = 0.59$) and 0.078 ($p = 0.44$), respectively. The EPW scores also did not correlate with the lowest oxygen saturation, percentage saturation below 90% or the arousal index. However, Epworth scores correlated strongly with percentage REM sleep (-0.553, $p < 0.0001$) and percentage slow wave sleep (-0.461, $p < 0.0001$) (Table 5). The AHI and the arousal index showed a high correlation of 0.828 ($p < 0.0001$), as did AHI and percentage time spent below 90% oxygen saturation (% Desat), a correlation of 0.782 ($p < 0.0001$). The odds-ratio of a patient having an AHI > 20 when the EPW score is > 10 is 5.25 (95% C.I. 2.52 – 10.9).

There was good correlation between BMI and AHI with a correlation coefficient of 0.325 ($p = 0.0008$). There was also a fair correlation between BMI and arousal index (0.308, $p = 0.001$). Our data also revealed that the odds-ratio of having an AHI > 20, for BMI > 30 is 3.07 (95% C.I. 1.53 – 6.16). The percentage time spent below 90% oxygen saturation also showed a moderate correlation with BMI of 0.386 ($p < 0.0001$).

Clinical Examination, Endoscopy and Polysomnography

Fifty-nine percent of the 102 patients had a Mallampati grade 4, while 41% had a Mallampati grade 3, with only less than 1% having Mallampati grade 1 and 2. Applying the Friedman clinical stages (17) for SDB, most patients (78.4%) were in the stage II

category. Spearman correlation showed a strong correlation between Mallampati grade and AHI (0.389, $p < 0.0001$), and Friedman clinical staging and AHI (0.331, $p = 0.0007$). There was very good correlation between Muller's grade of collapsibility at all 3 levels with the severity of OSA (Table 6).

There was a significant difference in the frequency and degree of base of tongue collapse in patients with severe OSA compared with patients with mild OSA. Only 6.9% of patients with mild OSA had a $>50\%$ collapse of the base of tongue region, as compared to 65.9% of patients with severe OSA; therefore, patients with severe OSA have a 10 times higher incidence of base of tongue obstruction compared to patients with mild OSA ($p < 0.00001$). Similarly, there was a 3-fold increase in the frequency of lateral pharyngeal wall collapse of more than 50% in patients with severe OSA compared with patients with mild OSA ($p = 0.0002$).

Discussion

The ability to predict the presence and severity of OSA based on clinical parameters remains controversial (5,7,8,10,11,12,19). In our cohort of 102 patients, we observed good correlation between patient-perceived OSA severity, clinical examination and OSA severity (AHI). Similar to other reported studies, 80.2% of our patients who snored daily had OSA (4,5) (Table 1). Moreover, it was noted that choking at night, witnessed apneas and unrefreshed sleep were more specific for OSA (89.7 – 91.5%). Contrary to other reports (18), we did not find a strong correlation between Epworth scores and AHI or AI. Consistent with Dixon et al (19), we found poor correlation between subjective tiredness, Epworth scores and AHI, AI and lowest oxygen saturation (LSAT). However, Guilleminault et al have shown that the severely sleepy patient (with Multiple Sleep Latency Test < 5 minutes) tends to have the greatest sleep fragmentation (higher arousal index) and lower percentage REM and slow wave sleep (SWS) (18,20). In 100 OSA patients, the percentage of Stage I sleep was significantly higher and percentage REM and SWS were lower in sleepy patients than in normal individuals (20). This was also reflected in our data, with Epworth scores showing correlation with arousal index, and a very strong negative correlation with REM percent and SWS percent (Table 5). These findings support the theory that sleep fragmentation and disruption of REM sleep with higher arousal index, lower REM and lower SWS result in higher Epworth scores and sleepy patients.

This is the first study to evaluate the patient's ability to perceive the presence and severity of OSA. We found a strong correlation between patient self-perception of their OSA severity and the AHI. There was also a good correlation between patient self-

perception and the arousal index, percentage oxygen desaturation < 90%, REM percentage and SWS percent (Table 4). We attributed this to the fact that most of our patients were symptomatic and subjectively sleepy (mean Epworth = 12.3), with correspondingly low REM and SWS sleep. Therefore, they were able to gauge their level of severity based on their tiredness and lack of refreshed sleep.

It is well-accepted that anatomic abnormalities associated with difficult endotracheal intubations might also be associated with OSA (21). Therefore, it has been suggested that clinical predictors of a difficult airway may also predict OSA (13). Neck circumference, body mass index (BMI) and oral cavity measurements have been widely used as clinical predictors of OSA (13,19). Thyroid-mental distance, hyoid-mental distance, crico-mental space, palatal height, maxillary intermolar distance, mandibular intermolar distance, and overjet measurements have also been reported (13,14,15). The Mallampati index, first described in 1985 (22), was used in anesthesiology, and later modified for the purpose of predicting OSA, known as the modified Mallampati index (MMP) (12). Tonsil size, modified Mallampati index, and BMI have been combined and a formula coined “OSA score” was introduced (12). Friedman et al described a clinical staging for SDB in order to predict the success rate of UPPP. He described three stages based on Friedman palate position (modified Mallampati index), tonsil size and BMI (17).

El-Ganzouri et al studied over 10,000 patients, stratifying high-risk and low-risk factors in patients according to difficulty of intubation. They found that Mallampati grade and thyro-mental distance was an independent predictive factor for difficulty of intubation (15). Hiremath et al extrapolated this result to the severity of OSA in difficult

intubations (21). They demonstrated that Mallampati grades correlated with severity of OSA. We likewise, found good correlation between the Mallampati grade and severity of OSA ($r = 0.389$, $p < 0.0001$). The Friedman clinical staging proved to have a fair correlation with severity of OSA, $r = 0.331$ ($p = 0.0007$).

The Muller maneuver was first described by Borowiecki and Sassin for the pre-operative assessment of OSA (23). According to Fujita's 3 types of collapse of the upper airway during sleep (24), the Muller maneuver was able to differentiate Fujita type I (soft palatal) collapse, and Fujita type III (base of tongue) collapse, hence, identifying the anatomical level of obstruction needed to be addressed surgically. Unfortunately, as there are multiple factors involved in the dynamics of OSA that are not fully understood, the likelihood of surgical success may not correlate with the clinical finding on Muller's maneuver (25,26,27). However, it has been shown that Muller's maneuver is reproducible and may correlate with severity of OSA (16).

Since the first description in 1983 (23), the Muller maneuver has been proposed to be predictive of success in patients undergoing uvulopalatopharyngoplasty (UPPP) (29). There are conflicting reports of its usefulness. Sher et al found that Muller's maneuver can increase success rate of UPPP to 73% (30). Katsantonis et al, however, found a low predictive efficacy, of only 33% predictive value for success rate of UPPP (25). Terris et al showed that the Muller maneuver was both reliable and reproducible (16). We sought to investigate the correlation of the maneuver with OSA severity and to identify which level of obstruction was more significant in patients with severe OSA. We found that all 3 levels (palatal, lateral pharyngeal wall, and base of tongue) correlated very well with the severity of OSA (Table 6). We also noted that there was a significant difference in

the frequency and degree of base of tongue collapse in patients with severe OSA. Only 6.9% of patients with mild OSA had a >50% collapse of the base of tongue region, as compared to 65.9% of patients with severe OSA; this implies that patients with severe OSA have a 10 times higher incidence of base of tongue obstruction compared to patients with mild OSA. This suggests that for patients with severe OSA, it is prudent to not only surgically address the soft palate, but to consider some form of procedure (hyoid myotomy, genioglossus advancement, and tongue suspension or midline glossectomy) to address the base of tongue in these patients.

Conclusion

Clinical symptoms of OSA are sensitive but not specific for OSA. Some clinical examination parameters can be useful and predictive of the severity of OSA. These parameters have been highlighted in this article and extensively discussed. These parameters should be considered during treatment planning (medical and surgical) and tailored to the patient's disease and severity. Finally, patient self-perception of the presence and severity of OSA correlates well with objective measure of their disease severity.

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	AHI > 5
Snoring (daily)	80.2%
Nocturnal Choking (daily)	91.5%
Witnessed Apneas (daily)	90.9%
Unrefreshed Sleep (daily)	89.7%

Table 1. Symptomatology and AHI

AHI - Apnea Hypopnea Index

N = 102 patients

	Percent (>3x/week)
Snoring	95.1%
Nocturnal Choking	78.4%
Witnessed Apneas	75.4%
Unrefreshed Sleep	78.4%
Nocturnal Palpitations	69.5%
Nocturia	70.5%
Globus Sensation	47.9%
Hoarseness of Voice	34.2%
Post Nasal Drip	33.2%

Table 2. Frequency of symptoms
N = 102 patients

	Mean	SD	Range
BMI	32.9	8.1	17.7 to 74.6
EPW	12.3	4.6	1 to 22
AHI	37.9	27.7	0.7 to 111.2
AI	16.1	17.7	0.1 to 80.5
LSAT	81.9	8.2	52.0 to 84.0
Arousal Index	33.9	24.8	1.0 to 119.0
% Desat	16.2	20.5	0.1 to 90.0
REM %	9.9	6.3	1.0 to 29.0
SWS %	9.5	4.3	0 to 19.0

Table 3. Showing clinical and PSG results

BMI - Body Mass Index

EPW - Epworth's Sleepiness Scale

AHI - Apnea Hypopnea Index

AI - Apnea Index

LSAT - Lowest Oxygen Saturation

% Desat - Percentage Oxygen Saturation < 90%

REM % - Percentage REM Sleep Stage

SWS % - Percentage Slow Wave Sleep Stage

N = 102 patients

	Self-Perception of OSA Correlation Coefficient	p value
BMI	0.24	0.02
AHI	0.499	<0.0001
AI	0.577	<0.0001
LSAT	-0.285	0.005
Arousal Index	0.366	0.002
% Desat	0.462	<0.0001
REM %	-0.312	0.002
SWS %	-0.397	<0.0001

Table 4. Correlation of Self-perception of OSA with PSG data

BMI - Body Mass Index

AHI - Apnea Hypopnea Index

AI - Apnea Index

LSAT - Lowest Oxygen Saturation

% Desat - Percentage Oxygen Saturation < 90%

REM % - Percentage REM Sleep Stage

SWS % - Percentage Slow Wave Sleep Stage

N = 102 patients

	BMI	Epw	AHI	AI	LSAT	Ar Ind	% Desat	REM %	SWS %
BMI	1	0.147	<i>0.325</i>	<i>0.286</i>	<i>-0.326</i>	<i>0.308</i>	<i>0.386</i>	-0.221	<i>-0.255</i>
Epworth	0.147	1	0.053	0.078	-0.034	0.229	0.104	<i>-0.553</i>	<i>-0.461</i>
AHI	<i>0.325</i>	0.053	1	<i>0.767</i>	<i>-0.603</i>	<i>0.828</i>	<i>0.782</i>	<i>-0.586</i>	<i>-0.685</i>
AI	<i>0.286</i>	0.078	<i>0.767</i>	1	<i>-0.476</i>	<i>0.574</i>	<i>0.612</i>	<i>-0.508</i>	<i>-0.619</i>
LSAT	<i>-0.326</i>	-0.034	<i>-0.603</i>	<i>-0.476</i>	1	<i>-0.497</i>	<i>-0.619</i>	<i>0.336</i>	<i>0.431</i>
Ar Ind	<i>0.308</i>	0.229	<i>0.828</i>	<i>0.574</i>	<i>-0.497</i>	1	<i>0.762</i>	<i>-0.542</i>	<i>-0.607</i>
% Desat	<i>0.386</i>	0.104	<i>0.782</i>	<i>0.612</i>	<i>-0.619</i>	<i>0.762</i>	1	<i>-0.449</i>	<i>-0.563</i>
REM %	-0.221	<i>-0.553</i>	<i>-0.586</i>	<i>-0.508</i>	<i>0.336</i>	<i>-0.542</i>	<i>-0.449</i>	1	<i>0.719</i>
SWS %	<i>-0.255</i>	<i>-0.461</i>	<i>-0.685</i>	<i>-0.619</i>	<i>0.431</i>	<i>-0.607</i>	<i>-0.563</i>	<i>0.719</i>	1

Table 5. Correlation Coefficient table of various indices

(Using Pearson Correlation Coefficient)

(Numbers in bold and italics are statistically significant)

BMI - Body Mass Index

Epw - Epworth's Sleepiness Scale

AHI - Apnea Hypopnea Index

AI - Apnea Index

Ar Ind - Arousal Index

LSAT - Lowest Oxygen Saturation

% Desat - Percentage Oxygen Saturation < 90%

REM % - Percentage REM Sleep Stage

SWS % - Percentage Slow Wave Sleep Stage

N = 102 patients

	AHI	p-value
Mod Mallampati Index	0.389	<0.0001
Friedman Stage	0.331	0.0007
Muller (Velopharynx)	0.493	<0.0001
Muller (Lateral wall)	0.398	<0.0001
Muller (B.O.T)	0.499	<0.0001

Table 6. Spearman Correlation Coefficient of Modified Mallampati Index, Friedman Clinical Staging and Muller's Maneuver with OSA Severity

Mod Mallampati Index - Modified Mallampati Index

Friedman Stage - Friedman Clinical Staging

Muller (Velopharynx) - Muller's Maneuver collapsibility of the soft palate

Muller (Lateral Wall) - Muller's Maneuver collapsibility of the lateral pharyngeal walls

Muller (B.O.T) - Muller's Maneuver collapsibility of the base of tongue

N = 102 patients

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