Roentgenographic Dimensions of the Upper Airway in Snoring Patients with and without Obstructive Sleep Apnea*

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The purpose of this study was to examine whether a simple test, such as routine roentgenographic views of the upper airway, is useful in identifying anatomic narrowing of the airway in patients with sleep apnea. To accomplish this, we prospectively studied a group of 117 patients (95 male and 22 female subjects) referred for evaluation of heavy snoring and possible obstructive sleep apnea. All patients had full nocturnal polysomnography, including measurements of snoring. Lateral view of the airway obtained after swallowing contrast material was used to measure pharyngeal diameters at three sites along the airway. All measurements were performed with the patients standing and supine. We used three different definitions of sleep apnea (apnea/hypopnea index of 10, 20, and 40), and compared airway diameters between the apneic and nonapneic snorers. Only when sleep apnea was defined as greater than 40 apneas plus hypopneas per hour of sleep was there a significant difference in airway diameter at the tip of the palate and 1 cm distal to it between apneic and nonapneic snorers. Both groups of patients demonstrated a significant reduction in the retropalatal distance on assumption of the supine posture. Stepwise, forward, multiple linear regression analysis showed that the retropalatal distance and airway diameter at the tip of the palate and 1 cm distal to it were significant predictors of snoring, but not apnea. We conclude that (1) airway diameters account for some of the variability in snoring, and (2) they do not differentiate between apneic and nonapneic snorers.

(Chest 1991; 100:81-5)

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\text{AHI} = \text{apnea/hypopnea index; BMI = body mass index; OSA = obstructive sleep apnea; SI = snoring index}
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Many patients with sleep apnea have reduced pharyngeal area as documented by several techniques, including x-ray cephalometry, fluoroscopy, computed tomography, magnetic resonance imaging, and acoustic reflections.¹⁻⁵ Our ability to identify these anatomic abnormalities⁶ is important since it may permit a more rational selection of patients with sleep apnea who will likely benefit from upper airway surgery. In some patients, the structural abnormalities of the airway are evident on physical examination, eg, in patients with micrognathia, retrognathia, tonsillar enlargement, acromegaly, hypothyroidism. However, the majority of patients with obstructive sleep apnea (OSA) do not have an obvious anatomic deformity; such patients are said to have idiopathic OSA. Using sophisticated imaging techniques, such as x-ray cephalometry, computed tomography, and magnetic resonance imaging, these patients were found to have smaller upper airways than nonapneic controls.

We wished to examine whether a simpler test, widely available and rapidly accessible in all hospitals, can discriminate the upper airway abnormalities in patients with and without sleep apnea. Consequently, the purpose of this study was to examine whether upper airway diameter and postural changes in airway size, measured from the routine lateral views of the upper airway, are useful in differentiating patients with OSA from nonapneic controls.

**Methods**

**Patients**

We prospectively studied 117 unselected patients referred to our sleep clinic for evaluation of possible sleep apnea. All patients complained of snoring, which was the main reason for their referral. Some, but not all patients also complained of daytime tiredness, fatigue, excessive daytime sleepiness, and had other symptoms suggestive of sleep apnea.

**Roentgenographic Measurements**

All patients had supine and upright soft-tissue views of the pharynx (taken with a Phillips Pendo Diagnostic and Traunob c Unit). Views were taken using a standard tube-film distance of 100 cm; the Kv was set at 70, and the Mas varied from 2 to 4. Film (Kodak 10 × 12” TMG) was used along with a screen (Kodak Lanex regular intensifier screen), using a grid technique. A standard ruler was included in the views to measure the magnification factor which was 1.3 X.

The measurements of airway size were taken during quiet respiration in both the supine and the upright positions. Although no cephalometric techniques were used, head position was standardized by having the patient first sit in a chair and then lie on a table with the head in relaxed neutral position against the film plate. The following dimensions were measured (Fig 1): distance A—from the back of the tongue to the posterior wall of the oropharynx, measured in the plane of the tip of the soft palate and perpendicular to the wall of the oropharynx; distance B1—1 cm superior to the plane of A, extending from the back of the soft palate to the posterior wall of the oropharynx; distance B2—in the plane of B1, from the back of the tongue to the posterior wall of the oropharynx; and distance C—1 cm inferior to the plane of A, from
the back of the tongue to the posterior wall of the oropharynx; this distance bears the closest relationship to the airway diameter at the base of the tongue. All of the above measured planes were parallel to each other and perpendicular to the posterior wall of the oropharynx. Figure 1 illustrates these distances schematically and using a roentgenogram obtained from one of the subjects.

All roentgenographic measurements were performed prior to the sleep study and the radiologist who measured the diameter of the pharyngeal airway was unaware of the results of the sleep study.

Sleep Studies

All patients had full nocturnal polysomnography that included monitoring of EEG, right and left EOG, submental and anterior tibial EMG, ECG, oronasal flow, chest wall and abdominal excursion by impedance plethysmography, oxygen saturation, and snoring. All measurements, except snoring, are quite standard and were performed in the conventional manner, displayed on a polygraph (Grass model 78D, Grass Instruments, Quincy, MA), analyzed for the presence of apneas and hypopneas, and scored according to the standard criteria by an experienced polysomnographer who was unaware of X-ray measurements.

Snoring was measured using a microphone and a sound meter (SL1220, Pacer Industries, Toronto, Ont); the microphone–sound meter system was calibrated in the range of 40 to 110 dB using 1-kHz signal and a sound chamber. The microphone was taped to the chest wall band of the respitrace. With this setup quiet breathing and simulated snoring always registered below 55 dB, and therefore only the spikes in sound intensity exceeding 60 dB were classified as snores. Snoring was quantified by reporting the number of snores per hour of sleep (snoring index–SI), maximum and mean nocturnal sound intensity (dBmax and dBmean). Apnea was quantified by reporting the apnea/hypopnea index (AHI).

Data Analysis

The patients were divided into apneic (AHI >10) and nonapneic (AHI ≤10) groups. Unpaired t test was used to compare airway diameters and between the apneic and nonapneic groups. Paired t test was employed to compare upright and supine diameters.

Correlation analysis was used to examine the correlation between airway diameters and weight or body mass index (BMI). Multiple, stepwise, forward, linear regression analysis was used to examine the relationship between AHI and SI (dependent variables) and age, BMI, and airway diameters (independent variables).

Realizing that the division of patients into apneic and nonapneic groups based on the AHI of 10 is relatively arbitrary, although widely employed in clinical studies, we used two more definitions of sleep apnea based on AHI of 20 and AHI of 40; t tests were repeated to compare airway diameters between apneic and nonapneic snorers defined according to the new criteria.

Finally, since the anthropometric variables may be expected to influence airway diameters, we performed exact, random, one-for-one matching for age and BMI between apneic and nonapneic snorers, and compared airway diameters in this matched group.

All statistical analysis, including random one-for-one matching for age and BMI was done using SAS statistics package (SAS Institute, Cary, IN), version 6.03. The significance level was take at 0.05.

Results

Of the 117 patients, 56 had OSA (39 male and 17 female subjects) and 61 were nonapneic snorers (56 male and five female subjects). The nonapneic group had significantly more female subjects than the apneic group. Patients with OSA were trivially, but significantly, older and more obese than the nonapneic snorers (Table 1).

There was no significant difference in snoring frequency between the apneic and nonapneic snorers, although apneic snorers snored somewhat louder than the nonapneic ones and were more profoundly hypoxic during the night (Table 1).

Mean airway diameters were not significantly different between the two groups, whether measured in the upright or supine posture (Table 2). In nonapneic

Roentgenographic Dimensions in Snoring Patients (Hoffstein, Weisae, Haney)
Table 1—Anthropometric and Sleep Data*

<table>
<thead>
<tr>
<th></th>
<th>Non-OSA</th>
<th>OSA</th>
<th>p</th>
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</thead>
<tbody>
<tr>
<td>M:F</td>
<td>39:17</td>
<td>56:5</td>
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<tr>
<td>Age, yr</td>
<td>44±10</td>
<td>50±11</td>
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<tr>
<td>Weight, kg</td>
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<td>94±</td>
<td>0.0001</td>
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<tr>
<td>BMI</td>
<td>29±5</td>
<td>30±6</td>
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<tr>
<td>AHI</td>
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<td>36±22</td>
<td></td>
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<tr>
<td>SI</td>
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<td>249±267</td>
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<tr>
<td>dbmax</td>
<td>81±11</td>
<td>96±10</td>
<td>0.02</td>
</tr>
<tr>
<td>Awake O₂sat</td>
<td>97±2</td>
<td>98±2</td>
<td>NS</td>
</tr>
<tr>
<td>Lowest O₂sat</td>
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<td>79±11</td>
<td>0.0001</td>
</tr>
<tr>
<td>Mean O₂sat</td>
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<td>93±3</td>
<td>0.05</td>
</tr>
</tbody>
</table>

*BMİ = body mass index; AHI = apnea/hypopnea index; SI = snoring index; dbmax = maximum nocturnal sound intensity; O₂sat = oxygen saturation.

snorers, there was a significant reduction in all airway diameters on assuming supine posture; in apneic snorers, only the retropalatal distance was significantly lower in the supine position as compared with the upright posture (Table 2).

Changing the definition of apnea to AHI = 20 resulted in having 44 patients in the apneic group and 73 patients in the nonapneic group. There was still no significant difference in any of the airway diameters between nonapneic and apneic snorers. When the definition of apnea was altered to AHI = 40, which resulted in 19 patients with sleep apnea and 98 nonapneic snorers, there was a significant reduction in airway diameter at the tip of the palate (14.2±4.7 mm vs 17.4±5.6 mm, p <0.009) and 1 cm distal to it (13.5±4.8 mm vs 16.2±5.4 mm) in apneic patients. This difference between the apneic and nonapneic groups was present only in supine, but not upright, posture.

Exact matching for age and BMI resulted in selection of 26 patients (13 apneic and 13 nonapneic) of the original set of 117 patients. Their mean age was 44±10 years and BMI was 29±4 kg/m². They differed significantly in the severity of their apnea (AHI of 6±3 vs 29±19, p <0.0009), but not snoring (SI of 167±216 vs 171±148). All of the airway diameters listed in Table 2 were similar in these two anthropometrically identical groups. Upright retropalatal diameters were significantly greater than the supine both in apneic and nonapneic snorers.

Among nonapneic snorers, there was no significant correlation between any of the airway diameters and weight or BMI. However, in apneic snorers, we found significant correlations between the supine airway diameters and weight; the highest correlation was between weight and the airway diameter at the level of the tip of the palate (r = 0.45, p <0.0005).

To examine the factors that significantly influence the AHI and the SI in the entire group of 117 patients, we employed multiple, stepwise linear regression analysis; the dependent variables were AHI and SI, and the independent variables were age, BMI, and all of the upright and supine airway diameters. We found that AHI was significantly correlated only with age and BMI. The SI, however, correlated significantly not only with BMI, but also with the retropalatal distance, airway diameter at the tip of the palate and 1 cm distal to it (multiple r²=0.26, p <0.05). This correlation was stronger in the group of nonapneic snorers (multiple r² = 0.49) than among the apneic snorers (multiple r² = 0.25).

**Discussion**

This study illustrates that upper airway dimensions determined from routine roentgenographic measurements do not differentiate between the apneic and nonapneic snorers, but account for some of the variability in snoring. An additional unique feature of this study is quantitative assessment of snoring and its relationship with airway size, which to our knowledge has not been previously measured in similar studies dealing with upper airway properties in apneic and nonapneic snorers.

There are several possibilities that may explain our main finding, ie, lack of significant difference in pharyngeal diameters between apneic and nonapneic snorers. These are the following: (1) head position; (2) the type of population studied herein; (3) influence of pharyngeal function, rather than structure; (4) availability of measurements only at one site along the pharyngeal airway; and (5) limitations of the technique.

Head position may influence upper airway patency, and it is possible that variations in neck flexion and extension during the procedure influenced the configuration of the airway, thus masking any difference between the two groups. We attempted to minimize the variation in head position by performing all roentgenographic measurements in a standard fashion.

Probably the most important reason for the lack of...
difference in upper airway measurements between the apneic and nonapneic group is our patient population. Although variable with respect to AHI, it was otherwise very homogeneous: all patients presented with very similar symptoms, all complained of snoring (confirmed by objective measurements), all were similar in age, and all were obese.

Structural narrowing of the upper airway has been clearly demonstrated in obese apneic patients vs nonobese, nonsnoring, nonapneic controls. This information is important for understanding the pathogenesis of sleep apnea, but it is not very valuable for clinical purposes, since the nonobese, nonsnoring patient is seldom, if ever, referred for a sleep study or measurement of upper airway area. It is the obese, snoring patient who will be investigated to rule out sleep apnea. In such patients, demonstration of sleep apnea may lead to a request for surgical opinion. One of the factors influencing surgical decision may be the size of the upper airway. The main result of the present study is that a simple lateral roentgenogram of the airway, easily available in all hospitals, is not useful to decide on the presence (or absence) of airway narrowing in apneic snorers.

It is known that obesity and snoring have an independent effect on reduction in the upper airway size. Our findings indicate that in awake patients, simple roentgenographic measurements of upper airway diameter in clinically closely related groups are not likely to distinguish apneic from nonapneic snorers, even after correcting for the differences in age and weight. However, the absolute diameters of the airway may be important since they do account for some of the variability in apnea and snoring.

It is possible that in our obese, snoring patients, upper airway function, rather than structure, was abnormal. Functional abnormalities of the upper airway in patients with sleep apnea have been well documented. We reasoned that postural changes in airway area provide a reflection of pharyngeal function, and therefore we compared upright and supine airway diameters in apneic and nonapneic patients. However, we failed to find a significant difference between the two groups. This is most likely explained by the fact that airway diameters may not be representative of airway cross-sectional area, because the geometry of airway cross-section is most likely not circular or elliptical, but more complex. Since it is the reduction in airway area that is important in the pathogenesis of sleep apnea, it is possible that measurements of airway diameters alone are not sufficient to demonstrate the difference between the apneic and nonapneic snorers. Furthermore, both groups were similar in terms of snoring, and we found that snoring has a stronger relationship to airway diameters than apnea.

Our measurements were confined to a small segment of the pharyngeal airway, which is thought to be the most likely site of airway obstruction during sleep. It is well known that there are other areas of narrowing, e.g., in the hypopharynx, oropharynx, and the nasopharynx, it is possible that had the areas been measured at these sites, the differences between the apneic and nonapneic snorers would become more apparent.

We found that age, BMI, and airway diameters account for only 26 percent of the variability in the SI. Clearly, there must be other factors, not accounted for in the present study, which better explain the variability in snoring. Such factors are most likely airway areas, compliance, and nasal resistance during sleep.

Finally, our present results have certain implications as to the usefulness of routine roentgenographic measurements of airway diameters in patients suspected of having sleep apnea. Based on our study, we believe that such measurements, when obtained from the routine lateral views of the airway, are of limited usefulness and cannot distinguish between apneic and nonapneic snorers. If accurate assessment of upper airway structure is necessary, it should probably be performed using more sophisticated imaging modalities, such as cephalometry, computed tomographic scans, or magnetic resonance.

REFERENCES

Am Rev Respir Dis 1987; 136:628-32

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