Snoring and Upper Airway Properties*

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Habitual snoring in adults may be related to upper airway dysfunction, although the precise relationship has never been studied. We quantitatively measured snoring and correlated it with upper airway properties in 50 apneic and 59 nonapneic adult male patients. Both groups were similar in terms of nasal airflow resistance and pulmonary function tests. We found a significant correlation between the severity of snoring and nasal airflow resistance in both groups, and between the severity of snoring and pharyngeal and glottic areas in the apneic group. We conclude that snoring may be associated with abnormalities in upper airway properties.

Methods

We prospectively examined 109 adult male patients (age range: 22 to 78 years) referred to the Sleep, Noise, and Sinus Clinic of St. Michael’s Hospital for assessment of habitual snoring and sleep-disordered breathing. They all underwent nocturnal polysomnographic studies which included continuous monitoring of the rib cage and abdominal movements by respiratory inductive plethysmography, arterial oxygen saturation using ear oximeter, and sound level. The latter was measured using a sound meter attached to a microphone positioned at the level of the cricothyroid notch. All variables were displayed on a polygraph recorder. The sound channel was calibrated in the range of 40 to 100 dB using 1KHz audio signal. For each subject studied, quiet tidal breathing was always registered below 60 dB.

All sleep and sound data were analyzed by experienced technicians who were unaware of the purpose of the study. Sleep tracings were scored to identify apneas and hypopneas according to the usual criteria.4 Apnea/hypopnea index was defined as the number of apneas and hypopneas per hour of sleep. Sound level tracings were analyzed to count the total number of snores and to identify the highest nocturnal decibel level (dBmax). Only snores higher than 60 dB were counted and the total number of snores per hour of sleep was calculated, this is referred to as the snoring index (SI).

In each patient, we studied the structure and function of the airways from the nose to the distal trachea as follows. We measured nasal airflow resistance (Rna) in 68 patients using the plethysmographic technique. Pharyngeal (Ap), glottic (Ag), and intrathoracic tracheal (At) areas were measured in 31 patients at functional residual capacity (FRC) using the acoustic reflection technique. Tracheal function was assessed in 95 patients by measuring the ratio of maximum inspiratory to maximum expiratory flow at 50 percent of vital capacity (V50exp/V50ins). All of the above measurements were carried out with the patients awake and in the sitting position.

The plethysmographic technique for measuring nasal airflow resistance, and the acoustic reflection technique for measuring pharyngeal, glottic, and tracheal areas have been described in detail previously.4,8 These techniques have been used extensively in our laboratory for studying various aspects of upper airway function.4,5,7,10

The results were analyzed using two-tailed Student’s t-test and linear regression analysis. Statistical significance was established as p<0.05.

Results

Table 1 summarizes the anthropometric, sleep, snoring, pulmonary function, airway areas, and nasal airflow resistance data in all 109 patients.

Based on the polysomnographic studies, we identified 50 apneic (apnea/hypopnea index>10) and 59 nonapneic snoring patients. The apneic patients were significantly overweight and snored louder and more frequently than the nonapneic patients.

Both groups had similar nasal airflow resistance, pulmonary function tests, pharyngeal area at FRC, and glottic areas at FRC and RV. However, pharyngeal area at RV was significantly lower in the apneic group than in the nonapneic group (1.88±0.35 cm² vs 2.60±0.52 cm², respectively, p<0.0005).

We used linear regression analysis to examine the correlations between the severity of snoring (snoring index and the maximum nocturnal decibel level) and the anthropometric, sleep, pulmonary function, airway areas, and nasal airflow resistance data in both groups.

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Table 1—Anthropometric, Sleep, Snoring, Pulmonary Function, and Upper Airway Data*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Apneic Snorers</th>
<th>N</th>
<th>Nonapneic Snorers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yrs</td>
<td>50</td>
<td>49 ± 11</td>
<td>59</td>
<td>46 ± 11</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>50</td>
<td>97 ± 22</td>
<td>59</td>
<td>94 ± 13</td>
</tr>
<tr>
<td>AHI</td>
<td>50</td>
<td>42 ± 30</td>
<td>59</td>
<td>4 ± 3</td>
</tr>
<tr>
<td>SI</td>
<td>50</td>
<td>630 ± 283</td>
<td>59</td>
<td>407 ± 321†</td>
</tr>
<tr>
<td>dBmax, dB</td>
<td>50</td>
<td>81 ± 13</td>
<td>59</td>
<td>73 ± 11†</td>
</tr>
<tr>
<td>FEV1, % pred</td>
<td>48</td>
<td>107 ± 20</td>
<td>54</td>
<td>107 ± 18</td>
</tr>
<tr>
<td>V50exp/V50ins</td>
<td>47</td>
<td>0.64 ± 0.27</td>
<td>48</td>
<td>0.62 ± 0.23</td>
</tr>
<tr>
<td>Aph (FRC), cm³</td>
<td>15</td>
<td>3.31 ± 0.66</td>
<td>16</td>
<td>3.22 ± 0.67</td>
</tr>
<tr>
<td>AgI (FRC), cm³</td>
<td>15</td>
<td>1.37 ± 0.26</td>
<td>16</td>
<td>1.68 ± 0.51</td>
</tr>
<tr>
<td>Atr (FRC), cm³</td>
<td>15</td>
<td>2.51 ± 0.98</td>
<td>16</td>
<td>2.66 ± 0.97</td>
</tr>
<tr>
<td>Aph (RV), cm³</td>
<td>15</td>
<td>1.88 ± 0.35</td>
<td>16</td>
<td>2.59 ± 0.52†</td>
</tr>
<tr>
<td>AgI (RV), cm³</td>
<td>15</td>
<td>1.39 ± 0.36</td>
<td>16</td>
<td>1.24 ± 0.50</td>
</tr>
<tr>
<td>Atr (RV), cm³</td>
<td>15</td>
<td>2.17 ± 0.40</td>
<td>16</td>
<td>2.13 ± 0.83</td>
</tr>
<tr>
<td>Rna, cm H₂O/L/s</td>
<td>29</td>
<td>3.33 ± 2.49</td>
<td>39</td>
<td>2.64 ± 3.17</td>
</tr>
</tbody>
</table>

*All values expressed as mean ± SD. N is number of patients with a given measurement; AHI, apnea/hypopnea index; SI, snoring index; dBmax, maximum nocturnal decibel level; FEV1, forced expired volume in 1 sec; V50ex, maximum inspiratory flow rate at 50 percent of vital capacity; V50ins, maximum expiratory flow rate at 50 percent of vital capacity; Aph (FRC), pharyngeal at FRC; and Aph (RV), pharyngeal area at RV, Atr (FRC), tracheal area at FRC; Atr (RV), tracheal area at RV; AgI (FRC), glottic area at FRC; AgI (RV), glottic area at RV; Rna, nasal airflow resistance; and % pred, percent predicted.
†Significantly different from apneic snorers.

Table 2 summarizes only those relationships where the correlation coefficient was found to be statistically significant. Nonapneic and apneic snorers showed a weak, but significant correlation between the severity of snoring and the nasal airflow resistance. Weak, but significant correlation was present between the snoring index and age only in nonapneic patients. In the apneic group, the severity of snoring correlated significantly with weight, apnea/hypopnea index, and pharyngeal and glottic areas at FRC and RV. It is noteworthy that no significant correlations were found between the severity of snoring and V50exp/V50ins, and tracheal area in both groups.

**DISCUSSION**

The novel feature of our study is the quantitative measurement of snoring and its correlation with upper airway properties. We found that the apneic patients snore louder and more frequently than the nonapneic ones. In apneic patients, snoring correlated with nasal airflow resistance and pharyngeal and glottic areas at low lung volumes. In the nonapneic group, snoring correlated only with nasal airflow resistance.

Our observations imply that increased nasal airflow resistance is an important contributing factor to snoring. Pharyngeal abnormalities at low lung volumes may worsen snoring and predispose these patients to develop obstructive sleep apnea.

The pathogenesis of snoring and the mechanisms by which loud sounds are generated in the upper airway are not completely understood. Direct cine-radiographic observations of the upper airway in snoring patients during sleep reveal inspiratory narrowing of the pharyngeal and laryngeal airway. Increased upper airway resistance results in lower intraluminal airway pressure and higher inspiratory flow rates, which causes vibrations of the collapsible oropharyngeal walls. These vibrations may partly account for the characteristic inspiratory snoring sound.

All upper airway measurements in this study were performed in sitting, awake patients. This is a potential drawback since pharyngeal and nasal properties are known to be affected by posture and the sleep state; hypotonia of the upper airway muscles and variations in the nasal cycle affecting nasal resistance have all been well documented. Nevertheless, there is evidence that upper airway properties in patients with sleep-disordered breathing are abnormal even in the awake state; for example, nonapneic snorers and patients with obstructive sleep apnea have reduced pharyngeal area, increased pharyngeal collapsibility, and higher lung volume dependence of pharyngeal area than suitably matched controls.4,7

Our results indicate that snoring is related to the properties of the nasal and pharyngeal airway; this may have important implications for rational selection of therapy.

**REFERENCES**


Cardiology and Cardiovascular Surgery: Interventions, 1988

The Annual Symposium of the Texas Heart Institute, the 18th, will be held at the Texas Heart Institute, Houston, September 28-October 1. For information, contact Ms. Susan Murray, Office of the Medical Director, Texas Heart Institutes, PO Box 20345, Houston 77225 (713:791-2157).

11th Annual Occupational Safety and Health Summer Institute

This course will be held August 1-5 in Williamsburg, Virginia. For information, contact Mr. Ted Williams, Occupational Safety and Health Educational Resource Center, University of North Carolina, 109 Connor Drive, Chapel Hill 27514 (919:962-2101).