Sleep Disturbance and Obesity
Changes Following Surgically Induced Weight Loss

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Background: Obesity causes sleep disturbance and is the most significant risk factor for sleep apnea. Only surgical methods provide substantial sustained weight loss for most severely obese subjects.

Objective: To study sleep disturbance in patients undergoing laparoscopic adjustable gastric banding with a commercially available product (Lap-Band).

Methods: In this study, 313 consecutive patients with severe obesity (body mass index [calculated as weight in kilograms divided by the square of height in meters] >35) completed a preoperative sleep questionnaire and clinical assessment. One hundred twenty-three patients completed the same assessment 12 months after surgery. The characteristics of sleep disturbance and changes in responses to weight loss have been assessed.

Results: There was a high prevalence of significantly disturbed sleep in men (59%) and women (45%), with women less likely to have had their sleep disturbance investigated. Observed sleep apnea was more common in men, but daytime sleepiness was not affected by sex. Waist circumference was the best clinical measure predicting observed sleep apnea ($R=0.36; P<.001$). The group lost an average of 48% (SD, 16%) of excess weight by 12 months. There was a significant improvement in the responses to all questions at follow-up, with habitual snoring reduced to 14% (preoperative value, 82%), observed sleep apnea to 2% (preoperative value, 33%), abnormal daytime sleepiness to 4% (preoperative value, 39%), and poor sleep quality to 2% (preoperative value, 39%) ($P<.001$ for all).

Conclusions: Obesity-related sleep disorders improve markedly with weight loss. Sustainable weight loss should be a primary aim in the management of severely obese patients with significant sleep disturbance, including sleep apnea. Low-risk laparoscopic obesity surgery should be considered for selected patients with this important comorbidity.

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**PATIENTS AND METHODS**

Patients with a BMI greater than 35; with significant medical, physical, or psychosocial disabilities; and who had attempted weight reduction by other means for at least 5 years were considered for surgery using an adjustable gastric banding system (Lap-Band; BioEnterics Corporation, Carpinteria, Calif).

The form of gastric restrictive surgery used involves the laparoscopic placement of an adjustable silicone band 2 to 3 cm below the gastroesophageal junction. Food within the small pouch of the stomach and above the band produces an early sense of satiety, thereby weight loss. The band has a balloon incorporated in its inner wall, and this is attached via tubing to a subcutaneous reservoir. Adjustments to gastric restriction are made by adding or removing isotonic sodium chloride solution from the reservoir.

Preoperative assessment included a medical assessment, including history of any diagnosed sleep disorder, previous sleep studies, and use of nasal continuous positive airway pressure, and a questionnaire on sleep symptoms and quality of sleep. The questionnaire inquired about habitual snoring, observed sleep apnea, and nocturnal choking. Patients also indicated subjective sleep quality and the presence of morning headaches or tiredness on waking. Responses to the written questionnaire were reassessed at clinical interview, where responses were clarified and the nature of sleep disturbance explored. Clarification of who observed habitual snoring, sleep apnea, and nocturnal choking was obtained from all patients, and input from the sleep partner and household members was encouraged. The Epworth Sleepiness Scale (ESS), a validated instrument that measures daytime sleepiness, was also completed. The community norm mean ± SD score is 4.0 ± 3.0, with excessive daytime sleepiness defined as an ESS score of greater than 10. Patients were considered to have significant sleep disturbance if they reported habitual snoring and poor sleep quality, habitual snoring and an ESS score of greater than 10, or habitual snoring and observed sleep apnea. Anthropometric measurements, including weight, height, neck circumference (measured at the level of the cricothyroid cartilage), and waist and hip measurements, were taken preoperatively and at yearly follow-up. Correlations between preoperative sleep disturbance and preoperative clinical and biochemical features were assessed.

Preoperative excess weight is calculated as the weight (in kilograms) at the time of surgery less the ideal weight (in kilograms), as measured by the Metropolitan Life Tables (1985). Percentage of excess weight loss is calculated by dividing the weight loss by the excess weight preoperatively, multiplied by 100.

The appropriate hospital ethics review board approved the questionnaires used. All patients gave preoperative written informed consent to the procedure and follow-up requirements.

Mean ESS scores were obtained, and a paired 2-sided t test was used to test the significance of differences. A χ² test was used to test the significance of differences between categorical variables and responses to the questionnaire. Data are given as mean ± SD. Bivariate, binary logistic, and stepwise linear regression analysis, using a statistical software package, was used to assess for clinical correlation with significant sleep disturbance, significant sleep apnea, and ESS score. P < .05 was considered significant.

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**RESULTS**

The preoperative characteristics of the 313 consecutive study patients are shown in Table 1.

**PREOPERATIVE SLEEP DATA**

**Observed Sleep Apnea**

The reported incidence of habitual snoring (Table 2) was high in men and women, with observed sleep apnea in men and women being more than 10 times that reported in the adult community. Men reported a higher incidence of observed sleep apnea, habitual snoring, and nocturnal choking, but there was no difference in reported daytime tiredness, daytime sleepiness, and poor sleep quality between men and women (Table 2). The mean ESS scores in men and women were 9.0 (SD, 5.8) and 8.4 (SD, 4.8), respectively, both significantly higher than the community normal score of 4 (P < .001).

Ninety-five patients (30%) reported habitual snoring and excessive daytime sleepiness (ESS score of >10). In this group, 52 (55%) reported observed sleep apnea; 48 (51%), poor sleep quality; and 62 (65%), morning headaches. Only 22 (23%) of these patients had their sleep disturbance investigated before referral for obesity surgery, and significantly more of the men than women (50% [11/22] vs 13% [11/71]; P < .01) underwent polysomnography.

Male sex (P < .001), high BMI (P < .001), and high waist-hip ratio (P = .001) are significant independent predictors of self-reported sleep apnea. However, the best predictor was waist circumference (R = 0.36; P < .001), and no other factors, including sex, were predictive after correcting for this. Sleep apnea was reported by 42% (45/108) of those with a waist circumference of 126 cm (median) or above and in 10% (10/102) of those with a waist circumference below this value. Figure 1 shows a linear relation of reported sleep apnea for each quartile of waist circumference. Several biochemical measurements were also predictive, including a high plasma insulin level (R = 0.15; P = .03) and a low high-density lipoprotein cholesterol level (R = 0.17; P = .01), but did not explain any significant variance when controlled for the waist circumference.

**Daytime Sleepiness**

Daytime sleepiness, as measured by an increased ESS score, was significantly correlated with nocturnal choking (R = 0.34; P < .001), observed sleep apnea (R = 0.33;
than 20% of the variance in ESS score (R2 = 0.36; P < .001). ESS indicates Epworth Sleepiness Scale; NCPAP, nasal continuous positive airway pressure.

†The significance of any difference in response between men and women using the x2 test.

Significant Sleep Disturbance

By combining the groups with symptoms of habitual snoring and any 1 or more of observed sleep apnea, daytime sleepiness (ESS score of >10), and poor sleep quality, a group with significant sleep disturbance was defined and included 59% (36/61) of the male and 45% (113/252) of the female patients overall. This definition provides us with an indication for further evaluation by sleep study.

As was found for OSA, there were many predictors of significant sleep disturbance, including male sex, high BMI, and the anthropometric measures. The best single predictor was waist circumference (R = 0.37; P < .001) and, when corrected for this, no other measurement added significantly to the variance of significant sleep disturbance. Sixty-two percent (67/108) of patients with a waist circumference of 126 cm or greater (median) reported significant sleep disturbance, with only 28% (29/102) of patients with a smaller waist circumference reporting such a disturbance.

Surgical Results

Laparoscopic placement of the adjustable gastric band was achieved in 300 patients. In only 1 was conversion to an open approach necessary, due to the presence of a massive liver preventing adequate access. The remaining 12 patients underwent elective open placement of the band, as all were undergoing revision after previous gastric restrictive surgery (gastroplasty in 10 and nonadjustable banding in 2). The median hospital stay for laparoscopic placement was 2 days.

Weight loss is progressive during the first 2 to 3 years, with a plateau out to 6 years. The results of all 740 persons treated with this method by one of us (P.E.O.) are shown in Figure 2. Early complications in our study group of 313 were 4 wound infections (1 [0.3%] of 300 after laparoscopic surgery and 3 [23%] of 13 after open surgery). There was no clinical evidence of deep venous thrombosis or pulmonary embolus in this series. There were no patients requiring postoperative respiratory support. The most significant late postoperative problem was prolapse of the stomach through the band. This occurred in 29 (9%) of these patients, and presents with symptoms of gastroesophageal reflux and band stomal obstruction; opening the band stoma relieves symptoms, and laparoscopic surgical revision is required. The incidence of prolapse is decreasing, probably as a result

Table 1. Patient Demographic Characteristics Before Surgery

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Men (n = 61)</th>
<th>Women (n = 252)</th>
<th>Total (N = 313)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>42.0 (9.0)</td>
<td>40.5 (9.4)</td>
<td>41.0 (9.0)</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>152 (31)</td>
<td>124 (21)</td>
<td>130 (26)</td>
</tr>
<tr>
<td>BMI†</td>
<td>48.0 (9.2)</td>
<td>45.7 (7.3)</td>
<td>46.3 (7.7)</td>
</tr>
</tbody>
</table>

Table 2. Prevalence of Self-Reported Sleep Disturbance in Patients Presenting for Surgery

<table>
<thead>
<tr>
<th>Sleep Disturbance</th>
<th>Men (n = 61)</th>
<th>Women (n = 252)</th>
<th>Total (N = 313) P†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitual snoring</td>
<td>88</td>
<td>73</td>
<td>76</td>
</tr>
<tr>
<td>Observed sleep apnea</td>
<td>52</td>
<td>26</td>
<td>30</td>
</tr>
<tr>
<td>Nocturnal choking</td>
<td>30</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>Waking unrefreshed</td>
<td>50</td>
<td>49</td>
<td>49</td>
</tr>
<tr>
<td>ESS score &gt; 10</td>
<td>39</td>
<td>31</td>
<td>33</td>
</tr>
<tr>
<td>Poor</td>
<td>32</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>Fair</td>
<td>40</td>
<td>44</td>
<td>43</td>
</tr>
<tr>
<td>Good</td>
<td>28</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>NCPAP</td>
<td>18</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

Figure 1. The prevalence of reported OSA vs quartiles of waist circumference. There were only 3 men in Q2 (1 reported OSA) and none in Q4. The correlation coefficient for observed OSA vs waist circumference is R = 0.36 (P < .001). OSA indicates obstructive sleep apnea; Q1, quartile 1; Q2, quartile 2; Q3, quartile 3; and Q4, quartile 4.

Figure 2. Early complications in our study group of 313 were 4 wound infections (1 [0.3%] of 300 after laparoscopic surgery and 3 [23%] of 13 after open surgery). There was no clinical evidence of deep venous thrombosis or pulmonary embolus in this series. There were no patients requiring postoperative respiratory support. The most significant late postoperative problem is prolapse of the stomach through the band. This occurred in 29 (9%) of these patients, and presents with symptoms of gastroesophageal reflux and band stomal obstruction; opening the band stoma relieves symptoms, and laparoscopic surgical revision is required. The incidence of prolapse is decreasing, probably as a result
of better fixation of the band to the stomach. There were 4 (1%) erosions of the band into the stomach and 4 (1%) cases of tubing leaks, requiring surgical correction.

SLEEP AFTER WEIGHT LOSS

One-year follow-up data are available for 123 of the 313 patients, and these patients have completed a follow-up clinical review and questionnaire. This group had a mean initial weight of 129.7 ± 24.0 kg and an initial BMI of 46.0 ± 7.5. At 1-year follow-up, the mean weight was 98.5 ± 18.0 kg and the BMI was 35.3 ± 5.8. This represents a mean weight loss of 31.2 ± 13.0 kg and a percentage excess weight loss of 48% ± 16% at 12 months. The preoperative and follow-up data for sleep disturbance are shown in Table 3. Highly significant improvement is seen for all measures of sleep disturbance. Table 4 shows the change in the ESS score and indicates a marked improvement in daytime sleepiness for men and women. The mean ESS score at 12-month follow-up of 4.0 ± 3.4 is identical with the community norm.

Of the 123 patients followed up, 10 were using nasal continuous positive airway pressure for treatment of OSA preoperatively. At follow-up, 7 were no longer using this therapy and symptoms had resolved. The remaining 3 reported sleep improvement with weight loss but still used continuous positive airway pressure therapy. One is awaiting upper airway surgery. This small group had an ESS score of 13.1 preoperatively and 2.75 at follow-up (P < .001).

**COMMENT**

This study confirms that sleep disturbance is a common comorbidity of obesity in men and women. The measured prevalence of habitual snoring, observed sleep apnea, and nocturnal choking of 52% of men and 26% of women is likely to be an underestimate, as many patients have not been observed during sleep. In addition, there may be differing reporting characteristics of men and women partners, with men perhaps less likely to report observed sleep apnea in a female partner.

Men on presentation to us are more likely to have had documentation of sleep disturbance by an overnight sleep study. Only 15% of women presenting with morbid obesity, habitual snoring, and excessive daytime sleepiness had been investigated, compared with 46% of men. This may indicate a belief that SDB predominantly affects men and, therefore, symptoms of sleep disturbance may not be elicited or recognized in women. Janson et al. studied sleep disturbance in young adults, found that young men were more likely to report habitual snoring and women more often reported daytime sleepiness. Our data indicate that obese women with sleep disturbance who present for weight loss surgery are underinvestigated.

There is clearly significant correlation between weight, BMI, and waist, hip, and neck measurements. Measurements that correlated best with obesity-related sleep disturbance were BMI and waist measurements, with neck measurements of less predictive value. Deegan and McNicholas found that waist measurement was a better predictor of the apnea-hypopnea index than was neck measurement in men, with the opposite being true in women. We found waist circumference a better predictor of reported sleep disturbance than neck circumference in men and women. For a waist measurement of
greater than 126 cm in men or women, there is a high prevalence of sleep disturbance and this simple test is easily performed in any physician’s office.

Obstructive sleep apnea in morbidly obese subjects has clear associations with male sex, increased waist circumference, and high waist-hip ratio—the android weight distribution. In contrast to this, we found that neither sex nor weight distribution nor the biochemical markers of the metabolic syndrome affect daytime sleepiness, after adjusting for BMI and age. It would appear that daytime sleepiness is a common feature of morbid obesity and, unlike OSA, is not related to weight distribution. This finding concurs with that of Vgontzas et al., who found that daytime sleepiness in obese patients is not always associated with SDB and may be related to other factors such as metabolic or circadian abnormalities. Daytime sleepiness can be a major disability with obvious effects on patients’ work, leisure, and safety. This study has found major improvement in daytime sleepiness associated with weight loss in men and women, with complete resolution of this important comorbidity in most of our patients.

Weight loss using the adjustable gastric banding system dramatically improves and often abolishes symptoms of SDB in morbidly obese patients. Symptoms directly due to upper airway obstruction, habitual snoring, observed OSA, and nocturnal choking are all improved. Asthma and gastroesophageal reflux are also improved after placement of the adjustable gastric band and subsequent weight loss. In addition to improving SDB, nasal continuous positive airway pressure also improves asthma and gastroesophageal reflux, both common comorbidities of obesity and often aggravated by OSA. There are likely to be multiple mechanisms for the improvement in upper and lower airway obstruction with weight loss.

While the exact nature and spectrum of obesity-related sleep disorder might be debated, it is clear that patient-reported sleep disturbance and daytime sleepiness improve substantially with weight loss. There are many studies showing that weight loss using dietary and surgical methods improves sleep disorders in obese subjects. The primary aim of management of obesity-related sleep disorder, including SDB in obese patients, should be sustainable weight loss. Surgery is the only available method to achieve this effect in severely obese subjects. Recent advances in weight loss surgery, particularly the use of the laparoscopic or minimally invasive approach and the ability to adjust the degree of gastric restriction, provide a safe, effective, and acceptable way to treat selected cases of obesity-related sleep disorder. Obesity surgery should be considered as one of the management options of SDB and excessive daytime sleepiness, both significant public health issues.

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The Department of Surgery at Monash University, Melbourne, Australia, is conducting clinical studies on “The clinical evaluation of the Lap-Band: an adjustable gastric banding system used in morbidly obese patients.” These studies are part of an international multicenter retrospective and prospective evaluation of the Lap-Band.

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REFERENCES