The Effect of Positional Dependency on Outcomes of Treatment With a Mandibular Advancement Device

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Objective: To evaluate retrospectively the efficacy of the mandibular advancement device (MAD) in patients with obstructive sleep apnea in terms of positional dependency.

Design: Retrospective analysis.

Setting: Academic tertiary referral center.

Patients: One hundred patients with obstructive sleep apnea treated with the MAD at the Department of Otorhinolaryngology sleep clinic were included from January 1, 2005, through December 31, 2010.

Interventions: All patients underwent nocturnal full-night polysomnography before and at least 3 months after intraoral MAD application.

Main Outcome Measures: Treatment results and prognostic factors deciding the success of MAD application.

Results: Of the 100 patients, 80 showed positional dependency and 20 showed nondependency. In the position-dependent obstructive sleep apnea group, the median (interquartile range) apnea-hypopnea index (AHI) decreased from 32.1 (24.4-41.9) to 8.6 (3.7-13.8) (P<.001); in the nondependent group, from 56.4 (26.2-71.5) to 15.7 (6.8-30.7) (P<.001). The success rate (AHI reduction ≥50% and AHI <10) was 57.5% and 30.0% in position-dependent and position-nondependent groups, respectively (P=.04).

Conclusion: Identifying patients with obstructive sleep apnea as position dependent or nondependent may have important therapeutic implications in predicting the outcome of MAD treatment.

with OSA, and we present practical guidelines that can be used by otorhinolaryngologists.

METHODS

PATIENTS

The study population consisted of 100 patients with OSA diagnosed by means of attended full-night PSG and treated with the MAD at the Ear, Nose, and Throat sleep clinic of Seoul National University Bundang Hospital from January 1, 2005, through December 31, 2010. Initially, 276 patients underwent MAD application. We excluded 176 patients who did not undergo PSG with the MAD application mainly because of economic reasons. We ultimately included 100 patients who had undergone a full-night PSG with or without MAD application.

The diagnosis of OSA was made when the patients had an AHI greater than 5. Patients with dental or temporomandibular diseases were excluded. We obtained general information, including age, sex, body mass index (calculated as weight in kilograms divided by height in meters squared), current medications, and medical history. An Epworth Sleepiness Scale score for daytime sleepiness was acquired, and PSG data were retrospectively reviewed for all subjects. This study was approved by the institutional review board of Seoul National University Bundang Hospital.

ATTENDED FULL-NIGHT PSG

Attended full-night PSG was conducted in all the patients using a commercially available recording system (N7000; Embla Recording Systems) and standard electrodes and sensors, with the supervision of an experienced technician. Electroencephalography electrodes were applied at C3-M2, C4-M1, O1-M2, and O2-M1, and 2 electro-oculography electrodes were applied at the sides of both eyes to record horizontal and vertical eye movements. Submental electromyography electrodes were applied at the submentalis muscle, and leg movements during sleep were recorded via electromyography electrodes from both anterior tibialis muscles. Strain gauges were used for recording chest and abdominal respiratory movements, and nasal pressure cannulas were used to record airflow. Arterial oxygen saturation was measured using pulse oximeters applied on index fingers. Based on the criteria of Rechtschaffen and Kales,7 scoring was performed every 30-second epoch as recorded on PSG. Apnea was defined as the total number of apneas and hypopneas per hour of sleep. The severity of OSA was defined according to the criteria of Cartwright.10 Positional dependency in OSA was defined when the supine AHI was at least 2 times greater than the lateral AHI. We also defined the positional dependency index (PDI) as the lateral AHI divided by the supine AHI to show the degree of positional dependency. In other words, if the PDI is less than 0.5, patients are described as having positional dependency; if greater than 0.5, patients do not have positional dependency.

The average age of the patients was 51.5 (10.6) years, and 87 male and 13 female patients were included in our study. Of the 100 patients, 1 had mild, 42 had moderate, and 57 had severe OSA. The mean body mass index was 25.9 (2.9) and the mean AHI was 38.7 (19.4).

MANDIBULAR ADVANCEMENT DEVICE

The MAD was made as previously described.9 In brief, all the patients were referred to a dentist, and a custom-made MAD was fabricated for each patient. The MAD was designed as a single piece (monobloc) that holds the mandible fixed at 60% of the maximum protrusion without an open bite. All the patients were regularly followed up to evaluate any dental or temporomandibular joint problems and to adjust the advancement length. Patients had a follow-up attended full-night PSG about 3 months later with the MAD in place. A successful treatment was defined in the following 2 ways: (1) reduction of AHI by 50% or more and an AHI less than 20 and (2) reduction of AHI by 50% or more and an AHI less than 10.

POSITIONAL DEPENDENCY

Sleeping position was analyzed by a position sensor on the chest and confirmed by direct observation of a technician using a low-light camera. The proportion of supine or lateral sleep position was measured as the percentage of time the subject was sleeping in a supine or lateral position. The AHI of supine or lateral sleep position was also recorded. All the subjects were divided into 2 groups as having position-dependent or position-nondependent OSA following the criteria of Cartwright.10 Positional dependency in OSA was defined when the supine AHI was at least 2 times greater than the lateral AHI. We also defined the positional dependency index (PDI) as the lateral AHI divided by the supine AHI to show the degree of positional dependency. In other words, if the PDI is less than 0.5, patients are described as having positional dependency; if greater than 0.5, patients do not have positional dependency.

STATISTICAL ANALYSIS

Descriptive statistics were first calculated. Data are presented as mean (SD) or median (interquartile range) unless otherwise stated. We used the Mann-Whitney test or Wilcoxon signed rank test to compare the demographic and PSG data. A Fisher exact test was performed to evaluate the effect of positional dependency on the outcome of MAD treatment, and AHI adjustment was accomplished using the Mantel-Haenszel test. All statistical analysis was performed using a commercially available statistical software package (SAS Institute Inc, Cary, NC). P < .05 was regarded as statistically significant.

RESULTS

Table 1

Of the total number of patients, 80 showed positional dependency and 20 showed nondependency. The median PDI in the position-dependent group was 0.17 (0.01-0.28) and that in the position-nondependent group was 0.77 (0.66-0.93) (P < .001). The position-dependent group included 1 patient with mild, 35 with moderate, and 44 with severe OSA, whereas the position-nondependent group included 7 with moderate and 13 with severe OSA. The median AHI was 32.1 (24.4-41.9) and 56.4 (26.2-71.5) in the position-dependent and position-nondependent groups, respectively (P = .045). The median supine AHI was 50.7 (34.1-65.9) in the position-dependent group and 38.2 (26.9-76.4) in the position-nondependent group, and there was no significant difference between the 2 groups (P = .83). The median lateral AHIs were 8.8 (0.7-15.0) and 43.5 (23.9-60.1) in position-dependent and position-nondependent groups, respectively (P < .001). The demographic and PSG data of the subjects are summarized in Table 1.
The median AHI decreased from 33.6 (24.7-49.2) to 9.6 (4.0-14.6) after MAD application in all patients (P < .001). In the position-dependent OSA group, the median AHI decreased from 32.1 (24.4-41.9) to 8.6 (3.7-13.8) (P < .001), and it decreased from 56.4 (26.2-71.5) to 15.7 (6.8-30.7) in the position-nondependent group (P < .001) (Figure, A). The median supine AHI decreased from 50.7 (34.1-65.9) to 10.8 (3.7-21.6) in the position-dependent group (P < .001) and from 58.2 (26.9-76.4) to 15.4 (93.0-33.7) in the position-nondependent group (P < .001) (Figure, B). The median lateral AHI decreased from 8.8 (0.7-15.0) to 1.8 (0-5.1) in the position-dependent group (P < .001) and from 43.5 (23.9-60.1) to 11.1 (5.2-24.9) in the position-nondependent group (P < .001) (Figure, C).

The success rate was 57.5% and 30.0% in position-dependent and position-nondependent groups, respectively (P = .04), when the success was defined as reduction of AHI by 50% or more and an AHI less than 10. When the effect of AHI severity was controlled by the Mantel-Haenszel technique, the difference between the 2 groups was more significant (P = .03).

TREATMENT OUTCOMES ACCORDING TO SEVERITY AND POSITION

When we compared the success rate (AHI reduction ≥50% and AHI <10) among patients with severe OSA, the success rate showed a tendency of difference between patients with position-dependent (52.3%) and position-nondependent (23.1%) severe OSA (P = .11). There was no significant difference in the success rate between the position-dependent (65.7%) and position-nondependent (42.9%) groups among patients with moderate OSA (P = .40) (Table 2).

The position-specific success rate was compared between the position-dependent and position-nondependent groups. The success rate in the supine position (supine AHI reduction ≥50% and supine AHI <10) was 48.8% and 25.0% in the position-dependent and position-nondependent groups, respectively (P = .08). The success rate in the lateral position (lateral AHI reduction ≥50% and lateral AHI <10) was 71.3% and 40.0% in the position-dependent and position-nondependent groups, respectively (P = .02).

CHANGE OF POSITIONAL DEPENDENCY AFTER MAD APPLICATION

The PDI was 0.31 and changed to 0.45 after MAD application (P = .76). In the position-dependent group, the PDI changed from 0.17 to 0.11 (P = .63). Among the 80 patients in the position-dependent group, 15 (19%) were changed to the position-nondependent group after MAD application. In the position-nondependent group, the PDI changed from 0.77 to 0.71 (P = .98). Of 20 patients, 10 (50%) changed to the position-dependent group after MAD application.

### Table 1. Demographic and Polysomnographic Data of the Patients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Position Dependent</th>
<th>Position Nondependent</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male/female, No.</td>
<td>70/10</td>
<td>17/3</td>
<td>.72</td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>51.3 (10.8)</td>
<td>52.0 (10.3)</td>
<td>.88</td>
</tr>
<tr>
<td>BMI, mean (SD), kg/m²</td>
<td>25.7 (2.7)</td>
<td>26.7 (3.7)</td>
<td>.38</td>
</tr>
<tr>
<td>AHI</td>
<td>32.1 (4.4-41.9)</td>
<td>56.4 (26.2-71.5)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Supine AHI</td>
<td>50.7 (24.1-65.9)</td>
<td>58.2 (26.9-76.4)</td>
<td>.83</td>
</tr>
<tr>
<td>Lateral AHI</td>
<td>8.8 (0.7-15.0)</td>
<td>43.5 (23.9-60.1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>PDI</td>
<td>0.17 (0.01-0.28)</td>
<td>0.77 (0.66-0.93)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: AHI, apnea-hypopnea index (calculated as total number of apneas and hypopneas per hour of sleep); BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); OSA, obstructive sleep apnea; PDI, positional dependency index (calculated as lateral AHI divided by supine AHI).

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### COMMENT

The treatment of OSA includes several modalities, such as airway surgery, application of the MAD, use of a tongue retainer, CPAP, weight reduction, and position therapy. Among these modalities, CPAP has been considered the most effective treatment. However, a critical limitation of CPAP is poor patient adherence to therapy. One study reported that only 46% of all CPAP-treated patients continued therapy for at least 4 hours on at least 70% of all nights. As another treatment option, various upper airway surgeries have some limitations, such as postoperative pain and bleeding and no consistent success owing to the various obstructive levels and mechanisms. In this situation, the use of the MAD is now gradually increasing because it is easy, reversible, quiet, and conservative and has quite a good outcome. Nevertheless, MAD treatment has shown some limitations, such as its discomfort, temporomandibular joint pain, malocclusion, and imperfect improvement in some patients. When it comes to treatment adherence, 17 months after the start of treatment, 82% of the patients were still using the MAD almost every night. Its mechanism of action is to maintain the upper airway not only by increasing retropalatal and retrolingual spaces but also by reducing pharyngeal collapsibility. Therapy with the MAD has been recommended, considered, and most commonly prescribed for patients with mild to moderate, but not severe, OSA. However, a previous study showed that the rate of successful outcomes in patients with severe OSA was almost comparable to that in patients with moderate OSA. The present study showed that patients with position-dependent OSA who have an AHI indicative of severe OSA also can achieve efficacious outcomes with MAD therapy. In this study, the success rate of MAD treatment in patients with position-dependent severe OSA was 52.3%.

Some studies have also suggested that the effectiveness of MAD therapy may be influenced by sleep posi-
tion.21,22 The study of Marklund et al.22 which included 263 patients who underwent PSG with or without MAD application, showed that the odds ratio for MAD treatment success was 6.0 in men with supine-dependent OSA. Although their study included a large population of patients, they used a different definition of positional dependence, showed that the odds ratio for MAD treatment success was 6.0 in men with supine-dependent OSA. Although their study included a large population of patients, they used a different definition of positional dependence, showed that the odds ratio for MAD treatment success was 6.0 in men with supine-dependent OSA. Although their study included a large population of patients, they used a different definition of positional dependence, showed that the odds ratio for MAD treatment success was 6.0 in men with supine-dependent OSA. Although their study included a large population of patients, they used a different definition of positional dependence, showed that the odds ratio for MAD treatment success was 6.0 in men with supine-dependent OSA.

We also compared the position-specific success rate between position-dependent and position-nondependent groups. In our study, 80 of the 100 patients had position-dependent OSA.

This study evaluated the usefulness of MAD therapy in position-dependent and position-nondependent patients with OSA. We found that patients with position-dependent OSA had substantially better treatment outcomes than did patients with position-nondependent OSA.

When treatment success was defined as an AHI less than 20 with MAD application, the MAD success rate was 77.5% in position-dependent and 60.0% in position-nondependent OSA. However, the difference was not statistically significant. On the other hand, when success was defined as more complete reduction of obstructive events to an AHI less than 10, the therapeutic outcome was much better in position-dependent (57.5%) than in position-nondependent (30.0%) patients. Because the MAD is also a device that, like a CPAP mask, should be put on every night, adherence cannot be perfect. Therefore, MAD application may not be enough as a treatment, especially for position-nondependent patients.

The present study has some limitations. For example, only a small number of position-nondependent patients were included. This imbalance may affect statistical interpretation of success rates between the 2 positional-dependency groups. In the future, investigations that include more position-nondependent patients are required. The previous studies also had some limitations in that they only reported the success rate of MAD treatment in position-dependent and position-nondependent groups. In our study, we tried to compare the success rate according to the severity of OSA. The success rate was likely to be different between the 2 groups in the patients with severe OSA, whereas there was no significant difference in patients with mild or moderate OSA. We also compared the position-specific success rate between position-dependent and po-

### Table 2. Success Rate of MAD Application According to Positional Dependency and Severity of AHI

<table>
<thead>
<tr>
<th>Position Dependency by AHI</th>
<th>Overall AHI</th>
<th>Position Nondependent</th>
<th>Position Dependent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AHI Reduction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥50% and ≥50% and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤20</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>≤10</td>
<td>84.1</td>
<td>52.3</td>
<td>58.2</td>
</tr>
<tr>
<td><strong>Success Rate, %</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position-dependent OSA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild (AHI &gt; 5 to &lt; 15)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Moderate (AHI 15 to 30)</td>
<td>71.4</td>
<td>65.7</td>
<td>71.4</td>
</tr>
<tr>
<td>Severe (AHI &gt; 30)</td>
<td>84.1</td>
<td>52.3</td>
<td>53.8</td>
</tr>
<tr>
<td>Position-nondependent OSA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild (AHI &gt; 5 to &lt; 15)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Moderate (AHI 15 to 30)</td>
<td>71.4</td>
<td>42.9</td>
<td>71.4</td>
</tr>
<tr>
<td>Severe (AHI &gt; 30)</td>
<td>53.8</td>
<td>23.1</td>
<td>53.8</td>
</tr>
</tbody>
</table>

Abbreviations: AHI, apnea-hypopnea index (calculated as total number of apneas and hypopneas per hour of sleep); MAD, mandibular advancement device; NA, not applicable; OSA, obstructive sleep apnea.
sition-nondependent groups. The success rate in supine position-dependent patients did not show a significant difference. In contrast, the success rate in lateral position-dependent patients was significantly higher in the position-dependent group. This may be because the lateral AHI was less than 10 in the position-dependent group; therefore, one of the 2 criteria of treatment success is already fulfilled in these patients. Most position-dependent patients maintained positional dependency after MAD application, and half the position-nondependent patients gained positional dependency owing to the MAD, implying that MAD application may give additional therapeutic effect in terms of sleep position.

CONCLUSIONS

Our study has shown that the therapeutic effect of MAD application was quite encouraging; therefore, the MAD should be considered one of the therapeutic options as a single treatment modality or an adjunctive modality to airway surgery or CPAP treatment. However, the extent of improvement should also be predicted before MAD application by clinicians. Our study showed that positional dependency and disease severity were significantly helpful for the prediction of treatment outcome. Position-nondependent severe OSA in particular may not be an indication for MAD treatment. Further studies for predictors are needed to estimate more precisely the treatment results. In addition, the criteria for success with the MAD should be clarified in terms of future disease morbidity or mortality.

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