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Restoration of Sleep Architecture after Maxillomandibular Advancement: Success Beyond the Apnea–Hypopnea Index

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Abstract. While effects of maxillomandibular advancement (MMA) on respiratory parameters for patients with obstructive sleep apnea (OSA) are well described, effects on sleep architecture before and after MMA are not. A retrospective cohort analysis on sleep architecture was examined in 10 OSA patients who underwent MMA surgery between July 2013 and November 2014, and had prespecified complete polysomnography (PSG) datasets. Sleep stages were examined relative to a Western European population-based control group. All of the respiratory parameters improved significantly post MMA. Rapid eye movement (REM) latency decreased from 178.0 ± 142.8 to 96.6 ± 64.5 min ($P = 0.035$). %NREM (non-rapid eye movement)1 ($P = 0.045$) and %WASO (wakefulness after sleep onset) ($P = 0.006$) decreased, while %REM increased ($P = 0.002$) after MMA. WASO decreased from 64.2 ± 57 min to 22.4 ± 15.4 min ($P = 0.017$). Preoperatively, OSA subjects showed significantly lower sleep efficiency ($P = 0.016$), sleep onset latency ($P = 0.015$), and % REM ($P < 0.001$) than the normative population dataset, while post MMA there was a significant decrease in %NREM1 sleep ($P < 0.001$) and in %WASO ($P < 0.001$). MMA results in a marked decrease in WASO and increase in REM, and to a lesser extent NREM sleep. Patients after MMA show values similar to population controls except for a lower WASO.

Key words: maxillomandibular advancement; obstructive sleep apnea; sleep architecture; Wakefulness after sleep onset.

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Of surgical options available to patients with obstructive sleep apnea (OSA) who are intolerant of positive airway pressure (PAP) therapy, maxillomandibular advancement (MMA) demonstrates consistently high rates of surgical success as measured by the apnea–hypopnea index (AHI). Case series report success rates from 56% to 100%[1–8]. The largest systematic review of MMA to date with 627 subjects in 22 unique patient populations shows pooled success and cure rates of

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86% and 43.2% respectively[9]. Vicini et al.[10] published the only randomized crossover trial comparing MMA to PAP, showing MMA as an effective alternative based on objective polysomnography, subjective symptoms, and health-related quality of life measures.

In contrast to reports using outcomes of AHI or oxygen saturation, there is a dearth of reports dedicated to changes in sleep quality and architecture after MMA, and how after surgery patients might compare to normal controls. One would assume that sleep quality and architecture improves as the AHI improves. For instance, the latest reports with hypoglossal nerve stimulation with surgical success as based on AHI do show that sleep architecture improves with treatment[11,12]. However, there is a less certain relationship of AHI to sleep architecture at diagnosis, and continuous positive airway pressure (CPAP) therapy for instance can both improve AHI with and without much change in sleep architecture[13].

The aim of this study was to compare changes in sleep architecture before and after MMA in OSA subjects and determine the possible extent of the effect on sleep architecture. We hypothesized that MMA, with expected improvement in the AHI, oxygen desaturation index (ODI), and lowest oxygen saturation, may also improve sleep quantity reflected by sleep staging and arousals, and sleep quality, namely wakefulness after sleep onset (WASO). We also hypothesized that after MMA there would be a restoration of age-appropriate sleep architecture, as had previously been reported with PAP therapy[13].

Materials and methods

Study design and patient recruitment

This study involves both a retrospective cohort analysis involving sleep architecture changes of perioperative MMA subjects, and a cross-sectional study comparing perioperative sleep architecture with a population-based control. Of 20 OSA patients who underwent MMA surgery with the first author (S.Y.C.L.) between July 2013 and November 2014, 10 subjects had perioperative diagnostic PSG studies from the same centers, using the same scoring criteria. Subjects were excluded if perioperative studies were performed at different centers ($n = 6$), perioperative studies were of different types (split-night vs. baseline, $n = 2$), or no follow-up study was available ($n = 2$).

The SIESTA database was the population-based control comparison group. The SIESTA database is the world's largest normative database of healthy human sleep architecture and includes parameters such as sleep onset latency, REM Latency, sleep efficiency, %NREM1, %NREM2, %slow wave sleep (SWS), %REM, and %WASO. The database is based on 200 adults with age ranging from 20 to 90 years old, without sleep disorders, and who underwent two separate diagnostic PSG studies[14].

Maxillomandibular advancement

The surgical procedures and perioperative care follow the Powell–Riley Stanford protocol matured in our institution over the last two decades[15–17]. Briefly, the surgery involves Lefort I osteotomy of the maxilla that is followed by advancement and anterior impaction. This is followed by mandibular advancement after bilateral sagittal splits to match the maxilla to restore preoperative jaw relationship and functional occlusion. This advancement is routinely greater than 12 mm at the mandibular osteotomy site when performed properly. Success of the procedure has been attributed to the postoperative stability of the upper airway, particularly of the lateral pharyngeal wall[18].

Polysomnography

Preoperative PSG was performed at the latest 1 month before surgery. All subjects underwent perioperative studies within 1 year of surgery. All the subjects were monitored with transcutaneous pulse oximetry. Respiratory effort was recorded using respiratory inductance plethysmography. Apnea was defined as a decrease of 90% or greater from previous baseline airflow as measured by an oronasal thermistor for at least 10 seconds. Hypopnea was defined as a partial obstructive event with diminution of airflow by more than 30% from baseline, for at least 10 seconds as measured using a nasal pressure cannula. It is also associated with oxygen desaturation of 3%, or with an arousal based on electroencephalogram (EEG). ODI represents the number of events per hour where oxygen desaturation of 3% or more was associated with a respiratory event followed by re-oxygenation. Percentage of sleep period time spent in sleep stages NREM1, NREM2, SWS, REM, and WASO are also compared with age-matched controls.

Statistical analysis

Descriptive statistics were used for demographic variables and PSG parameters of the study group. Continuous variables were summarized using means and standard deviations. The paired *t*-test was used to compare perioperative changes of PSG parameters. A p-value < 0.05 was considered statistically significant. Independent t-test was used to test homogeneity of variance between perioperative PSG parameters of MMA subjects and normal controls.

Results

Demographics

Subjects in this study ($n = 10$) were all males with an average age of 42.7 ± 7.4 years. They presented with baseline AHI of 50.6 ± 24.9 events/hour, and body mass index (BMI) of 29.0 ± 4.8 kg/m^2 (Table 1). Three patients underwent MMA as the first surgical intervention for OSA, while the remainder had previously undergone tonsillectomy, adenoidectomy, lingual tonsillectomy, and/or uvulopalatopharyngoplasty. The BMI was not significantly different perioperatively ($P = 0.092$). The mean Epworth Sleepiness Scale (ESS) decreased significantly from 17.5 ± 6.0 to 7.5 ± 3.1 ($P = 0.001$).

Changes in PSG parameters in subjects before and after MMA

The mean AHI decreased from 50.6 ± 24.9 to 10.7 ± 8.4 events/hour ($P < 0.001$), the ODI from 36.5 ± 21.0 to 5.7 ± 5.5 events/hour ($P < 0.001$), and the mean lowest oxygen saturation increased from 78.6 ± 7.3 to 87.7 ± 3.3 ($P = 0.003$). Surgical success was determined following Sher's criteria (postoperative AHI < 20 events per hour and >50% reduction of preoperative AHI), and in this cohort the success rate was 90%, and the cure rate (AHI < 5) was 20%[19].

The percentage of TST with oxygen saturation less than 90% decreased from 2.7 ± 2.2% to 0.5 ± 1.0% ($P = 0.004$), and REM latency decreased from 178.0 ± 142.8 min to 96.6 ± 64.5 min ($P = 0.035$). %NREM1 ($P = 0.045$), and %WASO ($P = 0.006$) decreased significantly, while %REM increased significantly ($P = 0.002$) (Table 1).

The number of awakenings, sleep efficiency, and sleep onset latency, % NREM2, %SWS, PLM index, PLM index in REM, and PLM index with arousals were not significantly different perioperatively. WASO in minutes decreased from 64.2 ± 57 min to 22.4 ± 15.4 min ($P = 0.017$) (Table 2).

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