Original Article

Polysomnographic Outcomes Before and After Skeletal Surgeries for the Treatment of Obstructive Sleep Apnea

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Objective: To evaluate polysomnographic (PSG) outcomes after common skeletal surgeries for the treatment of obstructive sleep apnea (OSA) in Thai patients.

Materials and Methods: The retrospective study included OSA patients aged 18 years and older treated by hyoid suspension (HS) plus uvulopalatopharyngoplasty (UPPP) (Group 1), genioglossus advancement (GA) plus tongue base radiofrequency (TBRF) (Group 2), and maxillomandibular advancement (MMA) (Group 3) at Siriraj Hospital between January 2007 and October 2018. Those with incomplete PSG data were excluded. The primary outcome was the apnea-hypopnea index (AHI). Secondary outcomes were other PSG parameters and postoperative complications.

Results: Twenty-four patients including 22 males and 2 females were included. Group1 (n=11), median AHI decreased from 45.4 to 24.1 events/hour (p=0.17), while lowest oxygen saturation (LSAT) changed from 72.0% to 71.0% (p=0.11). Group2 (n=3) median AHI decreased from 64.7 to 51.4 events/hour (p=0.11), LSAT increased from 76.0% to 79.0% (p=1.0), and rapid eye movement (REM) sleep increased from 0.0% to 12.4% (p=0.11). Group3 (n=12) median AHI decreased from 68.5 to 7.8 events/hour (p<0.002), LSAT increased from 75.5% to 88.0% (p=0.04), and REM increased from 0.0% to 21.5% (p=0.01). Surgical success rates as defined by Sher's criteria or a postoperative AHI of less than five events/hour were 44.4%, 33.3%, and 66.6% in patients in groups 1, 2, and 3, respectively. Common surgical complications included bleeding, mental or perioral paresthesia, and malocclusion after MMA.

Conclusion: The skeletal surgeries significantly improved some PSG parameters, and thus may be viable options for OSA treatment in Thai patients.

Keywords: Obstructive sleep apnea, Skeletal surgery, Hyoid suspension, Genioglossus advancement, Maxillomandibular advancement, Thai

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Obstructive sleep apnea (OSA) is a common sleep-related disorder characterized by repetitive cessation of or decrements in airflow through the upper airway[1] and subsequent events, such as repeated cycles of hypoxia-reoxygenation, negative swings of intra-thoracic pressure, increased sympathetic tone, and terminal arousals or sleep fragmentation. These pathophysiologic changes, if left untreated, could lead to several adverse side effects on health in both short term and long term[2-7]. The reported prevalence of OSA in men and women varies depending on the measurement methods and disease definition. Data from recent systematic reviews estimated that the prevalence of OSA, defined as an apnea-hypopnea index (AHI) of more than five events/hour, ranged from 9% to 38% and was higher in men and obese patients[8,9]. In Thailand, Neruntarat and Chantapant[10] reported the prevalence of OSA as 15.4% in men and 6.3% in women.

Continuous positive airway pressure (CPAP) is widely accepted as the first-line therapy for most OSA patients[11] since it can significantly reduce OSA severity by improving the respiratory parameters, especially the AHI and lowest oxygen saturation (LSAT). It can also improve sleep quality by lowering

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light sleep while increasing the amount of deep sleep and rapid eye movement (REM) sleep[12-15]. Unfortunately, several problems are associated with CPAP usage that led to a significant number of patients refusing or being unable to undergo this therapy[16,17]. For those who experience CPAP difficulty, certain surgical procedures, such as uvulopalatopharyngoplsty (UPPP), hyoid suspension (HS), genioglossus advancement (GA), tongue base reduction surgery, and maxillomandibular advancement (MMA), are available as viable alternatives. However, to select good candidates for surgical treatment, a comprehensive evaluation of patients, including underlying diseases, OSA severity, and upper airway structure, are required[18]. According to the well-known Powell and Riley (Stanford) surgical phase protocol, phase 1 refers to soft tissue surgeries, such as nasal surgery, UPPP, and minor skeletal surgeries, including GA and HS, while phase 2 refers to MMA or tracheostomy. From previous literature that has included a meta-analysis, the success rates of these phase 1 and phase 2 surgeries for OSA treatment are reported to be approximately 55% to 61% and 85.5% to 100%, respectively[19-22]. In Thailand, the success rate of GA plus HS (phase 1) was reported by Neruntarat[23] to be approximately 70%, and a case report study[24] of MMA (phase 2) showed that it reduced AHI from 73.1 to 44.4 events/hour. However, data regarding the outcomes of skeletal surgeries for OSA in Thai patients are still limited. Consequently, the present study aimed to evaluate the efficacy of the three most common skeletal procedures for the treatment of OSA, which are HS, GA, and MMA, in Thai patients as performed at Siriraj Hospital. The outcomes of interest were primarily related to the data from polysomnography (PSG), such as AHI, oxygen saturation (O_2 SAT), sleep efficiency (SE), and the proportions of the different sleep stages.

Materials and Methods

The present study was a retrospective study approved by the Siriraj Institutional Review Board (SIRB). Ethics approval No.932/2561(EC3) COA no.SI 096/2019. It was conducted by reviewing the medical records and PSG results of OSA patients treated at the Department of Otorhinolaryngology, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand, between January 2007 and October 2018.

Subjects

The inclusion criteria were OSA patients aged 18 years or older diagnosed with PSG that underwent skeletal surgeries, including HS, GA, and MMA, at the Department of Otorhinolaryngology, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand. Exclusion criteria were those who did not have postoperative PSG. The patients were classified into three groups, group 1 were the patients that underwent HS surgery, group 2 were the patients that underwent GA surgery, and group 3 were the patients that underwent MMA surgery, with or without GA. Prior to the surgical procedures, all the patients were comprehensively evaluated by clinical history and physical examination as well as by upper airway imaging and endoscopy.

Skeletal surgeries

HS was performed together with UPPP and tongue base reduction with radiofrequency (TBRF) under general anesthesia. The procedures started with a horizontal anterior cervical neck incision between the hyoid bone and the thyroid cartilages. After identifying the important surgical landmarks, the infrahyoid muscles were partially dissected from their hyoid attachment and the body of the hyoid bone was moved anteroinferiorly and fixed to the upper part of the thyroid lamina by non-absorbable suture.

GA was performed as sliding genioplasty combined with TBRF in patients who had retrognathia to forward movement of the genial tubercle to open the retrolingual pharyngeal airway. The procedures started with an incision at the lower gingivobuccal sulcus and a dissection of the mucoperiosteal tissue around the anterior border of the mandible. A horizontal cut was then made inferiorly to the roots of the canine teeth and extended posteriorly to the bilateral mental foramens. After bicortical osteotomy, the distal segment was mobilized and fixed with the proximal segment by titanium plates and screws. In some patients who had severe retronathia, GA was performed together with MMA.

MMA was performed in patients who have severe OSA and multilevel airway obstruction to increase the dimension of both the retropalatal and hypopharyngeal airway via Le Fort I maxillary osteotomy and bilateral sagittal split mandibular osteotomies. In most patients, the maxilla was moved forward about 7 to 9 mm and the mandible was moved forward about 10 to 12 mm.

Outcome measurement

Both the pre- and postoperative sleep studies

Table 1. Preoperative and postoperative polysomnographic parameters in patients who had underwent hyoid suspension plus uvulopalatopharyngoplasty and tongue base radiofrequency (Group 1)

Parameters	Preoperative		Postoperative		p-value
	Median (IQR)	Mean±SD	Median (IQR)	Mean±SD	
AHI (events/hour)	45.4 (12.6 to 81.0)	42.5±20.16	24.1 (2.9 to 71.8)	32.1±23.6	0.17
Apnea index (events/hour)	16.0 (6.0 to 81.0)	26±24.7	12.5 (0.0 to 69.0)	17.7±23.5	0.16
4% ODI (events/hour)	41.2 (12.8 to 78.3)	43.1±24	20.4 (2.9 to 72.9)	33.1±24.8	0.21
LSAT (%)	72.0 (47.0 to 76.0)	64.4±10	71.0 (56.0 to 90.0)	73.1±12.7	0.11
Time O_2 >90 (%)	89.4 (66.8 to 98.0)	85.6±11.4	94.1 (60.1 to 100)	91.4±13.4	0.12
Sleep efficiency (%)	87.4 (49.5 to 95.7)	79.4±18.9	87.4 (75.5 to 95.9)	86±5.6	1.00
Stage N1 (%)	14.2 (1.8 to 54.0)	22.2±20.6	19.0 (5.0 to 65.0)	25.8±16.4	0.78
Stage N2 (%)	46.9 (22.0 to 83.0)	48±17.9	46.0 (16.6 to 72.0)	44.9±18.6	0.78
Stage N3 (%)	15.5 (0.0 to 24.4)	12.3±10.6	10.0 (0.0 to 23.0)	7.5±5.5	0.29
Stage R (%)	17.4 (6.7 to 25.3)	16.8±6.8	20.0 (1.0 to 27.2)	16.9±8.7	0.78

AHI=apnea-hypopnea index; ODI=oxygen desaturation index; LSAT=lowest oxygen saturation; Time O_2 >90=time spent in sleep with oxygen saturation >90; N=non-rapid eye movement sleep; R=rapid eye movement sleep; IQR=interquartile range; SD=standard deviation

Statistical significance was accepted if p<0.05 by Wilcoxon signed rank test

performed in the present study were level 1 PSG scored by well-trained sleep technicians and interpreted by certified sleep specialists. The primary outcome was AHI, and the secondary outcome were the apnea index (AI) score, LSAT, 4% oxygen desaturation index (ODI), percentages of time with O_2 SAT greater than 90% (T90), SE, and the proportions of each sleep stage. These parameters were scored according to the standard criteria recommended by the American Academy of Sleep Medicine (AASM) version 2012. Obstructive apnea was defined as a reduction of the airflow of 90% or more for at least 10 seconds from baseline. Hypopnea was defined as a reduction of the airflow of 30% or more from baseline for at least 10 seconds plus an O_2 SAT drop of 4% or more (criteria 1B). Surgical success was defined by Sher's criteria, a postoperative AHI of less than 20 events/hour and a decrease from baseline of at least 50%, or a postoperative AHI of less than five events/hour. Postoperative complications, such as bleeding, malocclusion, and paresthesia, were also reported.

Statistical analysis

Continuous data were presented as mean ± standard deviation (SD) and median with interquartile range. Categorical data were presented as numbers and percentages. The normality test (Shapiro-wilk test) was done. The paired t-test was applied when the data had a normal distribution, but the Wilcoxon signed rank test was used when the data had asymmetrical distribution to compare the preoperative and postoperative results. A p-value of less than 0.05 was considered statistically significant. Data were analyzed using PASW Statistics, version 18.0 (SPSS Inc., Chicago, IL, USA).

Results

Twenty-four patients were included in the present study, which were 22 males and two females, with a mean age of 45.4±9.8 years and a mean body mass index (BMI) of 27.4±4.1 kg/m². The mean follow-up time in overall postoperative PSG was 7.49±6.3 months, ranging from 2.6 to 35.8 months. In Group 1 (HA with UPPP and TBRF), there were nine patients, all males, with a mean age of 47.2±11.1 years, a mean BMI of 26.1±2.1 kg/m², and a mean follow-up time of 6.3±1.5 months. The results for Group 1 are shown in Table 1. In Group 2 (GA with TBRF), there were three patients, two males and one female, with a mean age of 43.7±9.4 years, a mean BMI of 28±3.4 kg/m², and a mean follow-up time of 5.7±3.1 months. There was an increase in REM sleep (stage R) after surgery. Further information on pre- and postoperative PSG findings of patients in Group 2 is shown in Table 2. In Group 3 (MMA ± GA), there were 12 patients, 11 males and one female, with a mean age of 44.5±9.4 years, a mean BMI of 28±5.3 kg/m², and a mean follow-up time of 8.7±8.8 months. In addition, three of the patients underwent MMA with GA while nine patients underwent MMA alone. There was a statistically significant increase in several respiratory parameters, particularly for AHI and sleep stage R after surgery, as shown in Table 3.

Table 2. Preoperative and postoperative polysomnographic parameters in patients who had underwent genioglossus advancement plus tongue base radiofrequency (Group 2)

Parameters	Preoperative		Postoperative		p-value
	Median (IQR)	Mean±SD	Median (IQR)	Mean±SD	
AHI (events/hour)	64.7 (6.1 to 72.9)	47.9±36.4	51.4 (4.7 to 65.3)	40.4±31.7	0.11
Apnea index (events/hour)	33.7 (3.9 to 50.8)	29.4±23.7	5.6 (4.6 to 36.6)	15.6±18.1	0.28
4% ODI (events/hour)	62.6 (3.6 to 69.4)	45.2±36.1	50.3 (1.6 to 65.8)	39.2±33.5	0.11
LSAT (%)	76.0 (74.0 to 84.0)	78±5.2	79.0 (70.0 to 89.0)	79.3±9.5	1.00
Time O_2>90 (%)	83.6 (74.0 to 99.2)	85.6±12.7	95.8 (75.9 to 99.7)	90.4±12.7	0.11
Sleep efficiency (%)	82.5 (60.3 to 95.5)	79.4±17.7	94.0 (85.1 to 95.4)	91.5±5.5	0.28
Stage N1 (%)	52.2 (4.1 to 75.1)	43.8±36.2	3.0 (2.3 to 20.8)	8.7±10.4	0.11
Stage N2 (%)	44.8 (25.2 to 65.7)	45.2±20.2	66.1 (58.5 to 73.0)	65.8±7.2	0.28
Stage N3 (%)	0.3 (0.0 to 23.2)	7.8±13.3	9.0 (0.0 to 20.5)	9.8±10.2	1.00
Stage R (%)	0.0 (0.0 to 2.8)	0.9±1.6	12.4 (12.0 to 18.7)	14.3±3.7	0.11

AHI=apnea-hypopnea index; ODI=oxygen desaturation index; LSAT=lowest oxygen saturation; Time O_2 >90=time spent in sleep with oxygen saturation >90%; N=non-rapid eye movement sleep; R=rapid eye movement sleep; IQR=interquartile range; SD=standard deviation

Statistical significance was accepted if p<0.05 by Wilcoxon signed rank test

Table 3. Preoperative and postoperative polysomnographic parameters in patients who had underwent maxillomandibular advancement (Group 3)

Parameters	Preoperative		Postoperative		p-value
	Median (IQR)	Mean±SD	Median (IQR)	Mean±SD	
AHI (events/hour)	68.5 (20.0 to 121.2)	66.7±31.5	7.8 (0.0 to 48.4)	14.9±17.2	<0.002**
Apnea index (events/hour)	37.5 (4.9 to 100.8)	40.1±30.9	2.3 (0.0 to 45.9)	9.1±16.7	0.01*
4% ODI (events/hour)	62.2 (1.6 to 164.0)	65.2±47.2	3.6 (0.1 to 40.5)	11.4±14.9	0.008*
LSAT (%)	75.5 (34.0 to 97.8)	73.7±14.8	88.0 (52.0 to 93.0)	84.2±11.8	0.04*
Time O_2 >90 (%)	79.2 (46.9 to 99.8)	78.3±16.5	98.5 (82.2 to 100)	95.9±6.1	0.02*
Sleep efficiency (%)	91.3 (55.6 to 98.1)	87.8±11.4	90.6 (80.9 to 99.0)	90.3±5.3	0.58
Stage N1 (%)	33.0 (5.4 to 89.0)	37±27.5	17.3 (2.9 to 41.9)	17.2±11.9	0.06
Stage N2 (%)	51.1 (11.0 to 77.3)	49.9±19.7	51.4 (30.0 to 64.7)	52.2±7.3	0.96
Stage N3 (%)	0.5 (0.0 to 16.0)	5.1±6.2	8.6 (0.8 to 24.5)	11.7±8.5	0.11
Stage R (%)	0.0 (0.0 to 26.4)	7.7±10.2	21.5 (0.0 to 26.8)	18±7.8	0.01*

AHI=apnea-hypopnea index, ODI=oxygen desaturation index, LSAT=lowest oxygen saturation, Time O_2>90=time spent in sleep with oxygen saturation >90%, N=non-rapid eye movement sleep, R=rapid eye movement sleep; IQR=interquartile range; SD=standard deviation

Statistical significance was accepted if p<0.05*, p<0.001** by Wilcoxon signed rank test

Success rate and complications

The surgical success rate in patients in Groups 1, 2, and 3 were 44.4%, 33.3%, and 66.6%, respectively. Besides pain and minor or insignificant postoperative hemorrhage, there were some postoperative complications too. One patient in Group 1 had postoperative bleeding at the right side of the uvula from UPPP, which was resolved with bipolar cautery. Nine patients had postoperative paresthesia around their chin and perioral area from GA. Four patients developed postoperative malocclusion after MMA. Lastly, one patient developed postoperative perioral dyskinesia accompanied with difficulty chewing. However, most of these symptoms resolved without significant long-term problems.

Discussion

OSA is complex and heterogeneous due to it involving various pathophysiologic processes attributable to both anatomical and physiological dysfunctions of the upper airway during sleep. Although CPAP is considered the first-line treatment, its acceptance and long-term compliance have been shown to be inadequate[25]. Among various surgical approaches proposed for the treatment of OSA in those who cannot tolerate CPAP, skeletal surgeries, such as HS, GA, and MMA, are possibly the most common procedures performed in clinical practice in addition to UPPP, and tongue base and nasal surgery[26].

The results of the present study showed that HS + UPPP + TBRF (Group 1) had a success rate of 44.4% according to the criteria. In addition, there was a tendency of several respiratory parameters that improved, though they did not reach statistical significance. When compared with the findings from the literature, including those reported in Thai patients[27-35], the results of HS with UPPP and TBRF in the present study seem to be poorer. Neruntarat[36] reported that HS performed under local anesthesia had a success rate of 78%, together with a statistically significant decrease in the mean respiratory disturbance index (RDI) from 44.5 to 15.2 events/hour ($p<0.001$) and a statistically significant increase of LSAT from 82.1% to 87.9% ($p<0.01$). The poorer result in the present study might be from the small sample size and insufficient preoperative upper airway evaluation to select better surgical candidates as no drug-induced sleep endoscopy (DISE) was available at the time of the study. Given that all the HS procedures were performed simultaneously with UPPP and TBRF, rather than as an isolated procedure, the outcomes of HS might possibly be even lower. The position of the hyoid bone in OSA patients is commonly reported to be more inferior compared to a control group, potentially leading to an increase in the upper airway length and greater hypopharyngeal collapsibility during sleep[37]. Therefore, the role of HS in the treatment of OSA is still unclear and is not supported by the present study.

Regarding GA, the results of the present study showed that sliding genioplasty + TBRF yielded a success rate of 33.3% according to the criteria. Nevertheless, there was an increase in sleep stage REM from 0.0% to 12.4% after the operation ($p=0.11$). In addition, there was a tendency for other respiratory and sleep-related parameters to improve, although these improvements did not reach statistical significance. These results correspond with those of Sun et al[38], who reported that GA and HS plus UPPP increased the amount of REM sleep from 10.5% to 13.9% and increased the amount of stage N3 sleep from 3.0% to 7.1%. However, the results of the present study are poorer than those reported in recent studies[23,39-41], including the meta-analyses and the study of Neruntarat, who performed GA with HS under local anesthesia, which showed success rates of GA of approximately 70% in terms of improving AHI and LAST in OSA patients. The reasons for the present study poorer results than in previous studies are probably the same as those given above for Group 1, that is, the small number of patients and the lack of upper airway evaluation, as already mentioned. If performing DISE pre-operatively, the upper airway evaluation and the decision for selecting the type of surgery should be better.

In regard to MMA, the results of the present study showed that it yielded a success rate of 66.6% according to the criteria. All the respiratory parameters of interest (Table 3) and sleep stage R were found to be significantly improved after the operation. Furthermore, there was a tendency for other sleep-related parameters to be improved too, albeit these did not reach statistical significance. The results for MMA in the present study correspond with those well described in previous studies[42-44]. For example, a recent meta-analysis showed a significant improvement in the mean AHI from 57.2 to 9.5 events/hour and mean LSAT from 70.1% to 87% after MMA with a success rate and cure rate of 85.5% and 38.5%, respectively[20]. In regard to changes in the sleep architecture, Liu et al reported that the proportion of REM sleep significantly increased from 9.2% to 22.0% along with a reduction in stage N1 and REM latency[45]. One reason that MMA was the most efficacious procedure for the treatment of OSA compared to the other procedures is that it simultaneously corrects multilevel upper airway obstruction. Due to the heterogeneity of these three skeletal surgical procedures and a small number of patients in each group (especially in Group 2), the comparison of respiratory and sleep-related parameters among them were not done.

Besides pain and minor hemorrhage, there were few postoperative complications with the skeletal surgeries found in the present study. The most common one, though, was lower facial paresthesia, which may have come about from an intraoperative injury to the inferior alveolar nerve. However, these complications resolved by themselves over time. In addition, for MMA, four patients developed postoperative malocclusion and one patient developed perioral dyskinesia accompanied with a difficulty chewing. These problems could be corrected by orthodontic treatment. These findings were comparable to the complications reported in other studies[22,44-47].

There were several potential limitations in the present study to note. First, it involved a retrospective chart review from patients' medical records.

Therefore, there were possibly some incomplete data records, such as details about the upper airway evaluation and cephalometric analysis and details regarding the decision taken between the doctor and the patient in choosing the surgical procedure. In addition, some patients were lost to follow-up, and so did not have postoperative PSG taken, which may have had good results, thus affecting the mean. Second, the follow-up times were inconsistent, and the surgeries were heterogeneous, making it difficult to evaluate the post-operative results accurately, and possibly leading to unclear conclusions. Third, there were no data on the subjective outcomes of patients, particularly on daytime sleepiness and quality of life, which are probably more important from the patient's point of view. Finally, the sample sizes of the present study population were too small, especially in Group 2, with only three patients. This issue probably led to the statistically insignificant findings of some outcomes after the surgeries. However, the outcomes of skeletal surgeries in the present study may still yield more information for sleep surgeons to select better choices for the treatment of OSA patients. Further studies focusing on comprehensive upper airway evaluation for the selection of OSA surgery are required.

Conclusion

The common skeletal surgeries applied for the treatment of Thai patients with OSA who were intolerant to CPAP partially improved both their respiratory and sleep parameters as measured by PSG and showed acceptable success rates with few adverse side effects. Among these procedures, MMA demonstrated the most efficacious outcomes, but with potentially more serious complications due to its aggressive nature. Nevertheless, comprehensive evaluation should be done for a better selection of good surgical candidates.

What is already known on this topic?

The American Academy of Sleep Medicine (AASM) recommends that surgical procedure of the upper airway is acceptable in patients with narrow upper airway, which may be the alternative treatments in OSA patients who are intolerant to CPAP therapy. However, the outcomes of these surgeries for OSA treatment were insufficient in Thai patients.

What this study adds?

This study reported the PSG outcomes after three common skeletal surgeries in the tertiary hospital for the treatment of OSA in Thai patients. This information provided another set of data for clinicians to consider the proper alternative therapies for Thai OSA patients.

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Conflicts of interest

The authors declare that they had no conflicts of interest.

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