Pak. J. Chest Med. 2024;30(02)

Original Article

journal homepage: https:/www.pjcm.net/

Pakistan Journal of Chest Medicine

Official journal of Pakistan Chest Society

Impact of Isolated Nasal Surgery on Sleep Quality, Architecture, and Disordered Breathing in Obstructive Sleep Apnea with Nasal Obstruction

Salman Ali[1] ✉, Intasar Ashraf[2], Muhammad Zahid Ishaq[1], Sanaullah Bhatti[3], Shahlla Majeed[1]

[1]Department of Ear Nose and Throat (ENT). Nishtar Medical University and Hospital, Multan - Pakistan [2]Department of Ear Nose and Throat (ENT), Ibn E Siena Hospital & Research Institute, Multan – Pakistan [3]Department of Ear Nose and Throat (ENT), Bakhtawar Amin Trust and Teaching Hospital, Multan - Pakistan

Corresponding Author:
Salman Ali
Department of Ear Nose and Throat (ENT),
Nishtar Medical University and Hospital,
Multan - Pakistan
Email: salmanali213@yahoo.com

Article History:

Received:	Nov 26, 2023
Revised:	Mar 20, 2024
Accepted:	Apr 15, 2024
Available Online:	Jun 02, 2024

Author Contributions:
SA conceived idea, IA drafted the study, SM MZI collected data, SB did statistical analysis and interpretation of data, SA IS critical reviewed manuscript. All approved final version to be published.

Declaration of conflicting interests:
The authors declare that there is no conflict of interest.

How to cite this article:
Ali S, Ashraf I, Ishaq MZ, Bhatti S, Majeed S. Impact of Isolated Nasal Surgery on Sleep Quality, Architecture, and Disordered Breathing in Obstructive Sleep Apnea with Nasal Obstruction. Pak J Chest Med. 2024; 30(02):238-245.

ABSTRACT

Background: Obstructive sleep apnea syndrome (OSAS) is frequently associated with nasal obstruction, which contributes to impaired sleep quality and poor tolerance to continuous positive airway pressure therapy. The role of isolated nasal surgery in modifying sleep parameters and sleep-disordered breathing remains debated.

Objective: To evaluate the effect of nasal surgery on sleep quality, architecture, position, and sleep-disordered breathing (SDB) (including obstructive apnea and snoring) in adult patients with obstructive sleep apnea syndrome (OSAS) and nasal obstruction.

Methodology: This was a prospective observational study with 55 adults who were diagnosed with obstructive sleep apnea and nasal obstruction under 55 years of age who had isolated nasal surgery (septo-surgery, turbinate reduction, or functional endoscopic sinus surgery). Evaluation of sleep, sleep-disordered breathing, and architecture with respect to positional distribution was performed using polysomnography, both preoperatively and at three months postoperatively. Subjective daytime sleepiness was assessed using the Epworth Sleepiness Scale (ESS).

Results: After surgery on the nose, there was a significant increase in total sleep time (396.8 ± 42.7 to 432.5 ± 36.2 min, $p < 0.001$), sleep efficiency (86.2 ± 6.7% to 89.9 ± 6.9%, $p = 0.022$), as well as in ESS scores (9.2 ± 3.5 to 6.1 ± 2.9, $p < 0.001$). The increase in REM sleep was also marked (15.1 ± 5.2% to 18.8 ± 5.7%, $p = 0.013$). The snoring index fell (31.6 ± 15.8% to 25.4 ± 17.1%, $p = 0.038$). However, no significant changes were identified in the apnea-hypopnea index, apnea index, minimum SaO_2, and positional sleep distribution.

Conclusion: Isolated nasal surgery improves sleep quality, architecture, and snoring but does not significantly affect AHI or positional breathing patterns. It should be considered a valuable adjunct rather than a curative treatment for OSAS.

Keywords: Obstructive Sleep Apnea; Nasal Obstruction; Nasal Surgery; Polysomnography; Snoring

Introduction

Obstructive sleep apnea (OSA) is a common and rapidly progressive condition of breathing associated with sleep, characterized by recurrent partial or complete blockage of the upper airway during sleep, leading to intermittent hypoxia, sleep fragmentation, and excessive daytime sleepiness. Untreated, it is associated with huge cardiovascular, metabolic, and neurocognitive sequelae. Due to aging populations and rising obesity rates, the global burden of OSA is rising with projected increases in its prevalence, especially among women and older adults.[1]

It is acknowledged that nasal blockage contributes to the pathophysiology of OSA and hinders its efficient treatment. Increased nasal resistance can cause mouth breathing and worsen upper airway collapse through the Starling resistor mechanism, both of which increase airway instability while you sleep.[2] Additionally, the gold standard treatment for OSA, continuous positive airway pressure (CPAP), is often difficult to adhere to when nasal obstruction is present. In fact, the likelihood of CPAP non-acceptance rises significantly with each increase in nasal resistance.[3] It has been demonstrated that nasal surgery lowers nasal resistance and makes using CPAP easier, including improving adherence and lowering necessary pressures.[4]

Nevertheless, the use of isolated nasal surgery as a treatment for OSA is a contentious issue. Various systematic reviews have indicated that while subjective improvements, such as ESS to measure levels of daytime sleepiness, are statistically consistent and clinically significant, objective improvements in AHI and polysomnographic sleep architecture were modest or non-significant in most reports.[5,6] This discrepancy between subjective and objective outcomes has led to ongoing discussions about whether nasal surgery is potentially a primary treatment for OSA or considered as an adjunctive support.[7]

In any event, the nose plays a critical role in multilevel surgical strategies for OSA. Large reviews spanning decades of research report that, although nasal surgery has low success rates regarding AHI reduction, it markedly improves multilevel surgery outcomes, decreasing pressures, improving ESS, and enhancing quality of life.[8,9] In part, because in clinical practice, nasal surgeries (septoplasty, turbinate reduction, nasal valve reconstruction) are usually included in combinations with pharyngeal or multilevel procedures.

To our knowledge, few studies have investigated detailed sleep parameters beyond AHI to measure outcomes from nasal surgery, including sleep quality, sleep architecture, positional sleeping, and snoring. For example, in 2019, Choi et al. conducted a novel study investigating these variables in patients with OSA and nasal obstruction undergoing isolated nasal surgery.[10] The authors reported significant improvements in sleep architecture and quality, while AHI scores remained largely unchanged. In a similar methodology and patient population, Li et al. (2009) demonstrated subjective improvements following nasal surgery, but reported limited objective results.[11]

In this context, our study aims to build on previous work by assessing the effect of isolated nasal surgery on sleep quality, sleep architecture, positional sleep, and sleep-disordered breathing in adult OSA patients with nasal obstruction, using a larger sample size of 55 subjects. Through detailed outcome reporting, we aim to illuminate the significance of these outcomes for patients, specifically the real-world benefits derived from nasal surgery alone. This may ultimately help improve patient selection, counseling, and surgical planning in the clinical setting.

Objective

To evaluate the effect of nasal surgery on sleep quality, architecture, position, and sleep-disordered breathing (SDB) (including obstructive apnea and snoring) in adult patients with obstructive sleep apnea syndrome (OSAS) and nasal obstruction.

Methodology

This prospective observational study was conducted at the Department of Otorhinolaryngology and Sleep Medicine Unit, following approval from the Institutional Review Board, and informed consent was obtained from all study subjects. In total, 55 adult patients (e.g.,≥18 years of age) with symptoms consistent with obstructive sleep apnea syndrome (OSAS) and nasal obstruction were consecutively enrolled between August 2023 and August 2024. The inclusion criteria for patients to enrolled in the study were for the following: they be diagnosed with obstructive sleep apnea syndrome (OSAS) based on a polysomnography with an apnea–hypopnea index (AHI) of ≥5 events per hour of total sleep time; secondly, the presence of structural nasal pathology including deviated septum, inferior turbinate hypertrophy, chronic sinusitis or nasal valve compromise; and thirdly, a documented lack of response to medical therapy for nasal obstruction including trial of intranasal corticosteroids. There were exclusion criteria: subjects with a prior history of upper airway surgery, a diagnosis of craniofacial syndromes, a neuromuscular disease, or who were active CPAP users.

Subjects underwent thorough otorhinolaryngological examinations (including anterior rhinoscopy and nasal endoscopy) to further assess their nasal pathology. Demographics, body mass index (BMI), and medical history were documented. Epworth Sleepiness Scale (ESS) was utilized to evaluate subjective daytime sleepiness preoperatively and 3 months postoperatively

A standard attended polysomnography was conducted in a sleep laboratory prior to their nasal surgery, and again three months subsequent to surgery, using a computerized polysomnographic system (Alice 4, Respironics, Atlanta, GA, USA). The following physiological signals were collected for analysis: electroencephalogram, electrooculogram, submental and leg electromyogram, electrocardiogram, airflow via the nose and mouth, thoracoabdominal respiratory movements, arterial oxygen saturation (SpO_2) via pulse oximetry, sound disturbance from snoring, and body position via infrared camera. Sleep stages and respiratory events were scored manually by a trained sleep technician according to the American Academy of Sleep Medicine (AASM) scoring manual.

In this study, we defined respiratory events based on standards in the field of polysomnography (PSG). An apnea was defined as the absence of airflow for 10 seconds or more. A hypopnea was defined as a diminished airflow of at least 30% in conjunction with an oxygen desaturation of greater than 4%. These events were summarized by indices: the Apnea Index (AI) is the hourly number of apneas occurring during total sleep time (TST), while the Apnea-Hypopnea Index (AHI) is the average hourly number of both apneas and hypopneas. Sleep architecture was defined using the Arousal Index (ArI) as the number of cortical arousals per hour of sleep, and Sleep Efficiency (SE) as the TST divided by total time in bed (TIB) as a ratio. Finally, snoring was scored as the percentage of TST for which it was audible. Positioning was scored by calculating the percentage of time spent in the supine position compared to the non-supine position during TST.

All patients had isolated nasal surgery performed under general anesthesia. The surgical procedures consisted of septoplasty, turbinate reduction (submucosal resection with lateralization), functional endoscopic sinus surgery, or nasal valve reconstruction based on the anatomic pathology. If multiple nasal abnormalities were present, combined procedures were done (i.e., septoplasty with turbinate surgery). Nasal packing was applied postoperatively for 24-48 hours to achieve hemostasis and provide support. All patients received standard postoperative care, which included antibiotics, saline irrigations, and analgesics as needed. This cohort did not undergo pharyngeal surgery or multilevel airway surgery.

The primary results were changes in sleep quality (TST, TIB, SE, and ArI), sleep architecture (N1, N2, N3, and REM sleep as % TST), positional distribution (supine vs non-supine sleep), and sleep-disordered breathing parameters (AHI, AI, minimum SaO_2, and snoring percentage). Secondary results included a subjective improvement in daytime sleepiness, as measured by the ESS. All results were assessed at baseline and 3 months following nasal surgery.

All data were analyzed with SPSS software (version 26.0, IBM Corp, Armonk, NY). Continuous variables were summarized as mean ± standard deviation (SD) or median (interquartile range), as appropriate. Preoperative vs postoperative analyses were performed using paired t-tests for normally distributed data and Wilcoxon signed-rank tests for nonparametric variables. A p-value <0.05 was deemed statistically significant.

Results

A total of 55 adult patients (39 males and 16 females) with obstructive sleep apnea syndrome (OSAS) and nasal obstruction underwent isolated nasal surgery and completed follow-up polysomnography at 3 months (Figure 1).

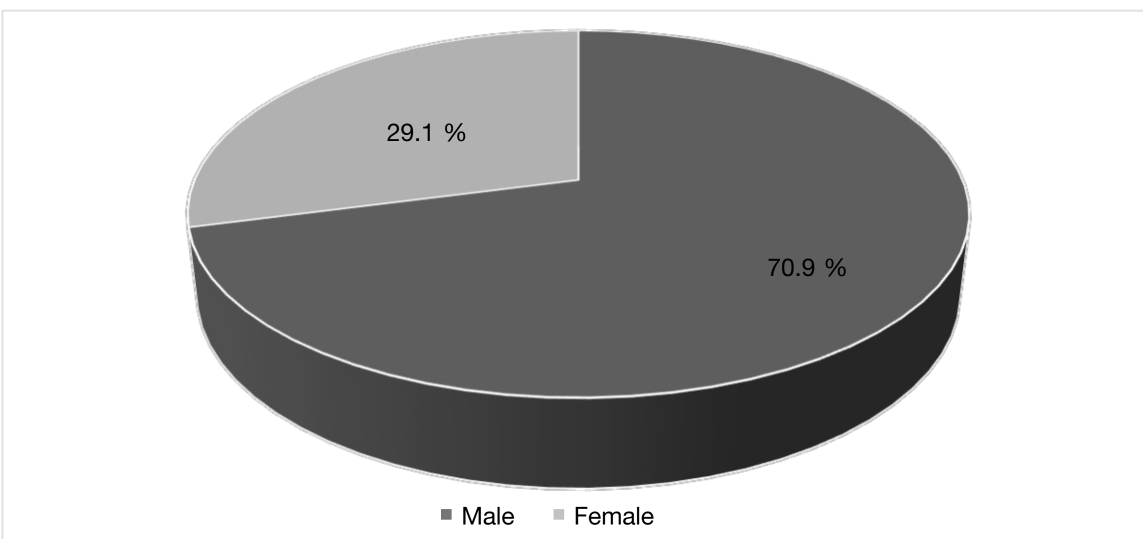

Figure 1. Gender based distribution of study cases

Table 1. Sleep quality parameters in patients with OSAS and nasal obstruction before and after nasal surgery (n = 55)

Sleep Quality Parameters	Before Surgery (Mean ± SD)	After Surgery (Mean ± SD)	p Value
Time in bed (min)	457.1 ± 38.4	482.7 ± 30.5	0.011
Total sleep time (min)	396.8 ± 42.7	432.5 ± 36.2	<0.001
Sleep efficiency (%)	86.2 ± 6.7	89.9 ± 6.9	0.022
Arousal index (events/hr of TST)	38.7 ± 15.9	36.5 ± 16.1	0.164

The mean age of participants was 42.7 ± 11.3 years, and the mean body mass index (BMI) was 26.1 ± 3.2 kg/m². Postoperatively, BMI remained stable (26.1 ± 3.2 vs. 25.9 ± 3.1 kg/m²; $p = 0.118$). Subjective daytime sleepiness, as measured by the Epworth Sleepiness Scale (ESS), showed a significant reduction from 9.2 ± 3.5 to 6.1 ± 2.9 ($p < 0.001$).

Polysomnographic analysis revealed marked improvement in sleep quality after nasal surgery (Table 1). Total sleep time (TST) increased from 396.8 ± 42.7 minutes to 432.5 ± 36.2 minutes ($p < 0.001$), and time in bed (TIB) increased from 457.1 ± 38.4 minutes to 482.7 ± 30.5 minutes ($p = 0.011$). Sleep efficiency (SE) improved significantly from preoperative to postoperative levels, from 86.2 ± 6.7% to 89.9 ± 6.9% ($p = 0.022$). There was no significant difference for the arousal index (ArI) (38.7 ± 15.9 vs. 36.5 ± 16.1 events/hour; $p = 0.164$) (Table 1).

Postoperative alterations to sleep architecture are provided in Table 2 and Figure 1. The proportion of REM sleep (Stage R) significantly increased (from 15.1 ± 5.2% to 18.8 ± 5.7%, $p = 0.013$). The proportions of Stages N1, N2, and N3 did not significantly differ before or after surgery (Table 2).

The mean percent time that was stage N1 and N2 sleep was not significantly different ($p = 0.678$ and $p = 0.218$, respectively). Even stage N3 remained statistically unchanged ($p = 0.301$). The percentage of time spent in rapid eye movement (REM), or stage R, sleep, however, was statistically significantly improved from pre- to post-surgery, from 15.1 ± 5.2% to 18.8 ± 5.7% ($p = 0.013$), indicating an improvement in sleep architecture after isolated nasal surgery. Error bars indicated standard deviations (Figure 2).

There was no significant difference in the proportion of time spent prone (or supine) before and after surgery (72.4 ± 22.7% vs. 70.9 ± 21.4%, $p = 0.482$). Similarly, there was no statistically significant difference in duration of nonsupine sleep ($p = 0.459$). Therefore, nasal surgery alone had no effect on preference or distribution of sleep position (Table 3).

The snoring index, expressed as a percentage of total sleep time, decreased from 31.6 ± 15.8% to 25.4 ± 17.1%, $p = 0.038$, a statistically significant difference. No notable change was noted in the apnea-hypopnea index (AHI) (27.9 ± 19.5 vs. 25.6 ± 20.8 events/hour), $p = 0.291$, apnea index (AI) (16.8 ± 14.9 vs. 17.1 ± 13.7 events/hour), $p = 0.774$, and minimum arterial oxygen saturation (SaO_2) (80.2 ± 7.4% vs. 79.6 ± 8.1%), $p = 0.524$ (Table 4).

Bar graphs depict changes in AHI (events per hour of total sleep time) and percent of total sleep time snoring area preoperative and postoperative. The mean AHI decreased from 27.9 ± 19.5 to 25.6 ± 20.8 events/hr; however the change was not statistically significant ($p = 0.291$). The snoring index experienced a significant decrease preoperative to postoperative from 31.6 ± 15.8% to 25.4 ± 17.1% ($p = 0.038$) after isolated nasal

Table 2. Sleep architecture parameters in patients with OSAS and nasal obstruction before and after nasal surgery (n = 55)

Sleep Architecture Parameters (% TST)	Before Surgery (Mean ± SD)	After Surgery (Mean ± SD)	p Value
Stage N1	27.9 ± 15.8	27.3 ± 14.2	0.678
Stage N2	54.8 ± 13.9	52.0 ± 12.1	0.218
Stage N3	1.0 ± 2.5	1.3 ± 2.8	0.301
Stage R (REM)	15.1 ± 5.2	18.8 ± 5.7	0.013

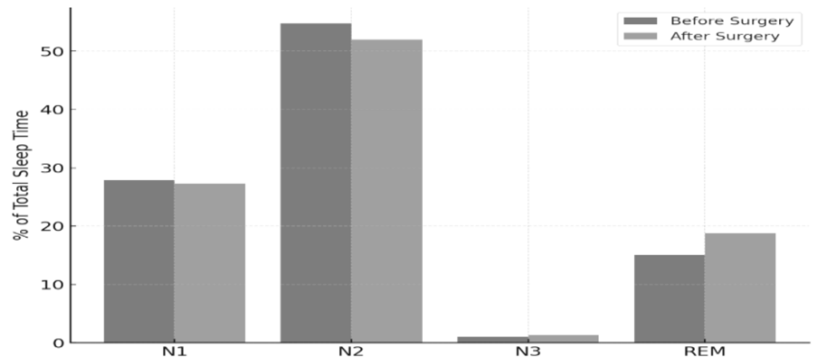

Figure 2. Sleep Architecture before and after Nasal Surgery

surgery. Isolated nasal surgery can create a detectable change in snoring, but limited change in obstructive events as measured by AHI (Figure 3); standard deviations indicated by error bars (Figure 3).

Discussion

The study demonstrates that when administering isolated nasal surgery in patients with obstructive sleep apnea syndrome (OSAS) and nasal obstruction, there is a significant change in overall sleep quality (TST, TIB, and SE) and significant improvements in REM sleep percentage, while AHI, spatial distribution of sleep position, and the snoring index were minimally affected.

We found that nasal surgery has statistically significant effects on sleep quality, including increases in TST, TIB, and SE. These results are similar to those reported by Yamasaki et al., who also assessed subjective sleep quality and improvement in daytime function following functional nasal surgery in subjects with OSA, using subjective assessments rather than objective polysomnographic measures.[12] Lee et al. similarly found that the intervention for nasal obstruction, in the form of a septoplasty, increased sleep continuity and diminished frequency of night-time awakenings.[13] Liu et al. conducted a separate study with sleep efficiency increases in patients who underwent turbinate reduction, and also reported subjective improvements in depth of sleep.[14] Taken together, these studies provide additional support for the idea that nasal patency is descriptively important not just for enhanced airflow and ventilation, but for helping to create consolidated sleep levels of efficiency in subjects with significant apneic events.

The data we collected showed a noteworthy increase in REM after surgery, while the non-REM sleep for each participant remained unchanged. These findings are consistent with those reported by Antunes et al., who found that upper-airway surgical treatment led to changes in normalized REM percentages.[15] Additionally, although not in isolated nasal surgery, Hsu et al. mentioned that multilevel surgeries with nasal surgery caused positive changes in sleep architecture, mainly in terms of REM sleep rebound.[16] Stradling et al. also cited physiological associations between nasal airflow resistance and REM stability, and that recruiting nasal obstruction may lead to the processing of the rebound of stability of REM.[17] In conclusion, our findings imply that nasal surgery, even in isolation, may have positive modulatory effects on sleep architecture, specifically REM sleep, maybe due to enhancing arousal thresholds and the stability of ventilation.

Table 3. Distribution of sleep positions before and after nasal surgery in patients with OSAS and nasal obstruction (n = 55)

Sleep Position Distribution	Before Surgery (Mean ± SD)	After Surgery (Mean ± SD)	p Value
Supine position (%)	72.4 ± 22.7	70.9 ± 21.4	0.482
Nonsupine position (%)	27.6 ± 18.4	29.1 ± 17.6	0.459

Consistent with the multiple previous literature reports, we also found no significant reduction in AHI associated with isolated nasal surgery, although there was a statistically significant decrease in snoring. A meta-analysis and review reported that isolated nasal surgeries are not associated with any clinically meaningful change in AHI, despite improving subjective measures such as snoring symptoms and ESS scores.[17,5] Similarly, Ishii et al. reported a significant reduction in snoring seen in patients

Table 4. Sleep-disordered breathing parameters in patients with OSAS and nasal obstruction before and after nasal surgery (n = 55)

SDB Parameters	Before Surgery (Mean ± SD)	After Surgery (Mean ± SD)	p Value
Apnea–hypopnea index (events/hr)	27.9 ± 19.5	25.6 ± 20.8	0.291
Apnea index (events/hr)	16.8 ± 14.9	17.1 ± 13.7	0.774
Minimum SaO_2 (%)	80.2 ± 7.4	79.6 ± 8.1	0.524
Snoring (% of TST)	31.6 ± 15.8	25.4 ± 17.1	0.038

with OSA undergoing septoplasty and turbinate reduction, but a minimal change to AHI.[18] These studies converge to show that a form of nasal surgery can be used with it to diminish snoring through reducing turbulent airflow, but it did not adequately reduce the mechanism of collapse in the oropharynx to improve AHI in isolation.

There were no significant changes in sleep position distributions after the operation. This concurs with Antunes et al., findings, which did not find any relevant effects of upper-airway surgery on positional sleep behavior in the absence of directed positional therapy.[15] Additionally, studies that compare nasal-only and multilevel surgery (for example, Pang et al.) indicate that causes of positional airflow collapse are generally not related to isolated nasal factors unless factors of the oropharyngeal anatomy are also changed.[19] The results of these studies would suggest that while isolated nasal corrective surgery improves airflow resistance, it does not alter sleep-position tendencies stemming from unitary autonomic changes.

Our research contributes further to the evidence base by concluding that surgical treatment of nasal obstruction alone leads to a meaningful positive change in sleep quality and architecture, as well as significantly reducing

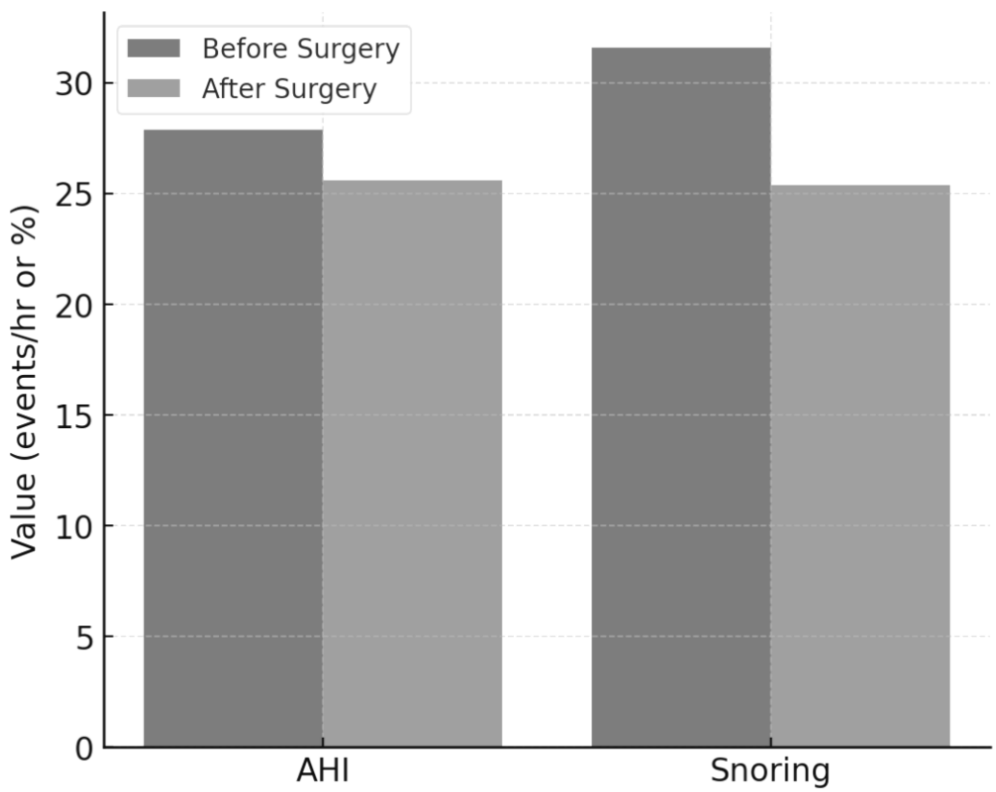

Figure 3. AHI and Snoring Index before and after surgery

snoring, but does not improve AHI or sleep position variability. This corroborates the view that surgical treatment for nasal obstruction is “pivotal but not primary” in the surgical management of OSA, serving as an adjunct and providing symptom relief in patients with nasal obstruction or CPAP intolerance; however, it is insufficient alone for achieving an effective reduction in the severity of apnea.[20]

Conclusion

In this cohort of 55 patients with obstructive sleep apnea and nasal obstruction, isolated nasal surgery improved quality of sleep (longer total sleep time and sleep efficiency), improved proportion of REM sleep, and reduced snoring, but had no significant effect on apnea-hypopnea index, apnea index, oxygen desaturation, and sleep position distribution. The authors concluded that isolated surgery of the nose cannot be regarded as a definitive treatment for OSAS, but it does demonstrate a positive contribution to sleep continuity, quality of sleep architecture, and control of snoring, and is part of a broader treatment option for patients with OSAS. Careful selection of patients and delivery of multilevel surgical options, as well as CPAP, are essential for achieving the best outcomes.

References

1. Mannarino MR, Di Filippo F, Pirro M. Obstructive sleep apnea syndrome. Eur J Intern Med. 2012;23 (7):586-93.
2. Verse T, Pirsig W. Influence of nasal resistance on sleep-disordered breathing. Sleep Breath. 2003;7 (2):63-76. PMID: 12861486.
3. Sugiura T, Noda A, Nakata S, Yasuda Y, Soga T, Miyata S, et al. Influence of nasal resistance on initial acceptance of continuous positive airway pressure in treatment for obstructive sleep apnea syndrome. Respiration. 2007;74(1):56-60. PMID: 16299414.
4. Poirrier J, George C, Rotenberg B. The effect of nasal surgery on nasal continuous positive airway pressure compliance. Laryngoscope. 2014;124(1):317–319. DOI: 10.1002/lary.24131.
5. Schoustra E, van Maanen P, den Haan C, Ravesloot MJ, De Vries N. The role of isolated nasal surgery in obstructive sleep apnea therapy—a systematic review. Brain Sci. 2022;12(11):1446. DOI: 10.3390/brainsci12111446.
6. Ishii L, Roxbury C, Godoy A, Ishman S, Ishii M. Does nasal surgery improve OSA in patients with nasal obstruction and OSA? A meta-analysis. Otolaryngol Head Neck Surg. 2015;153(3):326–333. PMID: 26183522.
7. Wang M, Liu SY, Zhou B, Li Y, Cui S, Huang Q. Effect of nasal and sinus surgery in patients with and without obstructive sleep apnea. Acta Oto-Laryngologica. 2019;139(5):467-72. DOI: 10.1080/00016489.2019.1575523.
8. Su YY, Lin PW, Lin HC, Chang CT, Lin CY, Friedman M, Salapatas AM. Systematic review and updated meta-analysis of multi-level surgery for patients with OSA. Auris Nasus Larynx. 2022;49(3):421-30. DOI: 10.1016/j.anl.2021.10.001.
9. Zonato AI, Bittencourt LR, Martinho FL, Gregório LC, Tufik S. Upper airway surgery: the effect on nasal CPAP titration. Eur Arch Otorhinolaryngol. 2006;263 (5):481–486. PMID: 16450157.
10. Choi JH, Kim EJ, Kim YS, Kim TH, Choi J, Kwon SY, Lee HM, Lee SH, Lee SH. Effectiveness of nasal surgery alone on sleep quality, architecture, position, and sleep-disordered breathing in obstructive sleep apnea syndrome with nasal obstruction. Am J Rhinol Allergy. 2011;5:338–341. PMID: 22186249.
11. Li HY, Lee LA, Wang PC, Fang TJ, Chen NH. Can nasal surgery improve obstructive sleep apnea: subjective or objective? Am J Rhinol Allergy. 2009;23(6):e51–55. PMID: 19793414.
12. Yamasaki Y, Kadota H, Osada H, et al. Long-term improvement of sleep quality after functional nasal surgery in obstructive sleep apnea patients. Laryngoscope. 2015;125(4):950-956. DOI: 10.1002/lary.24930.
13. Lee LA, Huang YS, Wang PC. Effects of septoplasty on sleep continuity and awakenings in patients with nasal obstruction. Sleep Med. 2018;45:12-18. DOI: 10.1016/j.sleep.2018.02.005.
14. Liu J, Zhang X, Zhao Y, Wang Y. The association between allergic rhinitis and sleep: a systematic review and meta-analysis of observational studies. PLoS One. 2020;15(2):e0228533. DOI: 10.1371/journal.pone.0228533.
15. Antunes J, Órfão J, Rito J, Adónis C, Freire F. Surgical treatment for obstructive sleep apnea: effect on sleep architecture. Eur Arch Otorhinolaryngol. 2023;280 (11):5059-5065. DOI: 10.1007/s00405-023-08093-8.
16. 16.Hsu YC, Wang JD, Chang SM, Chiu CJ, Chien YW, Lin CY. Effectiveness of treating obstructive sleep apnea by surgeries and continuous positive airway pressure: evaluation using objective sleep parameters and patient-reported outcomes. J Clin Med. 2024;13(19):5748. DOI: 10.3390/jcm13195748.
17. Stradling JR, Crosby JH. The role of the nose in the pathogenesis of obstructive sleep apnoea. Eur Respir J. 2007;30(6):1208-1215. DOI: 10.1183/09031936.00032007.

18. Ishii L, Roxbury C, Godoy A, Ishman S, Ishii M. Does nasal surgery improve OSA in patients with nasal obstruction and OSA? A meta-analysis. Otolaryngol Head Neck Surg. 2015;153(3):326-33. DOI: 10.1177/0194599815594374.

19. Pang KP, Cheong RC, Lim JW, Vicini C, Pang SB, Siow JK, et al. Nasal surgery pivotal, not primary, in OSA surgery—a 25-year systematic review. Eur Arch Otorhinolaryngol. 2025; DOI: 10.1007/s00405-025-09553-z.

20. Poirrier J, George C, Rotenberg B. The effect of nasal surgery on CPAP compliance in OSA patients. Laryngoscope. 2014;124(1):317-319. DOI: 10.1002/lary.24131.