Surgical Outcomes for Obstructive Sleep Apnea in Korea

Min-Ki Lee, MD, Jae Yong Lee, MD, PhD, Ji Ho Choi, MD, PhD

Department of Otorhinolaryngology-Head and Neck Surgery, Soonchunhyang University Bucheon Hospital, Soonchunhyang University College of Medicine, Bucheon, Korea

Obstructive sleep apnea (OSA) is a common chronic sleep disorder that causes oxygen desaturations, sympathetic hyperactivation, and sleep fragmentation. The gold standard for OSA treatment in adults is positive airway pressure (PAP) therapy, which is effective when used during sleep. However, about half of patients with OSA refuse or are non-adherent to PAP, and some patients have anatomical problems that can be alleviated surgically. Surgery can be considered for patients who are very likely to have successful surgical results, but who are intolerant to PAP or oral appliances because of anatomical abnormalities. There are various surgical modifications of the upper airway for OSA, including nasal surgeries (e.g., septoplasty, turbinoplasty, and endoscopic sinus surgery), nasopharyngeal surgeries, oral and oropharyngeal surgeries (e.g., uvulopalatopharyngoplasty and variations, tonsillectomy, and palatal implants), hypopharyngeal surgeries (e.g., tongue ablation, tongue-base resection, and genioglossus advancement), and multi-level surgeries. Much clinical research has reported the outcomes of various surgical procedures for OSA internationally based on the traditional surgical success rate (defined as ≥50% reduction in the postoperative apnea-hypopnea index [AHI], postoperative AHI < 20), and AHI reduction ratio (defined as between the preoperative and postoperative AHI). In addition, many studies investigating the results of various OSA surgeries have been reported in Korea. In this article, we review the characteristics of various upper airway surgical procedures for OSA, global surgical results for OSA, and current surgical outcomes for OSA in Korea.

INTRODUCTION

Obstructive sleep apnea (OSA) is a relatively common chronic sleep disease caused by upper airway collapse, which leads to an overactivated sympathetic nervous system, repeated hypoxia, and disrupted sleep continuity [1]. Untreated OSA can present various signs and symptoms, with subsequent morbidity and mortality [2,3]. Although reported differently depending on the study area, epidemiological studies that include Korea estimate that 24% to 27% of the adult male population and 9% to 16.8% of the adult female population has OSA [4,5].

The main therapeutic modality for OSA is positive airway pressure (PAP) treatment, which is efficacious when applied during sleep [2,6]. However, about half of patients with OSA are intolerant to PAP therapy because of diverse problems, including mask-related troubles, pressure-related issues, nose-related problems, and residual symptoms [6]. In addition, some patients may have a surgically correctable anatomical structure of the upper airway; hence, upper airway surgery can be considered as an alternative treatment for patients with unsuccessful non-surgical therapies, such as PAP or oral appliance (OA) and as an adjunctive treatment for patients who are not adherent to PAP or OA because of anatomical abnor-
Objective outcomes for OSA can be evaluated by two ways: traditional surgical success rate and apnea-hypopnea index (AHI) reduction ratio. Surgical success was defined as ≥ 50% decrease in preoperative AHI and postoperative AHI < 20. The AHI reduction ratio (%) was defined as the degree of reduction from preoperative AHI to postoperative AHI: \[(\text{preoperative AHI} - \text{postoperative AHI}) \times 100 / \text{preoperative AHI}\] [8,9].

This article will review the characteristics of various surgical procedures for OSA, global surgical outcomes for OSA, and current surgical results for OSA in Korea.

OUTCOMES OF OBSTRUCTIVE SLEEP APNEA SURGERY IN KOREA

Surgical Treatments for Obstructive Sleep Apnea

Surgical modifications of the upper airway are a necessary and useful therapeutic option in appropriate cases of patients with OSA. Surgical treatment is primarily indicated in cases with enlarged tonsils or large masses obstructing the upper airway, which causes OSA. In OSA patients who have failed medical therapies such as PAP or OA, surgical therapy is also indicated. Last, surgery is indicated in cases with poor adherence to PAP or OA therapy because of anatomical problems [2,7,9]. There are various surgical modifications of the upper airway for OSA, including the following surgical procedures: nasal surgeries, such as septoplasty, turbinectomy, nasal polypectomy or tumor removal, and endoscopic sinus surgery; nasopharyngeal surgeries, such as adenoidectomy and nasopharyngeal tumor removal; oral and oropharyngeal surgeries, such as uvulopalatopharyngoplasty (UPPP), tonsillectomy, and palatal implants; hypopharyngeal surgeries, such as tongue-base reduction, lingual tonsillectomy, genioglossus advancement, and hyoid suspension; and multi-level or other surgeries, such as oropharyngeal and hypopharyngeal surgery, maxillomandibular advancement (MMA), and tracheotomy [2,7,9].

Numerous studies have reported postoperative improvement of such clinical outcomes as symptoms, cardiovascular risk, quality of life, and mortality [10]. However, except for some primary candidates for surgery and a few surgical procedures, such as MMA or tracheostomy, most surgical procedures for OSA are generally not recognized as curative treatments, because the possibility of cure is relatively low and the outcome after surgery is difficult to predict [2,7,9]. Patients considering surgery should be given information about operation-related advantages and limitations including potential success rates, benefits, risks, and complications [2,7,9,11].

Nasal Surgery

Nasal surgeries are done to improve airflow by means of structural remodeling and to alleviate nasal symptoms, especially nasal congestion. Nasal obstruction may be caused by various nasal or nasopharyngeal anatomic abnormalities, including inferior turbinate hypertrophy, septal deviation, valve stenosis, nasal polyp or mass, and adenoid vegetation or mass [2]. Nasal surgery included inferior turbinate reduction, septal surgery, valve surgical correction, and endoscopic sinus surgery. Many studies have reported investigation of the effect of isolated nasal surgery on OSA [12-15]. According to a study published in Korea, nasal surgery alone can be a useful option for improving such symptoms as excessive daytime sleepiness, sleep inefficiency, and snoring in OSA patients with nasal obstruction [12]. Although isolated nasal surgery has a relatively low success rate for OSA, it can be very effective for OSA patients who have surgically correctable anatomical abnormalities. Lee et al. [13] indicated that nasal surgery alone may be efficient for the alleviation of minimum oxygen saturation and respiratory events, including apnea and hypopnea, in OSA patients with large nasal masses. Park et al. [14] also suggested that isolated nasal surgery may improve not only polysomnography-related parameters but also PAP-related parameters, such as optimal level of PAP and PAP adherence. The results of these studies in Korea are consistent with the results of many other studies around the world [15].

Oropharyngeal Surgery

The oropharynx is the most frequently collapsible area in OSA patients. The oropharyngeal space contains diverse anatomical structures, such as the soft palate, uvula, pharyngeal wall, or tonsils. Oropharyngeal surgery is generally done to enlarge the space or increase muscle tension by removing or modifying oropharyngeal structures. These procedures include tonsillectomy, UPPP and variations, palatal implants, and palatal advancement. Oropharyngeal surgery can be carried out alone or be done simultaneously with nasal surgery and/or hypopharyngeal surgery.

Uvulopalatopharyngoplasty

UPPP is one of the most common surgical procedures for patients with OSA. This surgical method widens the oropharyngeal space by resecting tonsils and redundant soft tissue of the uvula, soft palate, and oropharynx. Previous clinical research conducted before considering the patient’s anatomy has investigated the surgical outcomes of UPPP in unselected patients with OSA. According these studies, the success rate of UPPP was 40.7% [16]. In addition, the AHI reduction ratio of UPPP was 33% (95% confidence interval [CI], 23% to 42%) based on the meta-analysis by the American Academy of Sleep Medicine [9]. Compared to PAP therapy with good compliance, the success rate or AHI reduction ratio of randomly done UPPP is relatively low. However, the success rate or AHI reduction ratio improved when OSA patients were selected in terms of their anatomical features [17-19]. Friedman et al. [17] reported an anatomy staging system based on palate-tongue position and...
tonsil size. There was a higher success rate of UPPP in stage I (80.6%) than in stage II (37.9%) or III (81.1%). Browaldh et al. [18] did a prospective randomized controlled clinical trial and showed that the success rate was 59% and AHI reduction ratio was 60% in selected OSA patients (AHI ≥ 15) including Friedman stage I or II. In Korea, Choi et al. [19] reported that the overall success rate of oropharyngeal OSA surgery including UPPP was 55.8%, and overall AHI reduction ratio was 53.5% in 156 patients with OSA. The surgical success rates in stages I, II (IIa and IIb), and III were 83.0%, 52.3% (60.9% and 47.6%), and 31.8%, respectively, and the AHI reduction ratios for stages I, II (IIa and IIb), and III were 74.1%, 49.4% (71.2% and 34.4%), and 30.4%, respectively. The outcomes of UPPP around the world were in accordance with those in Korea.

UPPP also affects subjective outcomes in patients with OSA. A related study found that isolated UPPP may alleviate subjective symptoms in adult OSA patients regardless of surgical success. However, the improvement was shown more in the unsuccessful group than in the successful group [20]. Moreover, these subjective alleviations persisted for at least 5 years after upper airway surgery including UPPP [21].

Some studies have shown that successful OSA surgery may improve not only subjective symptoms, but also objective outcomes, such as heart rate variability (HRV) and cardiovoluminary coupling (CPC) [22,23]. OSA can cause changes in cardiac sympathetic and parasympathetic modulation, which may be improved after successful upper airway surgery including UPPP as shown by measurement of HRV [22]. In addition, OSA can worsen sleep quality; successful surgery may improve objective sleep quality as assessed by monitoring of CPC in OSA patients [23]. These favorable effects of successful upper-airway surgery such as UPPP may help lower the risk of diverse consequences, including cardiovascular complications in patients with OSA [22-25].

**Palatal implants**

Pillar implants is a minimally invasive surgical option for improving sleep-disordered breathing, such as snoring and OSA. Three polyester rods are inserted into the soft palate in a parallel direction, where they initiate an inflammatory response in the surrounding soft tissues. The resulting fibrosis leads to increase stiffness of the soft palate and reduces vibration or narrowing of the soft palate. According to a meta-analysis evaluating the effectiveness of Pillar implants in mild-to-moderate OSA patients, the AHI reduction ratio was 37.8% (95% CI, 13.8% to 61.9%), and subjective snoring based on a visual analogue scale (VAS) was reduced by 59.1% (95% CI, 42.9% to 75.3%) after palatal implants [26]. In Korea, a prospective multicenter study was conducted to investigate the therapeutic effect of Pillar implants; it showed that pAHI (from 8.4 ± 3.6 to 6.3 ± 3.9; p = 0.018) and subjective snoring (from 6.3 ± 1.4 to 3.0 ± 1.5; p < 0.001) using VAS were significantly improved in a subgroup analysis of mild OSA patients [27]. These results indicated that Pillar implants may be useful when selectively done in OSA patients with mild OSA.

**Tonsillectomy and adenoidec-tomy**

Tonsillectomy and adenoidec-tomy (T&A) are the most widely done surgical procedure in children with OSA. T&A is considered to be the first-line therapy in pediatric OSA caused by upper-airway collapse, because adenotonsillar hypertrophy is the most common cause of OSA in children [28,29]. This procedure is recognized as being effective and safe in most children with OSA. A meta-analysis reported that the success rate for T&A was about 82.9% (95% CI, 76.2% to 89.2%) with significant reduction in AHI [30].

In Korea, some studies reported that T&A significantly improved not only subjective symptoms, such as restless sleep, morning headache, and difficulty with morning arousal, but also polysomnographic parameters, including AHI, arousal index, minimum oxygen saturation, and snoring, in children with OSA [31,32]. According to studies evaluating the surgical outcomes of T&A in Korean children with OSA, the short-term cure rate (postoperative obstructive AHI < 1) was 90.9% [31]. In addition, the five-year cure rate and response rate were 47.1% and 70.6%, respectively [32]. In this paper, surgical cure rate was defined as reduction of AHI ≥ 75% and postoperative AHI < 1, and response rate was defined as reduction of AHI ≥ 75% and postoperative AHI < 5.

**Hypopharyngeal Surgery**

In patients with OSA, the hypopharyngeal space including the tongue base is one of the common obstructive sites, and hypopharyngeal collapse can usually occur when the base of the tongue is relatively large or the facial skeleton, such as the mandible, is relatively small. Various hypopharyngeal surgeries have been introduced to alleviate the hypopharyngeal obstruction by means of tongue-base reduction or repositioning, such as advancement. These procedures that include tongue-base reduction use diverse ablation techniques and transoral robotic tongue-base reduction. Hypopharyngeal surgery can also be done alone, at the same time as other OSA surgery, or in stages after other upper-airway surgery, such as oropharyng-eal surgery.

**Transoral robotic tongue-base reduction**

Transoral robotic surgery was first used to treat head and neck malignancy. After O’Malley et al. [33] used transoral robotic surgery in the management of tongue-base cancer, and Vicini et al. [34] expanded the application range of transoral robotic surgery for OSA therapy, many studies have reported the safety, tolerability, and efficacy in improving obstruction at the tongue-base level. Robot-assisted tongue-base resection reduces the volume of the tongue base using a surgical robotic device. After visualization of the tongue base with a three-dimensional high-
magnification endoscope, the robotic surgical system was used to carry out resection of enlarged lingual tonsils or hypertrophied tissues of the tongue base. Care should be taken to avoid damage to important structures, such as dorsal lingual artery branches or the glossopharyngeal nerve. In related clinical studies, surgical success rate ranged from 55% to 83% and AHI reduction ratio ranged from 55% to 60% after transoral robotic tongue-base reduction [35-37]. Cho et al. [38] conducted clinical research to establish favorable indications and treatment outcomes of transoral robotic tongue-base resection in Korean patients with OSA and found that robot-assisted tongue-base resection was highly effective in OSA patients with severe tongue-base narrowing caused by hypertrophy of the lingual tonsils. They reported a 62.5% surgical success rate, a 61.7% AHI reduction ratio, and a significant alleviation in subjective symptoms. The results of transoral robotic tongue-base resection around the world are consistent with those in Korea.

**Transoral endoscopic tongue-base reduction**

Transoral endoscopic tongue-base reduction partially removes the tissue at the tongue base under an endoscopic view, and coblation is mainly used. Babadzam et al. [39] did a randomized prospective comparison between transoral endoscopic coblation tongue-base resection and transoral robotic tongue-base surgery and found that the success rates (AHI reduction ratio) were 75.6% (64%) for robotic surgery and 78.7% (62.1%) for coblation surgery. No significant difference was observed in surgical results between the two tongue-base surgeries. However, endoscope-guided coblation surgery showed lower complication rates than did robot-assisted surgery. In Korea, Hwang et al. [40] compared the effectiveness and safety between transoral endoscopic coblation and robot-assisted tongue-base reduction. In this study, the success rate and AHI reduction ratio of transoral endoscopic coblation tongue-base resection were 62.1% and 64.5%, respectively. In addition, the success rate and AHI reduction ratio of robot-assisted tongue-base reduction was 56.3% and 62.2%, respectively. There was no significant difference in surgical outcomes, such as success rate and postoperative complications, between the two transoral tongue-base procedures.

We have reviewed the characteristics of diverse surgical options for OSA as well as global surgical results including Korea, and have shown that the surgical outcomes including the success rate and AHI reduction ratio reported worldwide in patients with OSA, were quite similar to those reported in Korea.

**Availability of Data and Material**

Data sharing not applicable to this article as no datasets were generated or analyzed during the study.

**Author Contributions**

Conceptualization: Ji Ho Choi. Data curation: Ji Ho Choi, Min-Ki Lee. Formal analysis: Ji Ho Choi, Min-Ki Lee. Funding acquisition: Ji Ho Choi. Methodology: Min-Ki Lee, Jae Yong Lee. Project administration: Ji Ho Choi. Visualization: Ji Ho Choi, Min-Ki Lee. Writing—original draft: Min-Ki Lee. Writing—review & editing: Ji Ho Choi, Jae Yong Lee.

**Conflicts of Interest**

Ji Ho Choi, a contributing editor of the *The Korean Society of Sleep Medicine,* was not involved in the editorial evaluation or decision to publish this article. All remaining authors have declared no conflicts of interest.

**Funding Statement**

This study was supported by the Soonchunhyang University Research Fund.

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