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A Cost-Effectiveness Analysis of Nasal Surgery to Increase Continuous Positive Airway Pressure Adherence in Sleep Apnea Patients With Nasal Obstruction

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Abstract

Objectives/Hypothesis—Nasal surgery has been implicated to improve continuous positive airway pressure (CPAP) compliance in patients with obstructive sleep apnea (OSA) and nasal obstruction. However, the cost-effectiveness of nasal surgery to improve CPAP compliance is not known. We modeled the cost-effectiveness of two types of nasal surgery versus no surgery in patients with OSA and nasal obstruction undergoing CPAP therapy.

Study Design—Cost-effectiveness decision tree model.

Methods—We built a decision tree model to identify conditions under which nasal surgery would be cost-effective to improve CPAP adherence over the standard of care. We compared turbinate reduction and septoplasty to nonsurgical treatment over varied time horizons from a third-party payer perspective. We included variables for cost of untreated OSA, surgical cost and complications, improved compliance postoperatively, and quality of life.

Results—Our study identified nasal surgery as a cost-effective strategy to improve compliance of OSA patients using CPAP across a range of plausible model assumptions regarding the cost of untreated OSA, the probability of adherence improvement, and a chronic time horizon. The relatively lower surgical cost of turbinate reduction made it more cost-effective at earlier time horizons, whereas septoplasty became cost-effective after a longer timespan.

Conclusions—Across a range of plausible values in a clinically relevant decision model, nasal surgery is a cost-effective strategy to improve CPAP compliance in OSA patients with nasal

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obstruction. Our results suggest that OSA patients with nasal obstruction who struggle with CPAP therapy compliance should undergo evaluation for nasal surgery.

Keywords

Obstructive sleep apnea; cost-effectiveness analysis; continuous positive airway pressure compliance; nasal surgery

INTRODUCTION

Obstructive sleep apnea (OSA) is a sleep disorder that is accompanied by upper airway collapse and obstruction of airflow, often with associated oxygen desaturations. The severity of OSA, as indicated by the apneahypopnea index (AHI), proportionately raises the risk for OSA-related comorbidities in multiple organ systems, leading to cardiovascular, respiratory, and neurologic impairments.¹ In addition, OSA patients with impaired sleep caused by obstructive events pose a risk for traffic accidents related to sleepiness and attention lapses.² In recent years, OSA has become an increasingly important healthcare challenge, not only due to its adverse health effects but also due to rising healthcare costs.^{1,3} Prevalence for OSA ranges between 3% and 20% of the general population depending on the definitions used⁴; however, certain subgroups with risk factors such as obesity, male sex, or cardiometabolic comorbidities have a higher risk.⁵ In some populations, such as refractory hypertension or bariatric surgery candidates, the rate of undiagnosed OSA may range as high as 80%.^{4,6} Continuous positive airway pressure (CPAP) therapy is currently considered the gold standard treatment for OSA, and the American Academy of Sleep Medicine, as well as many insurers, therefore recommend that patients should undergo a CPAP trial before other therapeutic options are considered.⁷ However, CPAP will only effectively improve sleep and mitigate daytime sleepiness, and reduce risk for comorbidities, if the machine is used sufficiently.⁸⁻¹¹ Despite the efficacy of CPAP to control OSA when the mask is worn, noncompliance is an ongoing concern; 50% discontinue therapy within the first weeks, and overall compliance to CPAP has been found to drop to 30% to 60% after several years.^{12,13} Previous studies demonstrated that untreated OSA patients utilized up to 50% more medical resources and accumulated more than double the healthcare costs of their healthy counterparts,^{1,3} whereas successful treatment reduced overall health expenditures within a few years.^{2,14}

Surgical treatment for OSA is considered a less effective solution compared to CPAP when considered at the population level, as only a subset of patients with optimal anatomical criteria for upper airway surgery improved their AHI comparably to CPAP.^{11,15} However, it has been pointed out that comparing surgical outcomes (which do not involve compliance) and CPAP outcomes (which do require compliance) presents an important challenge. Specifically, many CPAP users do not wear the mask 100% of their sleep time, and thus the overall CPAP effectiveness is lower than the CPAP efficacy at treating OSA while the mask is worn.⁸ This concept has been called the effective AHI or the apnea burden.^{11,16-18} Therefore, interventions aimed at improving compliance with CPAP usage are crucial for population-level chronic OSA management.⁸

Recent studies have highlighted the significant success of add-on nasal surgery for CPAP compliance in OSA patients with nasal obstruction and difficulty complying with mask use. Previous cost-effectiveness studies demonstrated that treatment of OSA with CPAP was highly cost-effective and significantly improved quality of life.^{19–21} Nasal obstruction plays a major role in upper airway resistance and contributes to OSA severity as it promotes negative pressure in the pharynx and thereby increases obstructive phenomena.^{22,23} CPAP users frequently complain about nasal resistance with concurrent nasal dryness, rhinitis, and epistaxis, and impaired nasal airflow has been associated with reduced CPAP compliance.^{24,25} Nasal surgery such as septoplasty and turbinate reduction increased the cross-sectional area and nasal volume in patients with obstruction and improved the tolerance of CPAP.²⁴

Although nasal surgery to relieve obstruction is not considered a sole therapy for OSA, this strategy could be more widely implemented for the specific goal of improving CPAP compliance in appropriate patients. We performed a cost-effectiveness analysis for nasal surgery in OSA patients with nasal obstruction undergoing CPAP therapy. Our study used a decision analysis approach to test the clinical conditions under which two types of nasal surgery are predicted to be cost-effective means to improve CPAP compliance in OSA patients with nasal obstruction and incomplete compliance.

MATERIALS AND METHODS

Our study focused on a hypothetical patient cohort with OSA and nasal obstruction, who have been prescribed CPAP therapy. Because nasal obstruction etiologies of septum deviation or turbinate hypertrophy are corrected by surgeries of quite different costs, we ran parallel models for each of the two surgical strategies. The time horizon used for analysis included three different run times—5, 10, and 15 years—to span a range of previously published long-term CPAP compliance data.^{12,26–28}

An overall chance for surgical complication was assumed at 18%, mainly attributed to perioperative and directly postoperative incidents that were caused by increased risk of anesthesia and respiratory complications after surgery due to respiratory depressive medications and postoperative desaturations in OSA patients.^{29–33} Given that both septoplasty and turbinate reduction are generally well-tolerated surgeries with only minor perioperative complication rates such as bleeding or infection, we did not explicitly model risks associated with the surgery itself.

Decision Tree

A decision tree (Fig. 1) was designed using TreeAge Pro (TreeAge Software, Inc., Williamstown, MA). The model compares two strategies for chronic OSA care: standard of care (nonsurgical) and surgical repair of nasal obstruction. In the surgical arm, complication may or may not occur; either way, we assume the eventual outcome of surgery is an increased probability of CPAP compliance (pCPAP). We assume that compliance with CPAP is all or none; that is, we do not model the impact of partial compliance in terms of hours per night, but rather model the population portion in compliance in the long-term horizon. In both arms (surgical and nonsurgical), OSA patients may or may not comply with CPAP.

Compliance with CPAP was assigned the maximum utility (quality of life) value of 1 (uRx). Noncompliance was assigned a reduced utility of 0.7 (unoRx). The probability of CPAP compliance at baseline was considered to vary between a lower compliance rate (pCPAP = 0.3) and a higher compliance probability (pCPAP = 0.7). Assuming that nasal surgery would increase the probability of compliance, we included factor *a* to scale upward the pCPAP (base case, *a* = 1.2).

Costs

We made several cost assumptions regarding chronic CPAP annual cost (cRx), one-time surgical costs (cSx), and annual costs of untreated OSA (cnoRx) within the range of reported health-care costs of CPAP treatment versus medical costs of untreated/undiagnosed OSA (Table I). We did not consider costs leading to the diagnosis of OSA (home vs. lab polysomnogram for example, which have been considered elsewhere).³⁴ We assumed the cost of septoplasty (\$6,000) or turbinate reduction (\$500) based on previous reports (cost of procedure varies between office- and hospital-based settings).³⁵ Cost of perioperative and immediate postoperative complications (cCx) was assumed as a one-time cost of \$1,000, to account for reasons such as delayed extubation, desaturations requiring oxygen, possible reintubation, or additional noninvasive ventilation, and therefore prolonged stay at the post-anesthesia care unit. The cost of untreated OSA and its related health challenges was evaluated across a range between \$500 and \$5,000 per year, based on previous studies.^{36–38} These costs include accident risk, general healthcare utilization, as well as specific events such as cardiac or cerebrovascular events. Cost of treating OSA (CPAP therapy) was assumed to be \$500 per year to cover equipment and biannual clinic visits. Willingness to pay (WTP) was assumed to be \$50,000 per quality-adjusted life year (QALY).

Analyses

We considered two distinct populations (base populations) with OSA and nasal obstruction that had difficulty adhering to their CPAP therapy to construct the tables (Table I). One base population represented a high probability of compliance (0.7, or 70%), whereas the other represented a lower probability of compliance (0.3, or 30%).^{1,3,5} We conducted a two-way sensitivity analysis for septoplasty or turbinate reduction, varying in each case the two most important factors that could theoretically shape the decision: the cnoRx (cost OSA), which refers to the impact of untreated OSA (which might vary depending on medical comorbidity for example), and pCPAP (probability for CPAP compliance), which reflects the baseline difficulty with using CPAP (which might vary depending on numerous factors).³⁹ These analyses were repeated over a time course of 5, 10, or 15 years.

RESULTS

Sensitivity analysis allowed us to explore a range of possible values for key parameters in the model. By comparing the two most important factors, the baseline population level probability of CPAP compliance (CPAP compliance or pCPAP), and cost of untreated OSA (cost OSA or cnoRx), we could assess the most cost-effective treatment option over different time horizons (5, 10, 15 years). Table I shows cost-effectiveness ratios (cost/QALY) for a base population with high and low probability of CPAP compliance. Two-way sensitivity

analysis was performed for a hypothetical cohort of CPAP users with nasal obstruction, who were considered for either more expensive septoplasty (Fig. 2a) or less expensive but equally effective turbinate reduction (Fig. 2b) to improve their CPAP compliance. The results are shown for the three time horizons (5, 10, 15 years), and with an assumed WTP of \$50,000. In the short term (5-year horizon), septoplasty surgery was not cost-effective to improve CPAP adherence in the patient cohort with a high baseline difficulty in using CPAP (low pCPAP). Over a longer time horizon of 10 or 15 years, septoplasty became increasingly more cost-effective.

Our sensitivity analyses revealed, however, that the cheaper turbinate reduction would be cost-effective to increase CPAP compliance across nearly the entire range of variables we considered in the sensitivity analysis, even for small improvements in compliance and a wide range of OSA-related healthcare costs. Even after WTP was severely reduced (data not shown) or assumed to be \$0 (Fig. 3), turbinate reduction (Fig. 3b), in contrast to septoplasty (Fig. 3a), was still cost-effective, when baseline probability of using CPAP was higher. Notably, perioperative and postoperative surgical complications did not unfavorably influence cost-effectiveness of either surgery, even if complication rates up to 60% were assumed (data not shown).

DISCUSSION

Our study evaluated cost-effectiveness of nasal surgery to improve population-level CPAP compliance in OSA patients with nasal obstruction. Both types of nasal surgery—septoplasty and turbinate reduction—were cost-effective, but under somewhat different conditions. This indicates that for almost everyone with nasal obstruction (with or without septum deviation) and OSA, nasal surgery would be a cost-effective choice to improve CPAP compliance, whether or not there are OSA-related comorbidities, or only mild to moderate sleep apnea, as represented by a broad range of costs of untreated OSA in the modeling. For either procedure, perioperative and postoperative risk for complication did not influence overall cost-effectiveness (data not shown).

Nasal obstruction has long been implicated as a predisposing or worsening factor of upper airway collapse and OSA.⁴⁰ A number of studies have tested the effects of nasal surgery alone on OSA improvement, based on the theory that nasal obstruction could worsen upper airway resistance. Nasal surgery generally involves septoplasty and turbinate reduction, and in select cases rhinoplasty or nasal valve surgery, all with the goal to increase the volume of air passing through the nose.⁴¹ Most studies mentioned improvement of subjective symptoms, such as sleepiness and quality of life, as well as nasal obstruction and snoring severity.^{37,42–44} The objective benefit of nasal surgery alone, however, remains controversial, as the AHI or respiratory disturbance index, which have routinely been used as a measurement for therapy success, more often than not remained unchanged in these patients independent of OSA severity.^{37,42–44} Thus, current practice guidance parameters still favor CPAP therapy before any surgical intervention,^{7,45} in part because of uncertainty that surgery may only partially improve OSA. Nasal congestion, rhinorrhea, or dryness of the mucosa associated with mask use are considered the major reason for failure of CPAP compliance in patients with OSA and occur in 15% to 50% of cases.^{46–48} Whereas isolated

nasal surgery is not considered a sole treatment for OSA,²² adjuvant nasal surgery to improve nasal airflow can reduce CPAP pressure on average by 2 mbar, leading to increased CPAP compliance.⁴⁹ Powell et al. demonstrated in a randomized, double-blind, placebo-controlled clinical pilot trial that adjunctive turbinate reduction alone already decreased subjective symptoms and significantly benefitted CPAP compliance.⁵⁰ Additionally, a meta-analysis by Camacho et al. and an overview by Verse suggested increased CPAP compliance in addition to reduced CPAP pressures after nasal surgery for OSA (Table II).^{25,49} Perioperative and postoperative complications in OSA patients undergoing nasal surgery specifically are not well described, but earlier reports indicated that OSA patients receiving upper airway surgery are considered at higher risk for postoperative desaturations related to recovery from general anesthesia or upper airway edema.⁵¹⁻⁵³ This is concordant with findings of overall increased perioperative and postoperative complication rates in OSA patients due to general anesthesia, which was independent of the type of surgery. Risk assessment varied between studies, but a 2- to 3-times higher risk for patients with OSA for immediate postoperative complications seems realistic.^{32,33,54,55}

Previous cost-effectiveness studies demonstrated that treatment of moderate or severe OSA with CPAP was highly cost-effective and significantly improved quality of life.¹⁹⁻²¹ However, successful compliance with CPAP treatment is critical for positive outcomes. CPAP compliance is commonly defined as CPAP usage of a minimum of 4 hours or more per night on at least 70% of nights.⁵⁶ Despite its effectiveness, the proportion of patients meeting this compliance criteria can run as low as 50% already within the first year of treatment, and causes can be manifold.⁴⁶ To this day, variables such as AHI or effectiveness of CPAP titration cannot predict whether a patient will ultimately adhere to his CPAP therapy or not.^{28,57-59} CPAP benefits require that the machine is used sufficiently, often using 4 to 5 hours per night for >70% of nights as a standard.¹⁸ However, a more granular perspective of individual CPAP usage patterns requires that one consider the combination of on-PAP and off-PAP sleep, also known as the apnea burden.^{16,18} In some OSA patients, respiratory events return immediately during off-PAP sleep time, which is clinically important for the majority of CPAP users that only wear their masks for a portion of the night.⁶⁰⁻⁶² These obstructive events are not recorded by CPAP, and therefore the readout of the machine may provide false reassurance of treatment success with CPAP, whereas the overall apnea burden could still be much higher. In such cases, a moderate to high remaining apnea burden could render CPAP treatment less effective than sleep surgeries.^{16,18} It is therefore important that every effort is undertaken to improve patient compliance, given that CPAP is the most widely prescribed therapy for OSA.

CONCLUSION

Our results demonstrate the cost-effectiveness of nasal surgery to improve CPAP compliance in the OSA population with nasal obstruction. Our data strongly indicate the value of considering surgical intervention for nonadherent CPAP users or partially adherent users, as part of a multifaceted approach to improving CPAP compliance.

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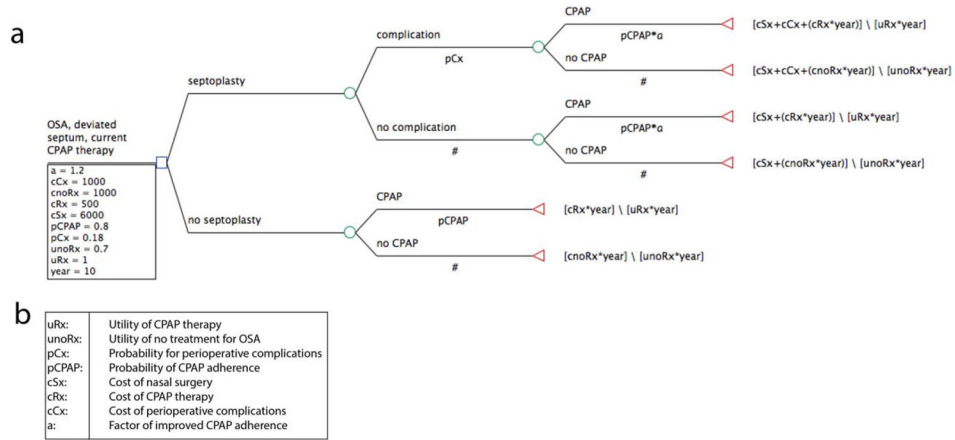


Fig. 1. Decision tree model for cost-effectiveness analysis. (a) Decision tree example for septoplasty is shown. Squares represent decision nodes, circles represent chance nodes, and triangles represent terminal nodes (outcomes). (b) Legend of baseline estimates used for cost-effectiveness analysis of septoplasty. cCx = cost of perioperative/immediate postoperative complications; cnoRx = annual cost of untreated OSA; CPAP = continuous positive airway pressure; cRx = cost of annual CPAP therapy; cSx = one-time surgical costs; OSA = obstructive sleep apnea; pCPAP = probability of continuous positive airway pressure compliance; pCx = probability of peri-/postoperative complications; unoRx = reduced utility of no CPAP therapy; uRx = maximum utility with CPAP (quality of life) value. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

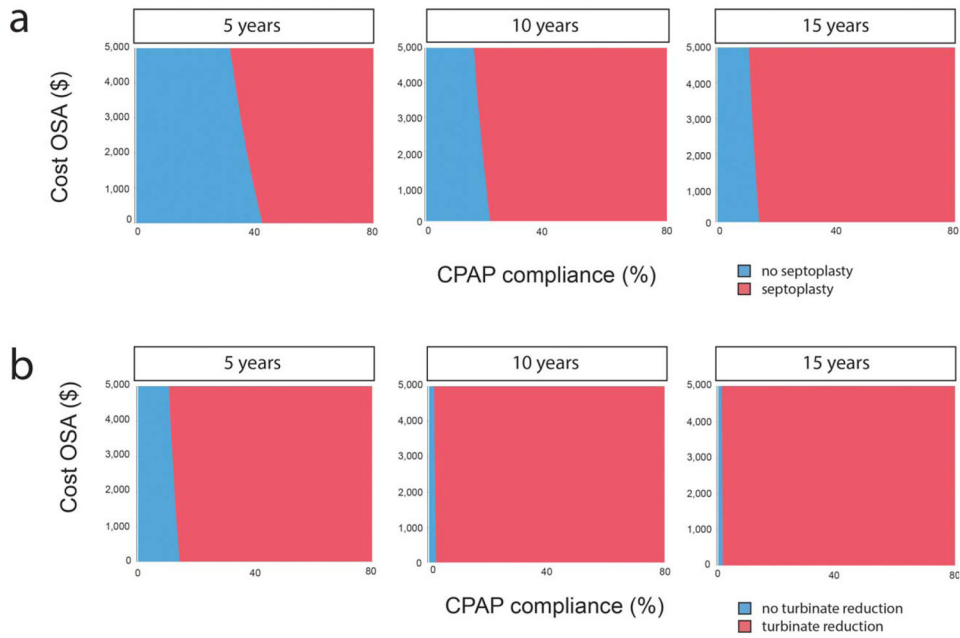


Fig. 2. Two-way sensitivity analysis for nasal surgery. (a) Septoplasty and (b) turbinate reduction (b) at three different time points (5, 10, and 15 years) when assumed willingness to pay is \$50,000. Cost of OSA (cnoRx, \$0–\$5000) is varied on the y-axis, and the probability for CPAP compliance (pCPAP, 0%–80%) is varied on the x-axis. CPAP = continuous positive airway pressure; OSA = obstructive sleep apnea. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

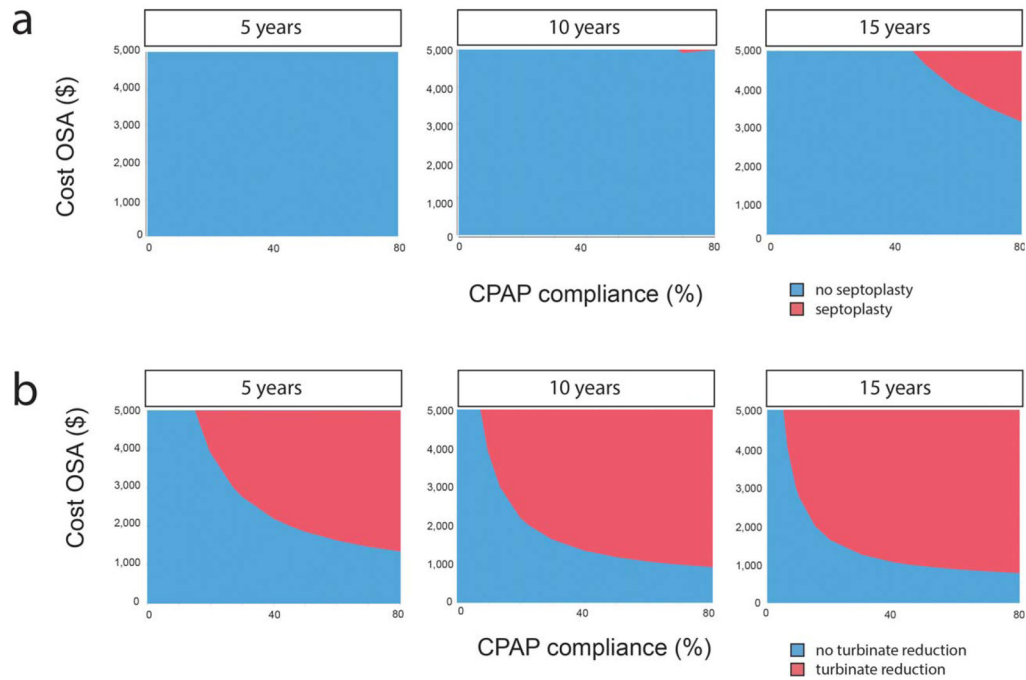


Fig. 3. Two-way sensitivity analysis for nasal surgery with \$0 WTP. Analysis for septoplasty (a) and turbinate reduction (b) at three different time points (5, 10, and 15 years) when assumed WTP is \$0. Cost of OSA (cnoRx, \$0–\$5000) is varied on the y-axis, and the probability for CPAP compliance (pCPAP, 0%–80%) is varied on the x-axis. Shaded areas: blue, no surgery is favored; red, surgery is favored. CPAP = continuous positive airway pressure; OSA = obstructive sleep apnea; WTP = willingness to pay. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

TABLE I

Cost/QALY Saved With Nasal Surgery.

		Septoplasty			Turbinate Reduction		
5 years	Cost OSA (\$)	pCPAP 70%	pCPAP 30%	5 years	Cost OSA (\$)	pCPAP 70%	pCPAP 30%
		Cost (\$)/QALY				Cost (\$)/QALY	
	500	1,823.53	618.81 *		500	668.07	787.13
	1,000	1,907.56	1,051.98 *		1,000	752.10	1,183.17
	2,000	2,075.63	1,918.32 *		2,000	920.17	1,975.25
	5,000	2,579.83	4,517.33 *		5,000	1,424.37	4,351.49
10 years	Cost OSA (\$)	pCPAP 70%	pCPAP 30%	10 years	Cost OSA (\$)	pCPAP 70%	pCPAP 30%
	500	1,174.37	1,383.66		500	596.64	702.97
	1,000	1,258.40	1,779.70		1,000	680.67	1,099.01
	2,000	1,426.47	2,571.78		2,000	848.74	1,891.09
	5,000	1,930.67	4,948.02		5,000	1,352.94	4,267.33
15 years	Cost OSA (\$)	pCPAP 70%	pCPAP 30%	15 years	Cost OSA (\$)	pCPAP 70%	pCPAP 30%
	500	957.98	1,128.71		500	572.83	674.92
	1,000	1,014.01	1,524.75		1,000	656.86	1,070.96
	2,000	1,210.08	2,316.83		2,000	824.93	1,863.04
	5,000	1,714.29	4,693.07		5,000	1,329.13	4,239.27

Calculations were made for two base populations with different pCPAP, 30% or 70%, and for time frames 5, 10, and 15 years.

* Only septoplasty within the 5-year time frame is not cost-effective; at all other times, nasal surgery is favored (WTP = \$50,000).

OSA = obstructive sleep apnea; pCPAP = probability of continuous positive airway pressure compliance; QALY = quality-adjusted life year; WTP = willingness to pay.

TABLE II

Improved CPAP Adherence After Nasal Surgery.

Therapeutic CPAP Pressure Before and After Nasal Surgery			
Author and Year	No.	Mean Preoperative CPAP Pressure (cwp)	Mean Postoperative CPAP Pressure (cwp)
Poirier et al. 2013	18	11.9	9.2
Sufioglu et al. 2012	28	11.2	10.4
Zonato et al. 2006	13	12.4	10.2
Nakata et al. 2005	5	16.8	12
Masdon et al. 2004	35	9.7	8.9
Nowak et al. 2003	10	10	7.1
Dorn et al. 2001	5	11.8	8.6
Friedmann et al. 2000	22	9.3	6.7
Mayer-Brix et al. 1989	3	9.7	6
Total	139	11.42	7.76

CPAP Adherence Before and After Nasal Surgery			
Author and Year	No.	No. of Patients Using CPAP Preoperatively	No. of Patients Using CPAP Postoperatively
Park et al. 2014	7	0	7
Poirier et al. 2013	16	0	16
Pniak et al. 2012	8	0	3
Bican et al. 2010	20	12	20
Nataka et al. 2005	12	0	12
Holland et al. 1997	6	0	2
Total	62	12	53

Data are published data on improved CPAP adherence after nasal surgery (modified from Camacho et al.²⁵ and Verse.⁴⁹). Previous data indicate a reduction of mean therapeutic CPAP pressure and increased number of patients using their CPAP after surgery.

CPAP = continuous positive airway pressure.