The Laryngoscope

Upper Airway Surgery for Obstructive Sleep Apnea Reduces Blood Pressure

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Objectives/Hypothesis: To evaluate if upper airway surgery reduces blood pressure in patients with obstructive sleep apnea (OSA).

Study Design: Prospective series.

Methods: A prospective series of 112 consecutive OSA patients with hypertension (HTN). All patients were > 18 years old, respiratory disturbance index >5, all levels of apnea-hypopnea index (AHI), with a history of HTN treated with medication for at least 6 months. Surgical procedures included septoplasty, turbinate reduction, palate surgery, and tongue base reduction.

Results: There were 92 men and 20 women, with a mean age of 48.6 years, mean body mass index (BMI) was 27.5 (range, 19.7–34.7). Mean follow-up was 16.1 months. The mean preoperative AHI was 32.6 (range, 1.2–104), with the mean lowest oxygen saturation (LSAT) of 79.9% (range, 52%–93%). The mean adjusted preoperative and postoperative systolic blood pressure (SBP) was reduced from 146 ± 15.3 mm Hg to 122 ± 12.5 mm Hg ($P < .001$), and diastolic blood pressure (DBP) was reduced from 91 ± 10.2 mm Hg to 76 ± 7.8 mm Hg ($P < .001$). There was a decrease in overall BMI from 27.5 ± 3.6 to 25.5 ± 3.0 ($P < .001$); however, based on multivariate analysis, the reduction in SBP and DBP was not affected by this BMI reduction. Fifty-eight patients (51.8%) did not require their antihypertensive after surgery. There was poor correlation noted between HTN with AHI, LSAT, and oxygen duration <90%.

Conclusions: Upper airway surgery does reduce SBP and DBP in patients with OSA.

Key Words: Blood pressure, upper airway surgery, obstructive sleep apnea.

Level of Evidence: 4.

***Laryngoscope*, 00:000–000, 2017**

INTRODUCTION

Obstructive sleep apnea (OSA) is a common sleep disorder. Young et al. studied 602 state employees with attended overnight polysomnography and found that the incidence of sleep-disordered breathing (SDB) was 24% in men and 9% in women.[1] It is estimated that up to 93% of females and 82% of males with moderate to severe OSA remain undiagnosed.[2] Obstructive sleep apnea is due to the collapsibility of the upper airway during sleep. These collapsible soft tissues, when subjected to negative pressure within the upper airway, may lead to complete or partial obstruction of the upper airway leading to cessation of breathing, increased sympathetic activity, increased blood pressure (BP), and hypoxemia. Multilevel upper airway surgery (similar to continuous positive airway pressure [CPAP] therapy) has been shown to be more efficacious in this recent decade, not only in terms of improving quality of life but also reducing the apnea-hypopnea index [AHI].[3–6]

The Sleep Heart Health Study and the Wisconsin Sleep Cohort have demonstrated a strong link between OSA and hypertension.[7,8] This is believed to be due to sleep fragmentation, nocturnal hypoxemia, and increased sympathetic tone.[9] This increased sympathetic tone is manifested not only during the nocturnal hypoxic events but also during the day as systemic hypertension. The physiologic changes that are the result of recurrent apneas and hypoxemia can cause acute thrombotic events, atherosclerosis, and cerebrovascular accidents. There is convincing evidence of the association between OSA and cardiovascular (CV) disease.[8] There is a higher mortality rate among patients with CV disease who also have OSA.[7–9]

When patients present for treatment of OSA, the main goal of therapy should not be to reduce AHI, but rather to improve target outcome measures that are either subjective (such as patient wakefulness or quality of life), and improve end-organ damage (most commonly considered to be hypertension [HTN]). To date, very few studies in the surgical literature have focused on BP as

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Editor's Note: This Manuscript was accepted for publication June 1, 2017.

K.P.P. conceived the study, collected the patients, performed the surgeries, and wrote the article. K.A.P., E.B.P., C.V., and B.W.R. wrote the results, conclusion, and methods. C.Y.H. performed the statistical analysis and wrote the statistical section.

The authors have no funding, financial relationships, or conflicts of interest to disclose.

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DOI: 10.1002/lary.26759

TABLE I.
Showing the Respective Decrease in Systolic and Diastolic Blood Pressure, Preoperatively and Postoperatively, Based on AHI Severity

AHI	No. of Patients	SBP, mm Hg		DBP, mm Hg		*P* Value
		Preoperatively	Postoperatively	Preoperatively	Postoperatively	
5–15	26	141	121	85.6	75.3	<.001
15–30	28	143	123	89.8	75.9	<.001
>30	54	150	122	91.8	76.2	<.001

AHI = apnea-hypopnea index; DBP = diastolic blood pressure; SBP = systolic blood pressure.

the main outcome measure, but this is a delinquency necessitating correction. We present our study on 112 patients with SDB who have reduced their systolic blood pressure (SBP) and diastolic blood pressure (DBP) after upper airway surgery.

MATERIALS AND METHODS

This was a nonrandomized prospective clinical study of 112 consecutively collected patients with OSA and HTN. Patients were evaluated in the snoring/sleep subspecialty clinic. The inclusion criteria were age >18 years, all body mass index numbers (BMIs), all tonsil size grades, all Friedman clinical stages, retropalatal and/or retroglossal obstruction, no previous oronasal surgical procedures, and all AHIs. All included patients were diagnosed with hypertension >6 months prior to surgery date and were on some form of antihypertensive medications. The study protocol and methodology was reviewed and approved by the hospital ethics committee/institutional review board. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

All patients underwent a comprehensive clinical assessment including a thorough physical examination, blood pressure readings, nasoendoscopy, and an overnight polysomnography. Patients completed the Epworth Sleepiness Scale (ESS) and a visual analogue scale (VAS) for snoring before and after surgery. The sleep partner completed a similar scale for snoring. The patient also completed a VAS for pain on postoperative days 1, 3, 7, and 14. Examination included height, weight, neck circumference, BMI, and blood pressure, and an endoscopic assessment of the nasal cavity, posterior nasal space, oropharyngeal area, soft palatal redundancy, uvula size and thickness, tonsillar size, and Friedman grade. Patients who complained of nasal obstruction and/or persistent runny nose with clinical endoscopic findings of either turbinate hypertrophy, septal deviation, and/or nasal polyps were offered nasal surgery at the same sitting as the palate/tongue surgery. The nasal surgery included endoscopic sinus surgery, septoplasty, and/or bilateral radiofrequency turbinate reduction. Patients with retropalatal collapse underwent palatal surgery (either expansion sphincter pharyngoplasty, anterior palatoplasty, uvulopalatopharyngoplasty with or without tonsillectomy/tonsillotomy) based on upper airway evaluation. Tongue surgery included tongue base radiofrequency volumetric reduction. All patients were given dietary advice regarding daily calorie counts and intake. There were no dropouts or withdrawals in this study.

The primary outcome measure of this study was change in SBP or DBP, as well as notation regarding the need for ongoing BP medications after surgery. Secondary outcomes were changes in BMI, subjective improvement in snoring based on the VAS, and improvement in sleepiness as indicated by the ESS.

Statistical Analysis

All analyses were performed using SPSS 24.0 (IBM, Armonk, NY) with statistical significance set at $P < .05$. Descriptive for numerical variables were presented as mean (range) and number (%) for categorical variables. Pre-post comparisons for SBP, DBP, ESS scores, and snore scores were assessed using paired *t* test and adjusted for BMI and demographical variables using mixed model. Overall subjects and subgroup analyses by AHI levels (<5, 5 to <15, 15 to <30, ≥ 30) were performed. Pearson correlation was presented for SBP and DBP with AHI, and lowest oxygen saturation and oxygen duration below 90%.

RESULTS

There were a total of 92 men and 20 women; 93 were Chinese, eight were Caucasian, six were Indian, and five were Malay. Their mean age was 48.6 years old (range, 28–67 years), mean BMI was 27.5 (range, 19.7–34.7), with a mean follow-up of 16.1 months. The mean preoperative respiratory disturbance index was 40 (range, 11–104), AHI was 32.6 (range, 1.2–104), with the mean lowest oxygen saturation (LSAT) of 79.9% (range, 52% to 93%). The mean preoperative and postoperative SBP (adjusted and controlled for BMI, age, race, and gender) was reduced from 146 ± 15.3 mm Hg to 122 ± 12.5 mm Hg ($P < .001$); the percentage change was a 16.4% decrease in systolic pressure. The mean preoperative and postoperative DBP (adjusted for BMI, age, race, and gender) was reduced from 91 ± 10.2 m mHg to 76 ± 7.8 mm Hg ($P < .001$); the percentage change was a 16.5% decrease in diastolic pressure. ESS score improved from 11.54 ± 4.1 to 4.88 ± 1.4 ($P < .001$), and the VAS snore score improved from 7.7 ± 0.8 to 2.3 ± 0.9 ($P < .001$). There was a decrease in overall BMI from 27.5 ± 3.6 to 25.5 ± 3.0 ($P < .001$); however, based on multivariate analysis, the reduction in BP was not affected by this BMI reduction.

We divided the cohort based on severity of OSA. There were 4 patients who had a normal AHI, but wanted the nose and palate surgery as they had extremely loud snoring that bothered their bed partners. Their SBP and DBP (adjusted for BMI, age, race, and gender) also decreased postoperatively from 148 ± 11.5 mm Hg to 127 ± 11.4 mm Hg and 86.9 ± 2.1 mm Hg to 65.9 ± 1.2 mm Hg, respectively (not statistically significant due to the small sample size in this group). There were 26 patients in the mild OSA group (AHI 5–15), and

TABLE II.
Showing the Respective Change in Systolic and Diastolic Blood Pressure, Preoperatively and Postoperatively, Based on AHI Severity

AHI	No. of Patients	Decrease in SBP, mm Hg	%	Decrease in DBP, mm Hg	%	*P* Value
5–15	26	20.0	14.1%	10.3	11.7%	<.001
15–30	28	20.0	13.9%	13.9	15.5%	<.001
>30	54	27.0	18.0%	15.6	17.1%	<.001

AHI = apnea hypopnea index; DBP = diastolic blood pressure; SBP = systolic blood pressure.

their SBP and DBP (adjusted for BMI, age, race, and gender) also decreased postoperatively from 141 ± 25.6 mm Hg to 121 ± 23.6 mm Hg (a 14.1% decrease in systolic pressure) and 85.6 ± 10.1 mm Hg to 75.3 ± 8.8 mm Hg (an 11.7% decrease in diastolic pressure), respectively ($P < .001$) (Table I). There were 28 patients who had moderate OSA (AHI 15–30), and their SBP and DBP (adjusted for BMI, age, race, and gender) decreased postoperatively from 143 ± 19.1 mm Hg to 123 ± 12.7 mm Hg (a 13.9% decrease in systolic pressure) and 89.8 ± 12.6 mm Hg to 75.9 ± 6.6 mm Hg (a 15.5% decrease in diastolic pressure), respectively ($P < .001$) (Table I). Severe OSA (AHI > 30) was the largest group, with a total of 54 patients, and postoperatively their SBP and DBP (adjusted for BMI, age, race, and gender) encouragingly decreased postoperatively from 150 ± 12.9 mm Hg to 122 ± 12.3 mm Hg (an 18% decrease in systolic pressure) and 91.8 ± 9.2 mm Hg to 76.2 ± 7.8 mm Hg (a 17.1% decrease in diastolic pressure), respectively ($P < .001$) (Tables I and II). There was a documented decrease in BMI in each group; however, this decrease in BMI did not statistically affect the outcome.

Correlation of SBP and DBP with AHI was poor at $r = 0.11$ and $r = 0.18$, respectively. Similarly, the correlation of SBP and DBP with LSAT was $r = 0.05$ and $r = 0.09$; however, there was mild correlation between DBP and oxygen duration below 90% with $r = 0.2$, whereas $r = 0.06$ was the correlation between SBP and oxygen duration below 90%.

The overall ESS score improved from 11.54 ± 4.1 to 4.88 ± 1.4 ($P < .001$), and the VAS snore score improved from 7.7 ± 0.8 to 2.3 ± 0.9 ($P < .001$). Of note, 58 out of 112 patients (51.8%) did not require their antihypertensive medications anymore and were normotensive. An additional 31 patients (27.7%) were on half their initial preoperative dosage and/or reduced their preoperative antihypertensive dosage. All patients were generally pleased with their postoperative outcome.

DISCUSSION

In a typical normal person, at night, the BP would have an average of 10% to 20% dip/drop in their SBP compared to their BP during the day. It is believed that in patients with mild or developing OSA, during the night, the BP might not drop at all; these patients are called "nondippers." In patients with moderate or severe OSA, BP surges can be observed in both systemic and pulmonary circulation[10]; this can be attributed to the sympathetic activity. Similarly, cyclical variations of the heart rate may also be evident (i.e., sinus tachycardia/bradycardia) in these OSA patients.[11] Furthermore, it has been documented that arrhythmias may occur in patients with severe OSA during the night during a profound hypoxemic event.[12] These include sinus arrests, atrioventricular conduction blocks, atrial fibrillation, and ventricular arrhythmias. It is also believed that through these arrhythmias, OSA may even cause sudden cardiac death; however, the evidence for this is still somewhat circumstantial.[13]

The detrimental effects of OSA on the CV system are carried over into daytime hours. It is known that up to one-half of these patients suffer from arterial hypertension. The OSA-associated arterial hypertension is characterized not only by nocturnal hypertension, but a high percentage of these OSA patients have refractory and masked hypertension, requiring dual or multipharmacotherapy.[14–16] Mainly through its pressor effects, OSA increases the risks for stroke, heart failure, and myocardial infarction.[17] CV risk in OSA depends on the severity of their OSA; that is, those patients with an AHI exceeding 30 per hour (severe OSA) of sleep are affected to a larger extent.[17] It is well accepted that patients with OSA have a higher incidence of hypertension, and some studies have showed as high as a 1.5 to 2.7 times higher incidence of hypertension associated with OSA.[18–20] Moreover, the incidence of OSA is very common in hypertensive patients, and the prevalence has been reported to be as high as 56%.[21,22]

In the medical literature, treatment of OSA patients with CPAP have consistently and reliably showed a decrease in BP. The mechanisms involved in this beneficial effect of CPAP on the vascular system likely include a reduction of BP and improvement of vascular function.[23–26] A randomized controlled trial (RCT) conducted by Weaver et al.[27] evaluated the efficacy of CPAP treatment on functional status assessed by the Functional Outcomes of Sleep Questionnaire in sleepy patients with mild and moderate OSA. They assessed a total of 239 patients with a mean AHI of about 13/hour; they were randomized to CPAP treatment or placebo. After 8 weeks, CPAP treatment significantly improved the functional outcome of patients with mild OSA, and there was also a significant change in daytime DBP values from baseline by −1.93 mm Hg (95% confidence interval [CI]: −3.8 to 0.0; $P = .048$) between the two groups.[27] In the Multicentre Obstructive Sleep Apnoea Interventional Cardiovascular (MOSAIC) trial of 391 patients with OSA, they were randomized to 6 months of autoadjusting CPAP therapy or standard care. The authors demonstrated that CPAP treatment significantly

improved subjective daytime sleepiness (adjusted treatment effect on ESS −2.0; 95% CI: −2.6 to −1.4; $P < .0001$). However, this positive treatment effect on symptoms was not accompanied by a reduction in BP.[28] The findings of the MOSAIC study were confirmed by a meta-analysis published by Bratton et al.,[29] in which the individual data of 1,206 patients from four RCTs were evaluated. Although CPAP treatment reduced OSA severity and sleepiness in minimally symptomatic patients, CPAP did not to have a beneficial effect on BP, except in those patients who used CPAP for >4 hours/night, suggesting that a minimum of 4 hours use per night is needed.[29]

There are a number of published RCTs on the effect of CPAP on BP in patients with resistant hypertension.[30,31] Lozano et al.[30] had 64 patients randomized to receive CPAP versus conventional medical treatment alone. After a 3 month period, patients who used CPAP >5.8 hours showed a greater reduction than patients treated with standard medication in daytime DBP (−6.12 mm Hg; 95% CI: −1.45 to −10.82; $P = .004$), 24-hour DBP (6.98 mm Hg; 95% CI: −1.86 to −12.1; $P = .009$), and 24-hour SBP (−9.71 mm Hg; 95% CI: −0.20 to −19.22; $P = .046$). Moreover, the number of patients with the nocturnal dipping pattern significantly increased in the CPAP group compared to conventional medical treatment (51.7% vs. 24.1%, $P = .008$).[31]

In 2014, Schein et al.[32] reviewed 16 RCTs that included 1,166 OSA patients in total, and demonstrated that CPAP usage resulted in clinically relevant reductions of BP. CPAP treatment was associated with a reduction of SBP by 3.20 mm Hg (95% CI: 1.72 to 4.67) and DBP by 2.87 mm Hg (95% CI: 0.55 to 5.18).[32] A meta-analysis by Montesi et al.[33] included 32 RCTs that showed similar results, with OSA patients treated with CPAP benefitting from significant reductions in SBP by 2.58 mm Hg (95% CI: 3.57 to 1.59) and DBP by 2.01 mm Hg (95% CI: 2.84 to 1.18). Nighttime SBP had the most prominent reduction after treatment with CPAP (4.09 mm Hg; 95% CI: 6.24 to 1.94).[33] In another recently published meta-analysis of 29 RCTs that included 1,820 patients, Fava et al. also showed a decreased SBP (2.6 ± 0.6 mm Hg) and DBP (2.0 ± 0.4 mmHg) in patients with CPAP treatment.[34]

It is well accepted, as illustrated above,[28–34] that CPAP usage does reduce BP; the caveat is that compliance is the issue and the patient has to use it throughout the night. Although there are not many published data on the effect of upper airway surgery in OSA patients on BP, most published data do show some marginal decrease in BP following surgery.[35–38] De Paula Seares et al. showed in a small 18-patient group with OSA, that following upper airway surgery, the mean systolic pressure reduced by 7.4 mm Hg, whereas the mean diastolic pressure reduced by 4.2 mm Hg at a 6-month follow-up.[36] Lee et al. demonstrated a decrease of between 6 and 10 mm Hg in 50 children with OSA, after adenotonsillectomy.[37] Similarly, in 78 children with OSA, Kuo et al. showed a decrease in systolic pressure of between 5.4 to 10.9 mm Hg and diastolic pressure between 12.0 and 18.8 mm Hg.[38]

TABLE III.
Showing Cohen's Effect of Body Mass Index Change on Preoperative and Postoperative Respective Parameters

	Cohen's *d*
SBP	0.05
DBP	0.14
Epworth	0.08
Snore	0.21

Cohen's interpretation: greater than 0.8, large effect; between 0.5–0.8, moderate effect;
less than 0.5, small effect.
SBP = systolic blood pressure; DBP = diastolic blood pressure

In our series, we demonstrated that with strict dietary control, weight loss, and upper airway surgery in tandem, we managed to achieve a clinically significant decrease in SBP (16.4%) and DBP (18%) following surgery. The greatest decrease in BP was noted in the group of patients (n = 54) with severe OSA (AHI > 30); there was an 18% decrease (mean = 27 mm Hg) in SBP and 17.1% decrease (mean = 15.6 mm Hg) in DSP. We attributed this specific group (severe OSA) to have the largest decrease in BP as they started out (preoperatively) with the highest mean BP. Half of the entire group of 112 patients (51.8%) did not require their antihypertensive medications postoperatively, and 31 patients (27.7%) had their initial preoperative dosage reduced.

After statistically adjusting for BMI, age, race, and gender, the decrease in both SBP and DBP was significant in all three groups. We acknowledge that there was an overall decrease in BMI from 27.5 ± 3.6 to 25.5 ± 3.0 ($P < .001$), which could have had an impact on the overall decrease of the postoperative BP (although based on the multivariate analysis, the reduction in BP was not affected by this BMI reduction). It is pertinent to note that the outcome of interest is the change in BP, and assessing the variables (change in BMI, age, race, and gender) that affect the outcome of interest (BP), none of the variables were significant, and hence, the change in BMI had no influence in the change in BP. Based on Cohen's effect of BMI change on the preoperative and postoperative BP readings, ESS, and Snore VAS (Table III), it is evident that the change in BMI had little or no effect in the changes noted for these parameters.

The overall changes in these OSA patients' inner milieu have a significant impact in reducing the patient's oxidative stress from the systemic effects of OSA; the drop in BP and reduction in BMI are important positive changes in the OSA patient's systemic health. As sleep physicians treating patients with OSA, perhaps we should consider other more pertinent systemic parameters that affect the patient's overall oxidative stress, rather than one single parameter called the AHI (which is nebulous to the patient), and consider systemic parameters like BP and BMI.[39,40]

We acknowledge the limitations of this study, in that the patient numbers were not large, most patients were Asian, follow-up was 16 months, and not all patients had a postoperative sleep test done.

CONCLUSION

Overall, this is an important issue in the outcome of treatment for the patient with OSA; not often addressed, but crucial as it affects the patient as a whole, including the oxidative stress that takes place in a patient suffering from repetitive episodes of hypoxia every night. Our data in 112 patients with OSA demonstrate that upper airway surgery can be effective in reducing postoperative SBP and DBP and provide the hope of eliminating the need for oral antihypertensive therapy.

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