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Does Airway Surgery Lower Serum Lipid Levels in Obstructive Sleep Apnea Patients? A Retrospective Case Review

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Background: Obstructive sleep apnea (OSA) is tightly linked to increased cardiovascular disease. Surgery is an important method to treat OSA, but its effect on serum lipid levels in OSA patients is unknown. We aimed to evaluate the effect of upper airway surgery on lipid profiles.





Material/Methods: We performed a retrospective review of 113 adult patients with OSA who underwent surgery (nasal or uvulopalatopharyngoplasty [UPPP]) at a major, urban, academic hospital in Beijing from 2012 to 2013 who had pre-operative and postoperative serum lipid profiles.

Results: Serum TC (4.86 ± 0.74 to 4.69 ± 0.71) and LP(a) (median 18.50 to 10.90) all decreased significantly post-operatively ($P < 0.01$, 0.01 , respectively), with no changes in serum HDL, LDL, or TG ($P > 0.05$, all). For UPPP patients ($n=51$), serum TC, HDL and LP(a) improved ($P=0.01$, 0.01 , <0.01 , respectively). For nasal patients ($n=62$), only the serum LP(a) decreased ($P < 0.01$). In patients with normal serum lipids at baseline, only serum LP(a) decreased ($P < 0.01$). In contrast, in patients with isolated hypertriglyceridemia, the serum HDL, TG and LP(a) showed significant improvements ($P=0.02$, 0.03 , <0.01 , respectively). In patients with isolated hypercholesterolemia, the serum LP(a) decreased significantly ($P=0.01$), with a similar trend for serum TC ($P=0.06$). In patients with mixed hyperlipidemia, the serum TC and LDL also decreased ($P=0.02$, 0.03 , respectively).

Conclusions: Surgery may improve blood lipid levels in patients with OSA, especially in patients with preoperative dyslipidemia, potentially yielding a major benefit in metabolism and cardiovascular sequelae. Prospective studies should examine this potential metabolic effect of airway surgery for OSA.

MeSH Keywords: **Cardiovascular Diseases • Dyslipidemias • Polysomnography • Sleep Apnea, Obstructive**

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Background

Obstructive sleep apnea (OSA) is a prevalent disease in adults (2–4%) that causes significant morbidity and mortality [1–3]. Recent studies have implicated OSA in causing metabolic abnormalities, including dyslipidemia and insulin resistance [4,5], with heightened risk for atherosclerosis, and resultant cardiovascular complications and/or development of diabetes mellitus. A number of animal and human studies have demonstrated that dyslipidemia and other components of metabolic syndrome may be caused by intermittent hypoxia [6–8]. Some studies suggest that treatment of OSA using continuous positive airway pressure (CPAP) improves these metabolic problems [4,5,9] by reducing these respiratory derangements during sleep.

Approximately 10–20% of patients refuse CPAP treatment and 30–40% are unable to tolerate this uncomfortable therapy despite recent improvements in delivery methods. Even those who tolerate CPAP often fail to comply with treatment for adequate hours per night or days per week. Surgery is another important method to treat OSA, especially for patients with relevant anatomic abnormalities who do not tolerate CPAP. There have been many reports that the improved airway resistance after surgery is beneficial, especially if it improves the ability of OSA patients to tolerate postoperative CPAP when it is indicated [10,11].

Although in other fields (morbid obesity, diabetes mellitus, and bariatric surgery) [12,13] surgery has been shown to improve metabolic function, there is no data on whether upper airway surgery for OSA can improve cardiovascular and metabolic systems. This may be important gap in our knowledge, as apnea-hypopnea index (AHI) may not be the only appropriate parameter to assess critical impairment of key target organs [14,15]. For these reasons, we designed this study to evaluate the effects of airway surgery on blood lipids in OSA patients.

Material and Methods

Subjects and setting

We performed a retrospective review of all adult patients (≥ 18 years) who underwent surgery in the Department of Otolaryngology, Beijing Chaoyang Hospital, a major, urban, academic center, between 2012 and 2013. OSAHS was confirmed by PSG (AHI ≥ 5 events per hour), as determined by the International Classification of Sleep Disorders. Subjects presented to our Sleep Unit reporting sleep-related breathing disorders with no prior treatment (CPAP or surgery). We included subjects with available pre-operative AHI from PSG and serum lipid profile. The ethics committee of Chaoyang Hospital

approved the study protocol and informed consent was obtained from all subjects.

At baseline, the patient's medical history was recorded and a standard physical examination was performed. Anthropometric data such as age, sex, BMI, neck circumference, waist circumference, and hip circumference were recorded. Sleepiness was evaluated by the Greek version of the Epworth sleepiness scale (ESS) [16]. We excluded patients with a history of smoking, alcohol use, mental illness, hypothyroidism, concomitant liver diseases, use of lipid-lowering medications, change in body mass index (BMI) of $>5\%$, and those who reported significant changes in dietary habits and physical activity at baseline (or at any time during the study period).

Blood was collected before surgery, between 8:00 and 9:00 am following an overnight polysomnography (PSG) test, in order to examine serum levels of total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C) and lipoprotein(a) (LP(a)).

Polysomnography

All subjects underwent full a full PSG in our government-certified sleep laboratory before surgery and were reexamined 3–8 months after the operation. This PSG included: continuous polygraphic recording of 2 electroencephalographic leads (C3/O1, C3/A2); right and left electro-oculographic leads; and chin electromyography for sleep staging. Ribcage and abdominal motion were monitored by inductive plethysmography (Respirtrace Systems, Respirtrace, Ardsley, NY, USA), airflow by thermistor (Ambulatory Monitoring, Ardsley, NY, USA), and arterial oxyhemoglobin saturation by finger pulse oximetry (Ohmeda Biox 3700, Ohmeda, Boulder, CO, USA). Sleep-stage scoring was done for 30-s intervals by trained technicians according to standard criteria. Apnea was defined as the complete cessation of airflow, and hypopnea as a discernible reduction in airflow or thoracoabdominal excursion lasting for 10 s or more, accompanied by a decrease in oxygen saturation of at least 4%. AHI was defined as the total number of apneas and hypopneas per hour of electroencephalographic sleep. Respiratory events were scored according to the criteria established by the American Academy of Sleep Medicine [17].

Intervention for OSA

All surgeries were performed under general anesthesia. All patients underwent preoperative CT imaging and upper airway endoscopy to find the obstructive area in the upper airway, which guided the indicated procedure. According to the different types of obstruction and operation, the patients were divided into 2 groups: OSA patients with nasal obstruction and relevant anatomic abnormalities were treated with nasal

surgery (septoplasty with turbinate reduction \pm endoscopic sinus surgery, $n=62$). OSA patients with oropharyngeal obstruction were treated with palatal surgery (UPPP with tonsillectomy, $n=51$). All patients met standard surgical criteria. For the nasal surgery, we performed surgical inferior turbinate reduction and standard septoplasty, and, if indicated, nasal polypectomy and functional endoscopic sinus surgery according to the patient's particular condition. For the palatal surgery, we excised of the tonsils and posterior soft palate, and trimmed the uvula, with suture closure of the tonsillar pillars. All nasal surgery and palatal surgery was performed using standard techniques by 3 attending surgeons fully-licensed to practice surgery in China.

To determine if baseline serum lipid profiles would affect the change of the serum lipid after surgery, we divided the patients into those with normal preoperative levels and those with dyslipidemia group. Dyslipidemia was diagnosed according to criteria set forth by the 2007 Guidelines for Prevention and Treatment of Dyslipidemia in Adults in China and divided into 4 phenotypes: 1) patients with isolated hypertriglyceridemia: TG ≥ 1.70 mmol/L and TC < 5.18 mmol/L; 2) patients with isolated hypercholesterolemia: TC ≥ 5.18 mmol/L; and TG < 1.70 mmol/L; 3) patients with mixed hyperlipidemia: TG ≥ 1.7 mmol/L, and TC ≥ 5.18 mmol/L; and 4) patients with normal serum lipids [18]. Then, we compared response to surgery in each group.

Outcomes and follow-up

At 3–8 months postoperatively, patients were asked to return to the hospital for blood draw for repeat lipid testing and PSG test. At that visit, we repeated the baseline evaluation, including: sleepiness scale, PSG, and serum lipids. Because all patients had been encouraged to lose weight and to adopt a healthier lifestyle, focusing on physical exercise and a improved diet, those presenting with changes in the BMI ($>5\%$ from baseline), significant alterations in physical activity, dietary or alcohol habits, along with those with a newly diagnosed disease or use of lipid-lowering medications were excluded from the study. Blood samples were obtained following an overnight PSG between 8:00 and 9:00 am. Some patients consented for this blood draw but refused PSG ($n=72$) (also obtained at the same time of day). Blood serum lipid profiles included TC, TG, HDL-C, LDL-C and LP(a). Lipid analysis was done in our government-certified hospital laboratory using standard methods.

Statistical analysis

Data are summarized as mean \pm SD or median (interquartile range). Shapiro-Wilks normality test was used to analyze whether the quantitative data were normally distributed. Paired-samples t test was employed for the analysis of dependent variables with normally distributed quantitative

Table 1. Baseline characteristics of the study population.

Characteristics (113)	Values
Gender, No.	
Male	87
Female	26
Age, yr	40.40 \pm 11.04
BMI, kg/m ²	28.85 \pm 3.15
Neck circumference, cm	40.313 \pm 2.38
Waist circumference, cm	96.78 \pm 13.26
Hip circumference, cm	102.82 \pm 13.06
Waist/hip ratio	0.94 \pm 0.18
Systolic BP, mm Hg	127.06 \pm 11.40
Diastolic BP, mm Hg	85.76 \pm 9.49
ESS score	13.69 \pm 5.75
AHI, events/h	43.31 \pm 25.68
AI, events/h	35.30 (14.32,50.19)
HI, events/h	7.58 (2.34,9.17)
Spo2,%	91.64 \pm 5.43
Minimum Spo2,%	70.67 \pm 14.17
Spo2 $< 90\%$,% TST	16.5 (4.23, 31.11)
Sleep HR, beats/min	68.04 \pm 11.62

The results are presented as mean \pm SD or median (interquartile range).

data. Wilcoxon test was used for the analysis of dependent variables with ordinal or quantitative data that were nonparametric. Data were analyzed using SPSS 20.0 software (SPSS Inc., Chicago, IL, USA).

Results

Demographics

There were 164 patients who met inclusion criteria and 113 of these (68.9%) agreed to return for postoperative lipid testing; 41 patients agreed to undergo postoperative PSG. Subjects ranged in age from 18 to 64 years old, with 87 males and 26 females. Demographic and clinical parameters are listed in Table 1.

Change of blood lipid parameters pre- and post-surgery

Serum lipids were obtained an average of 0.26 \pm 0.42 months prior to surgery (range 1 to 2) and an average of 5.47 \pm 1.56 months after the operation (range: 3–8 months).

Table 2. Effects of upper airway surgery (113 cases).

Variables	Group 1 (all 113 cases)			Group 2 (UPPP 51 cases)			Group 3 (nasal 62 cases)		
	Baseline	Follow up	p	Baseline	Follow up	p	Baseline	Follow up	p
TC	4.86±0.74	4.69±0.71	<0.01	4.91±0.80	4.67±0.72	0.01	4.83±0.69	4.69±0.69	0.09
HDL	1.17±0.21	1.20±0.21	0.20	1.16±0.20	1.26±0.21	0.01	1.18±0.21	1.15±0.21	0.47
LDL	2.82±0.59	2.85±0.50	0.53	2.85±0.62	2.94±0.55	0.25	0.79±0.57	0.78±0.45	0.79
TG	1.67 (1.27, 2.33)	1.52 (1.13, 2.37)	0.78	1.60 (1.09, 2.17)	1.32 (1.11, 2.10)	0.46	1.81 (1.38, 2.39)	1.72 (1.17, 2.62)	0.20
LP(a)	18.50 (14.85, 24.55)	10.90 (5.4, 22.4)	<0.01	18.80 (14.3, 26.3)	9.70 (3.01, 21.11)	<0.01	18.40 (14.95, 24.43)	14.65 (6.25, 22.73)	<0.01

The results are presented as mean±SD or median (interquartile range). In the whole group after operation, the serum TC and LP(a) decreased. In UPPP group, TC, HDL and LP(a) decreased. But, after nasal surgery, we saw significant decrease only in LP(a).

Table 3. Effects of upper airway surgery, subgroup analysis (113 cases).

Variables	Group 1 (n=42)		Group 2 (n=39)		Group 3 (n=15)		Group 4 (n=17)	
	Baseline	p Value	Baseline	p Value	Baseline	p Value	Baseline	p Value
TC-post	4.24±0.61		4.34±0.55		5.63±0.64		5.732±0.99	
HDL-pre	1.18±0.24	0.102	1.00±0.15	0.02	1.48±0.21	0.07	1.254±0.26	0.62
HDL-post	1.23±0.27		1.10±0.23		1.33±0.29		1.221±0.35	
LDL-pre	2.51±0.49	0.175	2.44±0.46	0.07	3.62±0.56	0.19	3.740±0.85	0.03
LDL-post	2.61±0.50		2.61±0.46		3.44±0.41		3.44±0.88	
TG-pre	1.22 (0.82, 1.43)	0.18	2.17 (1.96, 2.89)	0.03	1.45 (1.12, 1.60)	0.08	2.35 (1.87, 2.68)	0.87
TG-post	1.13 (0.86, 1.48)		2.09 (1.28, 2.82)		1.45 (1.14, 2.01)		2.10 (1.74, 3.69)	
LP(a)-pre	17.4 (13.35, 22.30)	<0.01	18.80 (16.70, 22.40)	<0.01	24.40 (17.20, 33.30)	0.01	20.00 (14.15, 33.94)	0.47
LP(a)-post	9.95 (5.92, 19.23)		9.9 (3.00, 20.10)		19.40 (3.00, 31.90)		22.10 (8.10, 30.75)	

The results are presented as mean ±SD or median (interquartile range). The improvements in TC, HDL, LDL and TG only showed in dyslipidemia group, but LP(a) decreased in nearly all groups. Group 1: patients with normal serum lipid. Group 2: patients with isolated hypertriglyceridemia. Group 3: patients with isolated hypercholesterolemia. Group 4: patients with mixed hyperlipidemia.

We first examined the entire group of subjects (n=113). Serum TC and LP(a) decreased after surgery (P<0.01, 0.01 respectively) (Table 2). There were no significant changes in serum HDL, LDL, or TG (P>0.05, all).

Subgroup analysis

We next divided the subjects according to the type of surgery. For patients who underwent UPPP (n=51), the serum TC,

HDL, and LP(a) decreased (P=0.01, 0.01, <0.01, respectively). However, the serum LDL and TG showed no significant changes after surgery (P>0.05, all). For those who had nasal surgery (n=62), only the serum LP(a) decreased (P<0.01). Serum TC, HDL, LDL, and TG did not change significantly after surgery (P>0.05, all) (Table 2).

We then divided the subjects according to pre-operative serum lipid levels to examine whether these results differed by lipid

Table 4. Effects of upper airway surgery on PSG and lipid parameters (41 cases).

Variables	Group 1 (all cases)			Group 2 (UPPP)			Group 3 (NOSE)		
	Baseline	Follow up	P Value	Baseline	Follow up	P Value	Baseline	Follow up	P Value
BMI	26.96±5.69	26.91±5.73	0.61	30.24±6.64	29.73±5.42	0.78	24.27±2.74	24.01±2.85	0.59
ESS score	14.78±5.38	4.08±2.22	<0.01	14.67±4.90	2.94±1.43	<0.01	13.45±5.60	4.77±2.27	<0.01
AHI	41.00±23.31	21.99±16.27	<0.01	42.44±22.51	18.75±9.43	<0.01	39.82±24.4	24.64±20.08	<0.01
AI	27.28 (11.70, 50.55)	11.25 (1.95, 30.06)	<0.01	27.01 (11.90, 50.15)	11.25 (2.40, 28.38)	<0.01	27.28 (4.07, 53.80)	10.75 (1.45, 35.80)	<0.01
HI	4.94 (2.50, 11.15)	8.45 (3.90, 18.96)	0.27	4.03 (2.50, 12.25)	14 (4.73, 34.10)	0.05	6.94 (1.84, 10.50)	6.65 (3.74, 13.00)	0.71
Spo2%	92.43±4.15	94.08±3.27	0.30	91.48±5.56	94.06±4.48	0.14	93.2±2.37	94.09±1.90	0.01
Spo2% _{min}	71.23±15.02	81.23±10.76	<0.01	68.94±16.28	83.44±9.78	<0.01	73.09±14.01	79.41±11.4	0.03
TC	5.13±1.27	4.79±1.00	<0.01	5.45±1.58	4.99±1.07	0.01	4.87±0.90	4.63±0.94	0.06
HDL	1.23±0.29	1.21±0.32	0.71	1.22±0.29	1.25±0.26	0.60	1.23±0.29	1.17±0.37	0.38
LDL	3.02±0.99	2.89±0.74	0.14	3.27±1.18	3.14±0.81	0.34	2.81±0.78	2.68±0.61	0.27
TG	1.96 (1.50, 2.41)	1.80 (1.28, 2.52)	0.23	1.86 (1.39, 2.86)	1.59 (1.21, 2.40)	0.10	1.60 (1.20, 2.40)	1.84 (1.43, 2.87)	0.60
LP(a)	17.30 (13.86, 21.98)	8.10 (2.93, 19.93)	<0.01	18.05 (11.73, 19.93)	6.65 (2.81, 20.33)	<0.01	16.65 (12.80, 20.33)	8.10 (3.00, 20.25)	<0.01

The results are presented as mean ±SD or median (interquartile range).

status. In group 1 (patients with normal serum lipids), only the serum LP(a) decreased ($P<0.01$). In group 2 (patients with isolated hypertriglyceridemia), the serum HDL, TG, and LP(a) all decreased significantly ($P=0.02, 0.03, <0.01$, respectively). In group 3 (patients with isolated hypercholesterolemia), the serum LP(a) showed significant improvement ($P=0.01$), with a similar trend with TC and HDL $P=0.06, 0.07$, respectively). In group 4 (patients with mixed hyperlipidemia), the serum TC and LDL significant decreased $P=0.02, 0.03$ respectively). The changes of serum lipid parameters pre- and post-surgery are listed in Table 3.

Effects of upper airway surgery on PSG and lipid parameters.

In 41 patients who agreed to postoperative PSG, the total rate of success (defined by AHI <5) of the surgery was 13.7%, although the rate of response (defined by AHI <20 or decreased by more than 20%) was 45.9%. Approximately 40.4% failed to respond to surgery. Changes in serum lipids in the subgroup of patients with PSG data after surgery showed similar changes with the overall group, and these 41 patients were similar to the overall group without post-operative PSG at baseline (Table 4).

Discussion

We report here for the first time that airway surgery may be associated with improvement in blood lipid profiles, suggesting

that improvement in airway dynamics in OSA may improve metabolic function. To date, most studies have focused on changes of pre- and post-surgery AHI to determine the effects of the operation. Our results support a role for non-traditional outcome measures in assessing the beneficial effect of surgery in OSA. Thus, our data support the concept that we should search for additional parameters that could reflect the effect of surgery on the cardiovascular system in addition to the standard respiratory measures included in the PSG.

In our study, we found a small but significant decrease in TC and LP(a), but no significant improvement in LDL, TG, or HDL. We also found that the UPPP group had a better improvement on lipid profiles than nasal surgery, especially for TC. We suspect that different lipid parameters are more or less sensitive to intermittent hypoxia, though we cannot exclude inadequate power as a reason for these differences. In subgroup analysis divided according to the pre-operative serum lipid status, we found that LP(a) decreased in nearly all groups, while TG decreased only in patients with isolated hypertriglyceridemia, albeit with small differences. When we focus on cholesterol, we find that in patients with isolated hypertriglyceridemia, the serum HDL decreased significantly; in patients with mixed hyperlipidemia, the serum TC and LDL decreased significantly, with a similar trend for TC. These findings suggest that OSA may be an important reason for dyslipidemia. Normal lipid profiles may indicate resilience from the negative metabolic effects of

OSA. One implication from our study is that treatment for OSA may improve patients' lipid profiles, especially those with pre-operative dyslipidemia. Prospective studies, especially in high-risk groups, are needed to confirm these findings obtained via retrospective analysis, with its attendant disadvantages.

Our findings have important clinical implications. Dyslipidemia caused by OSA can increase the morbidity and mortality of cardiovascular and metabolic diseases. Although the precise mechanisms are unknown, animal studies found that intermittent hypoxia causes increases in TC, HDL, TG, and LDL [18]. Drager et al. found that intermittent hypoxia may disrupt lipid metabolism by increasing adipose tissue lipolysis and FFA flux to the liver, up-regulating hepatic triglyceride biosynthesis and lipoprotein secretion, and suppressing lipoprotein clearance [6,13,19]. Paradoxically, some researchers found that sleep deprivation reduced triglycerides and very low-density lipoprotein (VLDL) cholesterol concentrations and increased TC and HDL [20]. These data support a concept of healthy sleep as a critical component of maintaining normal metabolic function. Unfortunately, the animal model of intermittent hypoxia cannot simulate all features of OSA such as negative intrathoracic pressure and arousal.

Nevertheless, in clinical studies, whether treatment for OSA improves lipid profiles is controversial. Some studies have suggested that CPAP can improve lipid profiles and other metabolic parameters [4,5,9,21,22], while others have been inconclusive [23–26]. In our opinion, these different results may be due to the lack of subgroup analysis in these studies and sample size, a problem our study also suffers from. We believe the key population of interest includes patients with abnormal pre-operative lipid profiles, where the most benefit may be had, consistent with our data. Indeed, our results suggest that sensitivity to intermittent hypoxia is different in different populations and treatment effects on lipids partly depend on the pre-operative metabolic state. Such effects may also be why some prior studies showed that blood lipids improved after CPAP treatment, but others did not. In addition, variable inclusion criteria, patients' adherence to CPAP, inadequate statistical power, short timeframes, and selection bias also may skew results, including ours.

Our study has several disadvantages. We had no suitable control group for comparison. We cannot rule out lifestyle changes that we did not measure (e.g., increased exercise due to better breathing during sleep and more daytime energy), although patients denied any changes to routine exercise. We limited

our study to parameters such as TC, TG, HDL, LDL, and Lp(a), but other more sophisticated measures of cardiovascular and metabolic function may be more closely associated with improvement after surgery (e.g., markers of endothelial dysfunction, inflammation, or assessment of sequelae [echocardiography, carotid intimal thickening]). The follow-up period was variable as per a retrospective study, so it was impossible to evaluate the precise timing of the effect on lipid metabolism disorder. There were many patients with missing data, potentially causing selection bias, an important issue. We note that the changes of serum lipid in the 2 groups (with and without post-operative PSG) were nearly the same, suggesting our groups were not particularly biased. Lastly, the magnitude of our effect seems small, but we note that finding any effect in these relatively healthy subjects is remarkable itself (due to no medication use whatsoever and younger age). We speculate that in higher risk patients we might see more dramatic effects. Interestingly, in those with several available preoperative lipid levels, levels increased in our OSA patients prior to surgery, so even a small decline may be clinically significant. Clearly, these results provide impetus for more conclusive, prospective studies to confirm our findings.

Conclusions

In summary, our results suggest that surgery for OSA may improve lipid profiles, with potential benefit for the cardiovascular and metabolic systems. We speculate that this may represent a key benefit of surgery for these patients. New prospective studies using metabolic outcome measures are needed to confirm our findings and demonstrate a novel benefit of airway surgery for OSA patients.

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Conflicts of interest

The authors report no conflicts of interest.

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