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Association of Adenotonsillectomy With Blood Pressure Among Hypertensive and Nonhypertensive Children With Obstructive Sleep Apnea

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Supplemental content

IMPORTANCE Hypertension in childhood may continue into adulthood and lead to adverse cardiovascular outcomes. Evidence suggests that adenotonsillectomy for childhood obstructive sleep apnea (OSA) may be associated with blood pressure (BP) improvement. However, how adenotonsillectomy is associated with BP in hypertensive and nonhypertensive children with OSA remains unclear.

OBJECTIVE To investigate disparities in BP changes after adenotonsillectomy in hypertensive and nonhypertensive children with OSA.

DESIGN, SETTING, AND PARTICIPANTS From January 1, 2010, to April 30, 2016, children (aged <18 years) with symptoms of OSA treated at National Taiwan University Hospital were enrolled in this retrospective case series study.

INTERVENTIONS Children underwent polysomnography for diagnosis of OSA (apnea-hypopnea index >1). All children with OSA underwent adenotonsillectomy.

MAIN OUTCOMES AND MEASURES Preoperative and postoperative overnight polysomnographic data were obtained. Office BP was measured in a sleep center before (nocturnal BP) and after (morning) polysomnography.

RESULTS A total of 240 nonobese children (mean [SD] age, 7.3 [3.0] years; 160 [66.7%] male and 80 [33.3%] female) with OSA were recruited. Postoperatively, the apnea-hypopnea index decreased significantly from 12.1 to 1.7 events per hour (95% CI of difference, −12.3 to −8.4 events per hour). The whole cohort had a significant decrease in nocturnal diastolic BP (66.9 to 64.5 mm Hg; 95% CI of difference, −4.1 to −0.7 mm Hg) and morning diastolic BP (66.9 to 64.4 mm Hg; 95% CI of difference, −4.2 to −0.8 mm Hg). The number (percentage) of patients with diastolic BP in the greater than 95th percentile decreased significantly nocturnally (48 [20.0%] to 33 [13.8%]; 95% CI of difference, −12.1% to −0.4%) and in the morning (52 [21.7%] to 34 [14.2%]; 95% CI of difference, −13.6% to −1.4%). Postoperatively, hypertensive children had a significant decrease in all BP measures, including mean (SD) nocturnal and morning systolic BP (nocturnal: 107.5 [8.6] mm Hg; morning: 106.0 [9.4] mm Hg), systolic BP index (nocturnal: −4.3 [8.6]; morning: −5.7 [8.5]), diastolic BP (nocturnal: 65.1 [11.5] mm Hg; morning: 64.4 [10.1] mm Hg), and diastolic BP index (nocturnal: −10.7 [17.3]; morning: −11.6 [15.7]), whereas the nonhypertensive group had a slight increase in nocturnal systolic BP (103.8 to 105.9 mm Hg; 95% CI of difference, 0.4-3.9 mm Hg). A generalized estimating equation model for subgroup comparisons revealed that children with hypertension, compared with those without, had greater improvement in all BP measures.

CONCLUSIONS AND RELEVANCE Hypertensive children with OSA had a significant improvement in BP after adenotonsillectomy. Hypertensive children with OSA should be screened and treated by adenotonsillectomy because proper treatment not only eases OSA symptoms but also potentially prevents future cardiovascular and end-organ disease.

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Obstructive sleep apnea (OSA) comprises a spectrum of repetitive episodes of partial to complete obstruction of the upper airway during sleep.[1,2] In adults, OSA correlates with hypertension and sequential cardiovascular morbidities.[3,4] High blood pressure (BP) in children with OSA was first described by Guilleminault et al[5] in 1976. Although in 2007 Zintzaras and Kaditis[6] reported in a meta-analysis that the associated evidence between moderate to severe childhood OSA and hypertension is insufficient, several subsequent studies[7-12] have suggested otherwise. Kang et al[13] reported that children with moderate to severe OSA have higher ambulatory BP compared with those who are primary snorers. Li et al[14] reported that OSA is associated with elevated daytime and nocturnal BP.

Upper airway obstruction, especially attributed to adenotonsillar hypertrophy, is widely accepted as the primary risk factor and cause of OSA in children.[15] Therefore, adenotonsillectomy is defined as the first-line treatment for OSA in children.[16-19] Even though adenotonsillectomy markedly alleviates OSA in children, few studies[20,21] have addressed BP changes after adenotonsillectomy for children with OSA. Previous studies[22-27] on the effects of adenotonsillectomy on BP have reported diverse results. Furthermore, discrepancies in postoperative BP changes between children with and without hypertension have not been sufficiently clarified. Lee et al[26] reported that hypertensive children's systolic BP (SBP) and diastolic BP (DPB) improves significantly after surgical intervention. However, their study group was relatively small, and they did not adjust for possible confounders, such as age, sex, or adiposity.

This study aimed to elucidate the association of adenotonsillectomy with BP among hypertensive and nonhypertensive children with OSA. We hypothesized that hypertensive children benefit more from adenotonsillectomy in terms of BP decreases compared with those without hypertension.

Key Points

Question How is adenotonsillectomy associated with blood pressure in hypertensive and nonhypertensive children with obstructive sleep apnea?

Finding In this case series of 240 children with obstructive sleep apnea, hypertensive children had significant improvement in all blood pressure measures, whereas nonhypertensive children had significant improvement in diastolic blood pressure.

Meaning Screening and treating hypertensive children with obstructive sleep apnea with adenotonsillectomy may not only ease obstructive sleep apnea symptoms but also improve blood pressure, which may prevent future cardiovascular and end-organ disease.

Methods

From January 1, 2010, to April 30, 2016, children (aged <18 years) with symptoms of OSA were enrolled.[28] Data collected included sex, age, symptoms and signs of sleep disturbance, and medical history of nasal allergy, otitis media with effusion, and asthma.[29] Thorough history and physical examinations were performed during each patient's first outpatient clinic visit. Children underwent polysomnography (PSG) for diagnosis of OSA (apnea-hypopnea index [AHI] >1).[30] All children had OSA and underwent adenotonsillectomy.[31-33] This retrospective case series study was approved by the Institution Review Board and Ethics Committee of National Taiwan University Hospital (Taipei, Taiwan), who waived the requirement for patient consent. Individual identities of the study participants were kept confidential.

The weight, height, and body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) of each child were obtained. Using established guidelines, we converted their BMI into BMI percentiles.[34] Children with obesity are at a significantly higher risk of elevated BP than children without obesity; thus, obesity may influence postoperative BP changes.[25,35] Consequently, children with obesity (ie, BMI >95th percentile) were excluded. Other exclusion criteria were as follows: (1) the presence of major underlying diseases, such as neuromuscular disorders; cardiac, respiratory, and renal insufficiencies; and craniofacial anomalies; (2) suboptimal PSG study (sleep time <4 hours or sleep efficiency <60%); and (3) history of pharyngeal surgery.

Polysomnography

Full-night PSG (Embla N7000, Medcare Flaga) was performed in the National Taiwan University Hospital Sleep Center following the established protocols.[36] All sleep measures, including sleep stage and respiratory events, were recorded following American Academy of Sleep Medicine (AASM) standards.[37] An apnea episode was defined as a 90% decrease in airflow for 2 consecutive breaths. Before 2014, a hypopnea episode was defined as a 50% decrease in oronasal airflow in association with awakening, arousal, or a 3% reduction in arterial oxygen saturation.[37] Since 2014, when the AASM 2012 criteria were adopted, hypopnea has been defined as a 30% decrease in oronasal airflow in association with awakening arousal or a 3% reduction in arterial oxygen saturation. Childhood OSA was defined as an AHI greater than 1 event per hour. Each participant underwent PSG for diagnosis and underwent PSG again approximately 3 to 6 months after surgery.

Adenotonsillectomy

Adenotonsillectomy was performed with the patient under general anesthesia with 2 to 3 days of hospitalization. Tonsillectomy was performed using the coblator-assisted method (Coblator II, Arthrocart Corp) with tonsillar pillar suturing.[31-33] Adenoidectomy was performed with an endoscope using the microdebrider-assisted method.[31-33]

Office BP Measurement

Office SBP and DBP of the children were measured in a sleep center by sleep center staff using an electronic sphygmomanometer (Terumo digital BP monitor model ES-H55).[38] The BP was measured 3 times after each participant had rested in a sitting position for 15 minutes.[39] The BP was measured in the evening (nocturnal BP) before the PSG study and in the morning

Table 1. Demographic and Polysomnographic Characteristics of 240 Nonobese Children With Obstructive Sleep Apnea Before and After Surgery[a]

Characteristic	Before Surgery	After Surgery	Difference (95% CI)[b]
Weight, kg	25.7 (11.7)	27.5 (12.0)	1.7 (1.5 to 2.0)
Weight percentile	54.9 (28.4)	58.4 (27.5)	3.5 (1.9 to 5.0)
Height, m	1.21 (0.19)	1.24 (0.19)	0.03 (0.02 to 0.03)
Height percentile	55.1 (30.3)	54.8 (30.6)	−0.3 (−2.0 to 1.5)
BMI	16.7 (2.5)	17.5 (5.1)	0.7 (0.2 to 1.3)
BMI percentile	55.5 (27.8)	58.9 (28.1)	3.4 (1.4 to 5.5)
AHI, events per hour	12.1 (17.0)	1.7 (4.1)	−10.4 (−12.3 to −8.4)
Central index, events per hour	0.52 (0.93)	0.36 (0.49)	−0.16 (−0.27 to −0.04)
NREM AHI, events per hour	9.7 (15.7)	1.2 (3.4)	−8.5 (−10.3 to −6.7)
REM AHI, events per hour	21.3 (29.7)	4.1 (8.5)	−17.2 (−20.8 to −13.6)
ODI, events per hour	11.4 (16.3)	2.3 (4.8)	−9.0 (−11.0 to −7.1)
Mean Sao_2, %	96.8 (5.8)	97.7 (0.9)	0.9 (0.2 to 1.7)
Minimum Sao_2, %	85.5 (8.1)	90.5 (5.3)	5.0 (4.0 to 6.0)
Total AI, events per hour	6.1 (4.7)	4.2 (2.2)	−2.0 (−2.6 to −1.3)

Abbreviations: AHI, apnea-hypopnea index; AI, arousal index; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); NA, not applicable; NREM, non–rapid eye movement; ODI, oxygen desaturation index; REM, rapid eye movement; Sao_2, arterial oxygen saturation.

[a] Data are presented as mean (SD).

[b] Paired sample, 2-tailed *t* test for continuous variables.

(morning BP) when the patient awoke. Previous studies[25,40,41] determined that nocturnal BP may demonstrate patients' baseline BP, whereas morning BP may reveal sleep effect on BP. The BP measurements were then compared with established guidelines for age and sex normative data and compared by applying the BP percentile and BP index. The BP index is calculated with the following formula: BP Index = (Measured BP − 95th Percentile)/95th Percentile × 100.

Pediatric hypertension was based on the nocturnal BP measurement. Hypertension was defined as a mean SBP and DBP greater or equal to the 95th percentile for age, sex, and height.[42]

Statistical Analysis

Data were compiled and analyzed using SPSS software, version 22 (IBM Inc). Changes in continuous data before and after surgery were analyzed using the paired sample, 2-tailed *t* test, and data are presented as mean (SD). Changes in categorical data before and after surgery were analyzed using the McNemar test, and the data are presented as number (percentage) of patients. We compared changes in BP before and after surgery for the whole cohort, the hypertensive group, and the nonhypertensive group using the paired sample, 2-tailed *t* test. The presurgery and postsurgery BP values of the nonhypertensive and hypertensive groups were compared with the independent sample, 2-tailed *t* test. The difference in the preoperative to postoperative changes between the hypertensive and nonhypertensive groups was examined using a generalized estimating equation (GEE) adjusted for age, sex, and BMI percentile. The GEE model included the intercept, main effect of the study group (hypertensive vs nonhypertensive), and time (before vs after), a 2-way interaction term of group × time, and the main effects of the 3 aforementioned covariates. The measures were considered to change more in one group than in the other group when the interaction term was statistically significant. $P < .05$ was considered to be statistically significant.

Results

A total of 580 symptomatic patients were initially enrolled. Of these patients, 162 with obesity were excluded, and 178 patients were not included in the study because of unavailability for follow-up, incomplete BP data, or having been excluded by the exclusion criteria. In total, 240 nonobese children (mean [SD] age, 7.3 [3.0] years; 160 [66.7%] male and 80 [33.3%] female) with clinical symptoms and PSG-diagnosed OSA (ie, AHI >1) were included in the final analysis. eTable 1 in the Supplement gives the demographic and PSG characteristics of nonobese children who were included and excluded from the study. In comparison, significant differences were found in the nonincluded group vs included group in age (6.3 vs 7.3 years; 95% CI of difference, 0.4-1.6 years), weight (22.5 vs 25.7 kg; 95% CI of difference, 1.0-5.4 kg), height (1.15 vs 1.21 m; 95% CI of difference, 0.02-0.10 m), and morning PSG SBP (102.3 vs 106.6 mm Hg; 95% CI of difference, 1.5-7.2 mm Hg), SBP index (−9.8 vs −7.2; 95% CI of difference, 0.1-5.0), and DBP (63.9 vs 66.9 mm Hg; 95% CI of difference, 0.04-5.9 mm Hg). **Table 1** summarizes the demographic and PSG characteristics for all patients. Each child underwent overnight PSG before surgery. Before surgery, the groups had a mean (SD) AHI of 12.1 (17.0) events per hour, mean (SD) oxygen saturation of 96.8% (5.8%), minimum (SD) oxygen saturation of 85.5% (8.1%), and mean (SD) total arousal index of 6.1 (4.7) events per hour.

Demographics and PSG Data After Surgery

The mean (SD) interval between surgery and postoperative PSG studies was 103 (114) days (25th, 50th, and 75th percentiles, 56, 94, and 115 days, respectively). Table 1 lists the changes in the demographics and PSG data before and after surgery. After surgery, children had a significant increase in weight (25.7 to 27.5 kg; 95% CI of difference, 1.5-2.0 kg), weight percentile (54.9 to 58.4; 95% CI of difference, 1.9-5.0), height (1.21 to 1.24 m; 95% CI of difference, 0.02-0.03 m), BMI (16.7 to 17.5;

Table 2. Blood Pressure Changes in 240 Nonobese Children With Obstructive Sleep Apnea Before and After Surgery

Measure	Before Surgery[a]	After Surgery[a]	Difference (95% CI)[b]
Before PSG (nocturnal)			
SBP, mm Hg	106.9 (9.8)	106.4 (10.3)	−0.5 (−2.0 to 1.0)
SBP index	−6.9 (8.9)	−7.2 (9.5)	−0.3 (−1.6 to 1.0)
DBP, mm Hg	66.9 (10.2)	64.5 (10.2)	−2.4 (−4.1 to −0.7)
DBP index	−10.7 (14.1)	−14.0 (14.7)	−3.3 (−5.6 to −1.1)
SBP >90th percentile, No. (%)	81 (33.8)	75 (31.4)	−2.5 (−9.7 to 4.7)
SBP >95th percentile, No. (%)	50 (20.8)	49 (20.5)	−0.4 (−7.1 to 6.2)
DBP >90th percentile, No. (%)	92 (38.3)	60 (25.1)	−13.4 (−21.0 to −5.7)
DBP >95th percentile, No. (%)	48 (20.0)	33 (13.8)	−6.3 (−12.1 to −0.4)
After PSG (morning)			
SBP, mm Hg	106.6 (10.7)	106.3 (10.4)	−0.3 (−2.0 to 1.4)
SBP index	−7.2 (9.4)	−7.3 (9.4)	−0.1 (−1.6 to 1.3)
DBP, mm Hg	66.9 (11.1)	64.4 (10.3)	−2.5 (−4.2 to −0.8)
DBP index	−10.7 (15.5)	−14.2 (14.9)	−3.5 (−5.8 to −1.1)
SBP >90th percentile, No. (%)	83 (34.6)	78 (32.6)	−2.1 (−9.7 to 5.5)
SBP >95th percentile, No. (%)	51 (21.3)	49 (20.5)	−0.8 (−7.2 to 5.6)
DBP >90th percentile, No. (%)	87 (36.3)	58 (24.3)	−11.7 (−18.9 to −4.6)
DBP >95th percentile, No. (%)	52 (21.7)	34 (14.2)	−7.5 (−13.6 to −1.4)

Abbreviations: DBP, diastolic blood pressure; PSG, polysomnography; SBP, systolic blood pressure.

[a] Data are presented as mean (SD) unless otherwise indicated.

[b] Paired sample, 2-tailed *t* test for continuous variables or McNemar test for categorical variables.

95% CI of difference, 0.2-1.3), and BMI percentile (55.5 to 58.9; 95% CI of difference, 1.4-5.5).

Postoperatively, children had a significant improvement in PSG measures. The mean AHI decreased from 12.1 to 1.7 events per hour (95% CI of difference, −12.3 to −8.4 events per hour), and the mean central index decreased from 0.52 to 0.36 events per hour (95% CI of difference, −0.27 to −0.04 events per hour). The mean oxygen saturation improved significantly from 96.8% to 97.7% (95% CI of difference, 0.2%-1.7%) and the minimum oxygen saturation from 85.5% to 90.5% (95% CI of difference, 4%-6%). Meanwhile, the total arousal index decreased from 6.1 to 4.2 events per hour (95% CI of difference, −2.6 to −1.3 events per hour).

Office BP Changes After Surgery

Table 2 gives the preoperative and postoperative BP changes in the entire cohort. For nocturnal BP, all SBP measures, including the mean SBP (mean difference, −0.5 mm Hg; 95% CI, −2.0 to 1.0 mm Hg), SBP index (mean difference, −0.3; 95% CI, −1.6 to 1.0), frequency of patients with SBP in the greater than 90th percentile (mean difference, −2.5%; 95% CI, −9.7% to 4.7%), and frequency of patients with SBP in the greater than 95th percentile (mean difference, −0.4%; 95% CI, −7.1% to 6.2%), showed no significant change. By contrast, we observed a significant decrease in nocturnal DBP (mean difference, −2.4 mm Hg; 95% CI of difference, −4.1 to −0.7 mm Hg), DBP index (mean difference, −3.3 mm Hg; 95% CI of difference, −5.6 to −1.1 mm Hg), frequency of patients with DBP in the greater than 90th percentile (mean difference, −13.4%; 95% CI of difference, −21.0% to −5.7%), and frequency of patients with DBP in the greater than 95th percentile (mean difference, −6.3%; 95% CI of difference, −12.1% to −0.04%).

Similarly, morning SBP measures, including mean SBP (mean difference, −0.3 mm Hg; 95% CI, −2.0 to 1.4 mm Hg), SBP index (mean difference, −0.1; 95% CI, −1.6 to 1.3), frequency of patients with SBP in the greater than 90th percentile (mean difference, −2.1%; 95% CI, −9.7% to 5.5%), and frequency of patients with SBP in the greater than 95th percentile (mean difference, −0.8%; 95% CI, −7.2% to 5.6%), showed no significant changes, whereas morning DBP measures showed a significant decrease in mean DBP (mean difference, −2.5 mm Hg; 95% CI of difference, −4.1 to −0.8 mm Hg), DBP index (mean difference, −3.5 mm Hg; 95% CI of difference, −5.8 to −1.1 mm Hg), frequency of patients with DBP in the greater than 90th percentile (mean difference, −11.7%; 95% CI of difference, −18.9% to −4.6%), and frequency of patients with DBP in the greater than 95th percentile (mean difference, −7.5%; 95% CI of difference, −13.6% to −1.4%).

BP Changes Among Children With and Without Hypertension

The children were assigned to nonhypertensive and hypertensive groups for further investigation (**Table 3**). In subgroup analysis, 169 patients (70.4%) were classified as nonhypertensive and 71 (29.6%) as hypertensive on the basis of their preoperative nocturnal BP data. Postoperatively, hypertensive children had a significant decrease in all BP measures, including nocturnal and morning SBP (nocturnal: 107.5 [8.6] mm Hg; morning: 106.0 [9.4] mm Hg), SBP index (nocturnal: −4.3 [8.6]; morning: −5.7 [8.5]), SBP (nocturnal: 65.1 [11.5] mm Hg; morning: 64.4 [10.1] mm Hg), and SBP index (nocturnal: −10.7 [17.3]; morning: −11.6 [15.7]). eTable 2 in the Supplement is a cross-table of hypertensive status before and after surgery. A total of 47 hypertensive patients (66.2%) became nonhypertensive after surgery. However, 36 children (21.3%) who were nonhypertensive before the surgery became hypertensive after surgery. The **Figure** illus-

Table 3. Blood Pressure Changes in Hypertensive and Nonhypertensive Nonobese Children With Obstructive Sleep Apnea

Measure	Before Surgery[a]	After Surgery[a]	Difference (95% CI)[b]	Difference Between Nonhypertensive and Hypertensive Children: P Before Surgery[c]	P After Surgery[c]	P for Interaction[d]
Before PSG (Nocturnal)						
SBP, mm Hg						
Nonhypertensive	103.8 (9.1)	105.9 (10.9)	2.1 (0.4 to 3.9)	<.001	.27	<.001
Hypertensive	114.3 (7.4)	107.5 (8.6)	−6.8 (−9.1 to −4.4)			
SBP index						
Nonhypertensive	−10.5 (7.2)	−8.4 (9.6)	2.1 (0.6 to 3.6)	<.001	.002	<.001
Hypertensive	1.6 (6.5)	−4.3 (8.6)	−5.9 (−8.0 to −3.9)			
DBP, mm Hg						
Nonhypertensive	63.8 (9.1)	64.3 (9.6)	0.4 (−1.4 to 2.3)	<.001	.59	<.001
Hypertensive	74.3 (8.8)	65.1 (11.5)	−9.2 (−12.2 to −6.2)			
DBP index						
Nonhypertensive	−16.1 (11.1)	−15.5 (13.3)	0.6 (−1.9 to 3.1)	<.001	.02	<.001
Hypertensive	2.1 (12.0)	−10.7 (17.3)	−12.7 (−16.7 to −8.8)			
After PSG (Morning)						
SBP, mm Hg						
Nonhypertensive	104.4 (10.5)	106.5 (10.8)	2.0 (−0.05 to 4.1)	<.001	.74	<.001
Hypertensive	111.8 (9.4)	106.0 (9.4)	−5.8 (−8.3 to −3.4)			
SBP index						
Nonhypertensive	−10.0 (8.4)	−8.0 (9.7)	2.0 (0.2 to 3.8)	<.001	.09	<.001
Hypertensive	−0.6 (8.2)	−5.7 (8.5)	−5.2 (−7.2 to −3.1)			
DBP, mm Hg						
Nonhypertensive	64.9 (11.1)	64.4 (10.4)	−0.4 (−2.4 to 1.5)	<.001	.97	<.001
Hypertensive	71.7 (9.5)	64.4 (10.1)	−7.3 (−10.5 to −4.2)			
DBP index						
Nonhypertensive	−14.7 (14.3)	−15.3 (14.4)	−0.6 (−3.2 to 2.1)	<.001	.08	<.001
Hypertensive	−1.3 (14.3)	−11.6 (15.7)	−10.3 (−14.6 to −6.0)			

Abbreviations: DBP, diastolic blood pressure; PSG, polysomnography; SBP, systolic blood pressure.

[a] Data are presented as mean (SD).

[b] Paired sample, 2-tailed *t* test for continuous variables.

[c] Independent sample, 2-tailed *t* test.

[d] Interaction of group × time obtained from the generalized estimating equation adjusted for age, sex, and body mass index percentile.

trates the postoperative changes in SBP and DBP in the hypertensive and nonhypertensive groups.

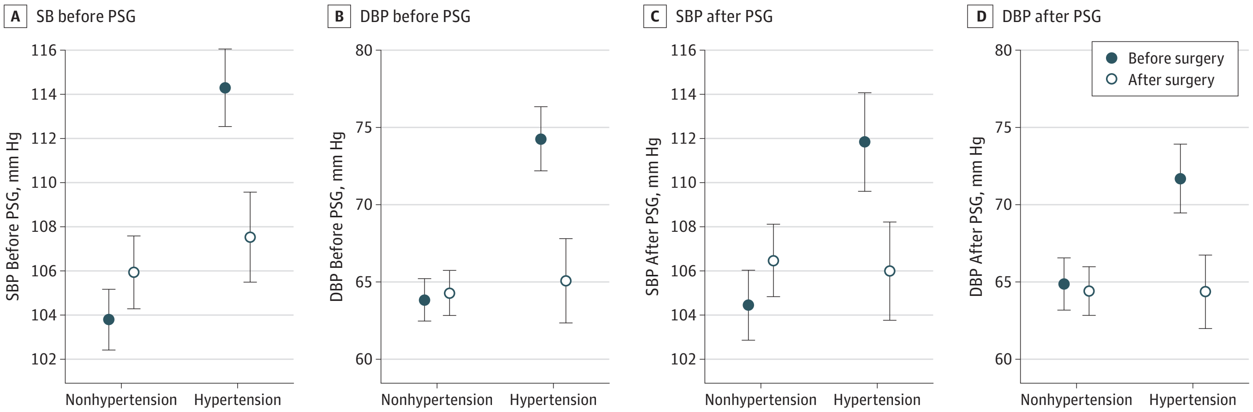
The BP measures of children with and without hypertension were compared (Table 3). The difference in BP changes after surgery between the nonhypertensive and hypertensive groups was tested using the GEE model, which revealed that the hypertensive group achieved superior improvements in all BP measures compared with the nonhypertensive group after surgery.

Discussion

To our knowledge, this study included one of the largest cohorts for evaluating postoperative BP changes in nonobese children with OSA. Because obesity is a significant risk factor of elevated BP, it may influence postoperative BP changes. In the present study, we adjusted for possible confounders, such as age, sex, and adiposity. We aimed to elucidate the disparities in postoperative BP changes among nonobese, nonhypertensive and hypertensive children with OSA. Children with OSA showed a decrease in DBP after surgery. Our subgroup analysis results revealed that hypertensive children with OSA had significant improvements in all BP measures after surgery. These findings highlight the need to screen children with OSA to determine their hypertensive status and appropriately treat these children to ease their OSA symptoms and potentially prevent future adverse cardiovascular outcomes.

Several previous studies[16,22-24,27] have addressed BP changes after adenotonsillectomy in children with OSA. A large-scale, prospective randomized clinical trial that included 464 children with OSA in the Childhood Adenotonsillectomy Trial observed no significant change in cardiometabolic measures in children with OSA after surgery compared with those undergoing watchful waiting.[16,27] Amin et al[23] found that children had significant improvements in DBP 6 months after surgery. Apostolidou et al[22] reported that Greek children with OSA had no significant reduction in BP after surgery. Ng et al[24] reported that the DBP load decreased significantly after surgery. In the present study, children with OSA had a significant decrease in DBP after surgery. The most recent Guideline for the Prevention, Detection, Evaluation, and Management of

Figure. Mean Postoperative Changes in Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP) in Hypertensive and Nonhypertensive Children With Obstructive Sleep Apnea



PSG indicates polysomnography; error bars, 95% CIs.

High Blood Pressure in Adults[43] revealed that SBP and DBP are associated with increased cardiovascular risk. However, to our knowledge, no pediatric studies have discussed the disparity between SBP and DBP effects in children. Nonetheless, Sharabi et al[44] reported that DBP was the first to increase in association with early OSA. During sleep, patients with OSA experience repetitive hypoxemia events, which consequentially activate the sympathetic system via stimulation of the peripheral chemoreceptors and translate into decreases in BP followed by surge elevations in BP to compensate. Obstructive sleep apnea–induced sympathetic activation results in a long-term increase of catecholamine, which eventually affects DBP.[45] A significant decrease in DBP after surgery may suggest reversal of OSA-induced hypertension, and adenotonsillar surgical procedures may reverse adverse cardiovascular outcomes in children with sleep apnea.

In adults, OSA correlates with hypertension and sequential cardiovascular morbidities.[3,4,46,47] Phillips and O'Driscoll[46] reported that intermittent hypoxia and hypercapnia promote nocturnal hypertension, leading to the development of sustained daytime hypertension through sympathetic activation, inflammation, oxidative stress, and endothelial dysfunction. In children, despite Zintzaras and Kaditis[6] suggesting that the correlation between OSA and hypertension is insufficient evidence for establishing a connection between children with moderate to severe OSA and hypertension, other studies[13,48,49] have proven otherwise. In a hospital-based study, Kang et al[13] reported that children with moderate to severe OSA have higher ambulatory BP compared with those who are primary snorers. Hartzell et al[48] reported that hypertensive children are significantly more likely to have OSA as a comorbidity. In a prospective 4-year follow-up study, Li et al[49] found that childhood OSA was associated with elevated BP independent of obesity. Among participants in our study, the number of hypertensive children was significantly higher than that reported for children with a healthy weight,[42,50] implying an association between OSA and hypertension in children.

Recent studies[51-53] have addressed the clinical implications of childhood hypertension for public health. Juonala et al[52] found that elevated BP in youth predicts atherosclerosis in the form of increased carotid artery intima media thickness, which eventually leads to adult cardiovascular disease. The Young Finns study[53] reported that childhood hypertension is associated with increased arterial stiffness in adulthood. Accordingly, hypertension in childhood may continue into adulthood and be associated with adverse cardiovascular outcomes; thus, early screening and appropriate treatment of hypertension in the pediatric population is important.

The association of hypertensive status on postoperative BP changes in children with OSA has not been adequately clarified. Ng et al[24] and Lee et al[26] noted that the preoperative hypertensive group had significantly decreased DBP after surgery. However, their results were drawn from a small sample, and they did not adjust for possible confounders, such as age, sex, and adiposity. By contrast, in the present study, disparities in BP changes were observed between children with and without hypertension, and a GEE model was adopted to adjust for confounders of age, sex, and BMI percentile. Our main findings suggest that the BP of hypertensive children with OSA improves significantly after surgery. Although we observed that 36 children (21.3%) who were not hypertensive before surgery became hypertensive after surgery, the current study and other pediatric OSA studies[54,55] found that adenotonsillectomy may be inadequate to achieve complete resolution of OSA and its comorbidities. However, increase in age is accompanied with somatic growth and blood pressure increase, which may overcome the reduction in BP after surgery. Although we adjusted the BP index for age and sex, the statistical adjustment may still be inadequate. Because high childhood BP has clinical implications for cardiovascular health,[51-53] children with OSA should receive BP monitoring before and after surgical intervention for early detection and appropriate management of hypertension in high-risk individuals.

Limitations

Several limitations in the present study should be addressed. First, this study was a retrospective medical record review study for which we were unable to collect other cardiovascular measurements, such as arterial stiffness and carotid intima thickness, to improve the analysis. Second, BP was measured as office BP in a hospital sleep center instead of as 24-hour ambulatory BP. Therefore, we may have overestimated hypertension in the children because of white coat syndrome. Third, the BP normative reference was adopted from the US population because we lack data for Taiwanese children.[42] Fourth, the AASM revised the criteria of hypopnea in 2012, which our sleep center starts to implement in 2014. Before 2014, hypopnea was defined by the 2007 AASM alternative criteria. According to a study by Duce et al,[56] the revision of the 2012 AASM would increase the AHI in patients undergoing PSG compared with the 2007 criteria. Use of 2007 AASM alternative criteria from 2010 to 2013 would slightly underestimate the number of children with OSA compared with patients who underwent PSG from 2014 onward. Fifth, other than those who has major underlying disease, most of the nonincluded patients were those who were unavailable for follow-up or chose not to receive surgery. It is difficult to eliminate selection bias because parents usually address the need for their children to receive surgery at a younger age. Younger children also tend to have suboptimal PSG studies or incomplete BP data. Increase in age is accompanied by somatic growth and BP increase, which may have overcome the reduction in BP from surgery. Finally, although we observed improvements in BP measures within 6 months after surgery for hypertensive children with OSA, the long-term effects of surgery on BP remain uncertain.[57] A follow-up study is thus necessary to clarify such effects.

Conclusions

This study compares the association of adenotonsillectomy with blood pressure in nonhypertensive vs hypertensive children with OSA. After adenotonsillectomy, hypertensive children had significant improvement on all BP and OSA measures. We recommend screening and treating hypertensive children with OSA by adenotonsillectomy because proper treatment not only eases OSA symptoms but also potentially prevents future cardiovascular and end-organ disease.

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