Comparisons of Office and 24-Hour Ambulatory Blood Pressure Monitoring in Children with Obstructive Sleep Apnea

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Objective To compare office blood pressure (BP) and 24-hour ambulatory BP (ABP) monitoring to facilitate the diagnosis and management of hypertension in children with obstructive sleep apnea (OSA).

Study design Children aged 4-16 years with OSA-related symptoms were recruited from a tertiary referral medical center. All children underwent overnight polysomnography, office BP, and 24-hour ABP studies. Multiple linear regression analyses were applied to elucidate the association between the apnea–hypopnea index and BP. Correlation and consistency between office BP and 24-hour ABP were measured by Pearson correlation, intraclass correlation, and Bland-Altman analyses.

Results In the 163 children enrolled (mean age, 8.2 ± 3.3 years; 67% male). The prevalence of systolic hypertension at night was significantly higher in children with moderate-to-severe OSA than in those with primary snoring (44.9% vs 16.1%, $P = .006$). Pearson correlation and intraclass correlation analyses revealed associations between office BP and 24-hour BP, and Bland-Altman analysis indicated an agreement between office and 24-hour BP measurements. However, multiple linear regression analyses demonstrated that 24-hour BP (nighttime systolic BP and mean arterial pressure), unlike office BP, was independently associated with the apnea–hypopnea index, after adjustment for adiposity variables.

Conclusions Twenty-four-hour ABP is more strongly correlated with OSA in children, compared with office BP. *(J Pediatr 2017;182:177-83).*

Sleep-disordered breathing includes a spectrum of upper airway disorders ranging from primary snoring to obstructive sleep apnea (OSA).[1,2] Untreated OSA is associated with hypertension[3,4] and other cardiovascular morbidities in adults.[5,6] For the pediatric population, Guilleminault et al[7] first described high office blood pressure (BP) in children with OSA in 1976. Several subsequent studies have linked OSA with BP in the pediatric population.[7-22] Li et al[8] and Xu et al[12] have reported a dose-response relationship between OSA and ambulatory BP (ABP) in children. Weber et al[11] demonstrated that diastolic and mean ABP were higher in children with OSA than in those with primary snoring. Studies have revealed that children had elevated BP in conjunction with increased OSA severity, implying that BP monitoring is necessary for the early detection of patients with high BP.[7-23]

BP measurement in the office and 24-hour ABP monitoring have been used.[24-26] Twenty-four-hour ABP monitoring provides an estimate of the mean BP level, BP diurnal rhythm, and BP variability.[25,27-29] Several studies have indicated that ABP monitoring may be superior to clinical office BP measurements in predicting preclinical organ damage in the pediatric population.[30-32] However, the associations and disparities between office and 24-hour ABP monitoring in children with OSA have not been studied. This study evaluated the correlation, consistency, and differences between office BP and 24-hour ABP in children with obstructive sleep disorders.

Methods

Approval for this study was obtained from the Ethics Committee of National Taiwan University Hospital (201206011RIB). The study population was a cohort from a

ABP	Ambulatory BP
AHI	Apnea-hypopnea index
BMI	Body mass index
BP	Blood pressure
MAP	Mean arterial pressure
OSA	Obstructive sleep apnea
PSG	Polysomnography
ICC	Intraclass correlation

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previous study published by our research group.[23] Participants with both office BP and ABP data were chosen for this study.

The study population was initially recruited from the respiratory, pediatric, and otolaryngology clinics from general pediatric clinic and sleep medicine clinic. Those aged 4-16 years with symptoms suggestive of OSA, including snoring, witnessed breath pause, daytime sleepiness, mouth breathing, awakening, hyperactivity, bedwetting, or attention problems, were invited to participate in this study.[33] Each child was sent to a sleep medicine clinic and evaluated by the same author to decide whether or not to include this child into this study. Children were enrolled in the study after they or their parents had completed written informed consent. Exclusion criteria were (1) previous adenotonsillar or pharyngeal surgery; (2) genetic disorders, neuromuscular diseases, or neurocognitive deficits; (3) craniofacial anomalies; and (4) significant medical illnesses such as cardiac, respiratory, or renal diseases. The height and weight of each child were measured. Age- and sex-corrected body mass index (BMI) was applied for each child using established guidelines (ie, BMI percentile).[34] Obesity was defined as a BMI greater than the 95th percentile for a child's age and sex.[2,34]

Overnight polysomnography (PSG) (Embla N7000; Medcare Flaga, Reykjavik, Iceland) was performed in our sleep laboratory using the established protocol.[2,15,33,35-41] The scoring criteria for sleep stage and respiratory events followed the 2007 standard of the American Academy of Sleep Medicine.[42] Briefly, hypopnea was defined as a ≥50% decrease in airflow for the duration of ≥2 breaths associated with arousal, awakening, or reduced arterial oxygen saturation of ≥3%. Obstructive apnea was defined as continued inspiratory effort associated with a >90% decrease in airflow for the duration of ≥2 breaths. Disease severity in children was classified as primary snoring (apnea–hypopnea index [AHI < 1), mild OSA (1 ≤ AHI < 5), and moderate-to-severe OSA (AHI ≥ 5).[8,35-41]

Children received 24-hour ambulatory BP (ABP) monitoring using an Oscar 2 oscillometric monitor (Model 222; SunTech Medical, Morrisville, North Carolina). The Oscar monitor passed the validation process and requirements of the International Protocol of the European Society of Hypertension and British Hypertension Society.[43,44] Moreover, the Oscar device passed the Association for the Advancement of Medical Instrumentation/International Organization for Standardization standard testing as part of its 510K submission. BP was measured using an appropriately sized cuff on the nondominant arm. The monitors were programmed to measure BP at 15-minute intervals during the daytime (from 7:00 a.m. to 10:00 p.m.) and at 30-minute intervals during the nighttime (from 10:00 p.m. to 7:00 a.m.). The exact cut-off time for the daytime and nighttime measurements was adjusted according to the sleep diary provided by children or their parents. Pediatric ABP measurement requires at least 1 valid reading per hour, including during sleep, as a primary criterion for an interpretable study.[25] Mean arterial pressure (MAP) and systolic and diastolic BP were measured during daytime and nighttime. The BP load was defined as the percentage of valid BP measurements greater than the 95th percentile of BP for age and sex.[45,46] Disparities in age and sex were compared by applying the BP index, which was calculated through the following formula: BP index = (measured BP—95th percentile)/95th percentile × 100.[25] Systolic or diastolic hypertension was defined as average systolic or diastolic BP values above the 95th percentile of the ABP norm.[25] Nocturnal dipping of systolic or diastolic BP was derived by computing the difference between mean daytime and nighttime BP, and expressed as a dipping percentage. Nondippers were defined as subjects with nocturnal BP dipping <10%.[25]

Office BP was measured by an electronic sphygmomanometer (Terumo Digital Blood Pressure Monitor ES-H55; Terumo Medical Corporation, Tokyo, Japan) with proper sized cuffs.[47] Children were asked to rest in a sitting position for 10-15 minutes before BP measurements.[47] Office BP was measured on each participant 3 times before (10:00 p.m. to 11:00 p.m.) and after (6:00 a.m. to 7:00 a.m.) each PSG study. The mean systolic and diastolic BP before and after each PSG study were calculated and reported separately. Different age and sex groups were compared by applying the BP percentile and index.[26] BP index and average systolic and diastolic BP values were obtained for further analysis.

Statistical Analyses

Data were analyzed using IBM SPSS Statistics v 22 (IBM Corporation, Armonk, New York). The distribution of continuous variables among the disease severity groups was compared using the Kruskal-Wallis test, followed by Bonferroni post hoc multiple comparison when the overall test was significant. In addition, the differences in proportions between groups were compared using Fisher exact test with a post hoc test. Association between sleep variables (ie, AHI) and BP measurements were investigated through multivariable linear regression analysis. Several models evaluating the association between the AHI and BP measures were evaluated with adjustment for age, sex, height, and adiposity (ie, BMI percentile and obesity). The AHI values were normalized by logarithmic transformation (using natural log[x + 0.1]). Correlations between office BP and 24-hour ABP were tested by Pearson correlation and intraclass correlation (ICC) analyses, with P value of < .05 considered to be statistically significant. Consistency and agreement between office BP and 24-hour ABP were assessed by Bland-Altman analyses.

Results

From 2012 to 2015, 163 participants were included in the analysis. The mean age of the participants was 8.2 ± 3.3 years, and 66.9% (109/163) of the participants were male. **Table I** showed comparisons of basic characteristics and PSG data among children with different disease severity levels. Children with moderate-to-severe OSA had a higher prevalence of obesity than children with primary snoring (34.8% vs 9.7 %, P = .002).

24-Hour ABP

Although children exhibited a trend toward BP elevation as the severity of OSA increased, the BP measures and