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Childhood nasal obstruction and sleep-disordered breathing during clinical setting: Myth or reality?

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ABSTRACT

Objectives: .The severity of sleep apneas largely depends on abnormal size of upper airway. Therefore, nasal examination is essential part of clinical evaluation of children with sleep-disordered breathing.

Methods: We performed a retrospective survey involving children aged 4 years and older which underwent in-laboratory overnight cardiorespiratory polygraph study between January 2016 and May 2017. Nasal obstruction test was used to score severity.

Results: Fifty-three children (62% males) with a median age of 6.1 (IQR 3.1) years were enrolled in this study. Linear regression analysis showed that nasal obstruction score was correlated with apnea-hypopnea index ($\beta = 0.345$; $p < 0.014$) and oxygen desaturation index ($\beta = 0.328$; $p < 0.022$), whilst no association was found with age, BMI z-score, snoring and phase angle. Correlation analysis also showed that nasal obstruction score was correlated with apnea-hypopnea index ($r = 0.364$; $p = 0.009$) and oxygen desaturation index ($r = 0.350$; $p = 0.012$) after adjustment for age and BMI z-score., but not with snoring time or phase angle degree.

Conclusions: Nasal obstruction test may be a useful, time saving assessment which aid exploring sleep disordered breathing in children. However, this test should not be used alone because it is plagued by objective consideration and at risk of under or overestimation.

Keywords: children, nasal obstruction, overnight respiratory polygraph, obstructive sleep apnea, sleep-disordered breathing

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Obstructive sleep apnea (OSA) consists of episodes of partial or complete closure of the upper airway that occur during sleep and lead to breathingcessation and oxygen desaturation [1, 2]. The severity of sleep apnea largely depends on abnormal size of the airway [3]. Turbulence of airflow, or nose, oropharynx, and hypopharynx resistance conventionally defines OSA severity. Hyperplasia of tonsils and adenoids [4] and craniofacial disharmonyare the major contributors to high airway narrowing in children [5]. Some narrow regions such as nostrils, lips, palate and larynx limit the high airway

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patency [6].

Nasal difficulty decreases pharyngeal patency andnasal airway resistance may be explained by Starling resistance model. The Starling model describes upper airway as a hollow tube, with a partial obstacle at the inlet (nose), and a collapsible part downstream (oropharynx) [1]. Severe nasal block is then associated with a switch to oral breathing and an enhanced risk of sleep-disordered breathing (SDB) [7].

Albeit nasal examination is an essential part of clinical evaluation of children with SDB, there is still insufficient evidence to define whether or not nasal obstacle to respiration may be a risk factor for OSAS [1].

The aim of the present study was to evaluate the correlation between nasal difficulty severity and sleep respiratory actigraphy.

METHODS

Study population

The present study included compliant children aged 4 years and older, who were subjected to in-laboratory overnight polygraph study for SDB between January 2016 and May 2017, in our local Department (University Hospital of Verona, Verona, Italy). All children were referred to the local ambulatory, which belongs to a larger pediatric pneumology service. Medical records were accurately filled, including age, sex, body growth parameters, nasal patency assessment (as described below), and history for inhalant allergy. Children with allergic diseases were defined having disease history identified before the index date and lasting at least for three medical visits. Records review was carried out as previously described elsewhere [8]. The study was performed according to the Declaration of Helsinki and under the terms of relevant local legislation.

Nasal barrier test

The assessment of nasal obstacle (ICD-9-CM 478.19) [9] was performed by alternatively closing the nostrils with a finger, accurately preventing to constrict the other nostril. The patient was then invited to breathe through the free nostril keeping the mouth closed. The test was then repeated closing the other nostril. One-sided nasal block was classified according to the air flux recorded by the operator, as follows: 0 (open), 1 (mildly obstructed), 2 (severely obstructed) and 3 (obstructed). The score calculated for either nostril (i.e., right + left score) was then summed for all patients (minimum 0 -maximum 6). Three skilled blinded operators performed independently of the test and the final score was the mean of the three independent measurements. Nasal patency manoeuvre was performed the day of in-laboratory respiratory actigraphy study.

Anthropometry

Height and weight were measured by the same skilled personnel, using standardized techniques. Body mass index [BMI: weight (kg) / height $(m)^2$], BMI percentiles and BMI z-scores were calculated according to age and sex (http://nccd.cdc.gov/dnpabmi/Calculator.aspx).

In-laboratory overnight respiratory polygraph

The in-laboratory overnight respiratory polygraph study (SOMNO screen ^{TM}PSG, SOMNO medics GmbH, Randersacker, Germany) was used to continuously record nasal airflow, chest and abdominal respiratory movements (thoracic and abdominal belts), arterial oxygen saturation (SaO_2; digital pulse oximetry), heart rate (HR; finger probe), electrocardiogram (ECG; three chest electrodes), body position (mercury sensor) and tracheal sounds (microphone). Electroencephalography (EEG), eye movements (electrooculogram; EOG) and muscle activity or skeletal muscle activation (electromyogram; EMG) studies were not performed. The device was applied between 7:00 PM and 8:00 AM, and data were continuously recorded throughout the night. During the test, all children were monitored for ≥ 6 h in a quiet, properly prepared sleep room, in the presence of one of their parents [10]. The estimated total sleep time (TST) was calculated was the time between the child fell asleep and wake up, and was recorded in a nocturnal diary by the healthcare staff, which was also trained to promptly intervene, when needed. The nocturnal awakenings were identified considered from TSTcalculation and were then removed from final analysis.

The sleep analysis (DOMINO® software, Somnomedics v.2.6.0) of the valid recording session

was manually performed. Obstructive respiratory events were scored as previously reported [11]. In particular, the number of obstructive apneas (OA; n./hour) plus central apneas (CA; n./hour) plus hypopneas (H; n./hour) was divided by hours of TST and then expressed as apnea-hypopnea index (AHI, n./hour) [12].

All O_2 desaturations (≥ 3%; n./hour) from baseline, mean SpO_2 (%) and minimum SpO_2 (%) were quantified. The Oxygen Desaturation Index (ODI; n./hour) was measured as total number of desaturations divided by TST. Snoring (time% of the TST) was also regularly calculated [13].

Phase angle vector analysis is an index of thoracoabdominal asynchrony (TAA) and inspiratory airflow resistance. An increased value suggests compromised upper airway patency, leading to enhanced inspiratory work of breathing. Phase angle analysis and related thoracoabdominal asynchrony may be a useful parameter to detect upper airway obstacle [14, 15]. An increased inspiratory resistance as maintained during OA and H produces an asynchrony between rib cage and abdomen (no obstacle: phase angle close to 0 degrees; obstructive apnea: phase angle close to 180 degrees).

Statistical Analysis

Statistical analysis was performed using SPSS Statistics 22.0® software for Windows. Kolmogorov-Smirnov test for one sample was used to explore normal distribution of continuous variables. The demographic, clinical characteristics and actigraphy results, were presented as number and percentage for categorical variables, or as median and 95% confidence interval (CI) for continuous variables, respectively.

Linear regression (backward) analysis, in which nasal barrier score was entered as dependent variables, was carried out to explore potential associations with demographic, clinical and polygraphic variables (age, BMI z-score, snoring, phase angle, AHI or ODI). The value of statistical significance was set at $p < 0.05$. Partial correlation analysis was performed between nasal barrier score and clinical and polygraphic results (AHI, ODI, snoring and phase angle), adjusted for age and BMI z-score.The value of statistical significance was set at $p < 0.05$.

RESULTS

The final study population consisted of 53 children. A summary of demographic (sex, age), clinical (body growth parameters) and in-laboratory overnight polygraph results (AHI, ODI, snoring, phase angle) of the study population is shown in Table 1

Table 1. Summary of the demographic, clinical characteristics (Panel A) and overnight polygraph study (Panel B) of 53 consecutive children*

	Median	IQR
Panel A		
Number (males %)	53 (62.3)	-
Age (years)	6.1	3.1
Weight (kg)	22	11
Height (cm)	116	15
BMI Percentiles	71.6	58.3
BMI z-score	0.6	1.8
Panel B		
eTST (hours)	9.0	1.4
AHI (events/h)	2.9	3.8
ODI (events/h)	0.6	0.9
Snoring (% time)	0.2	1.7
Phase angle (degrees)	57	32

*Selection criteria were the absence of genetic and neurological conditions, and age range between 4 to 15 years. AHI = apnea-hypopnea index, BMI = body mass index, IQR = interquartile range, ODI = oxygen desaturation index, eTST = estimated total sleep time

Table 2. Linear regression (backward) analysis between nasal barrier test (score) and age, BMI Z-score, snoring, phase angle and apnea-hypopnea index (AHI; model 1) or oxygen desaturation index (ODI; model 2).

	MODEL 1			MODEL 2		
Dependent variable:	**Nasal barrier test**			**Nasal barrier test**		
STEP1	*B*	*CI*	*p*	*B*	*CI*	*p*
Age (years)	-0.121	-0.286÷0.114	0.393	-0.144	-0.302÷0.098	0.310
BMI z-score	-0.022	-0.335÷0.285	0.873	0.034	-0.276÷0.355	0.802
AHI (n./hr)	0.345	0.016÷0.133	0.014	-	-	-
ODI (n./hr)	-	-	-	0.328	0.014÷0.167	0.022
Snoring (% TST)	0.130	-0.046÷0.127	0.347	0.112	-0.053÷0.123	0.427
Phase angle (degrees)	0.061	-0.013÷0.020	0.660	0.061	-0.013÷0.021	0.665
Model Significance	0.104			0.138		
adj. R^2	0.084			0.069		
STEP2						
Variable included	AHI				ODI	
Model Significance	0.005				0.009	
adj. R^2	0.125				0.108	

AHI = apnea-hypopnea index, BMI = body mass index, ODI = oxygen desaturation index, TST = total sleep time

Panel A and B. Kolmogorov-Smirnov test for one sample showed that the variables in Table 1 (age, weight, height and BMI percentiles in Panel A; AHI, ODI and snoring in Panel B) are not normally distributed ($p < 0.05$).

The linear regression (backward) analysis (Table 2, model 1 and model 2) showed that nasal barrier score was significantly associated with AHI ($\beta = 0.377$; $p = 0.005$) and ODI ($\beta = 0.353$; $p = 0.009$) variables. Age, BMI z-score, snoring and phase angle variables were excluded from the models.

Interestingly, with partial correlation analysis, nasal barrier score was associated with both AHI ($r = 0.364$; $p = 0.009$) and ODI ($r = 0.350$; $p = 0.012$), but not with snoring time ($r = 0.170$; $p = 0.232$) and phase angle ($r = 0.49$; $p = 0.734$) (Table 3).

Figure 1 shows the distribution of AHI values according to the different values of nasal barrier score.

DISCUSSION

The potential contribution of the nose to the pathophysiology of OSAS remains a largely unexplored issue [1]. Daytime nasal difficultywas shown to be an independent risk factor for OSAS [16]. Nose difficulty strongly influences pharynx patency, since the inspiratory flow through the upper airway may promoteits closure. The luminal pressure at which the airway begins to close is defined as critical closing pressure [17]. In the presence of nasal or upper airway congestion, oral breathing becomes prevalent.

Nasal difficulty and mouth breathing have been associated with adenotonsillar hypertrophy, which in turn is the leading cause of OSAS in children [18, 19]. In particular, enlarged adenoids dramatically influence the amount of air inhaled through the nose. Nasal difficulty and crowded oropharynx double the risk of

Table 3. Partial correlation analysis between nasal obstruction score, adjusted for age and BMI z-score, and apnea-hypopnea index (AHI) or oxygen desaturation index (ODI) or phase angle.

		Nasal barrier score	
		r_{par}	*p*
Adjusting variables: age (years) & BMI z-score	AHI (n./hr)	0.364	**0.009**
	ODI (n./hr)	0.350	**0.012**
	Snoring (% TST)	0.170	0.232
	Phase angle (degrees)	0.049	0.734

AHI = apnea-hypopnea index, BMI = body mass index, ODI = oxygen desaturation index, TST = total sleep time

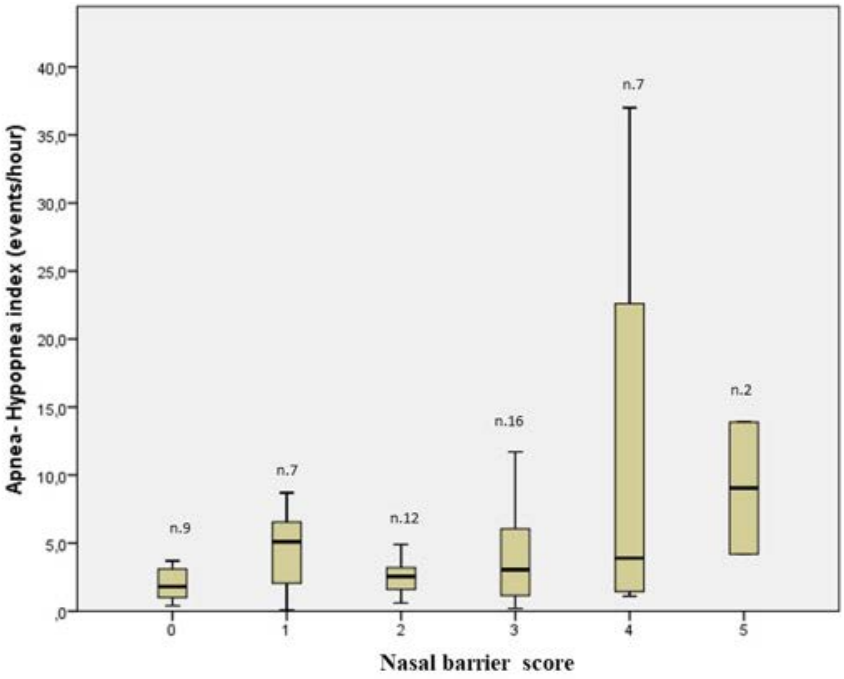

Figure 1. Box plot of nasal barrier score and apnea-hypopnea index.

OSAS [9]. Nasal video-endoscopy is a useful tool to assess airway difficulty due to adenoid hypertrophy [29]. Medical treatments (nasal steroids and leukotriene receptor antagonists) or adeno(tonsillectomy) interventions are the most widely used medical measures for improving both symptoms and polysomnographic signs associated with adenoid hypertrophy [21, 22]. However, recent evidence has been provide that specific craniofacial characteristics may be commonplace in snoring children [2, 23]. Persistent allergy is another factor potentially involved in reducing air inhalation through the nose. Upper allergic persistent inflammation of both nasal mucosa and adenoid tissue are often causes of persistent nasal difficulty, even in children who underwent adenoidectomy [24].

The nasal examination is an important part of the ambulatory clinical assessment of children with SDB. A simple, straightforward and time wasting analysis can be useful to assess for SDB severity in cooperating children, before otorhinolaryngologic evaluation. In particular, the main finding of the present study was that nasal barrier score was significantly correlated with AHI and ODI. However, no correlation was found with snoring or with phase angle (i.e., thoracoabdominal asynchrony). Taken together, these findings would suggest that nasal barrier score and AHI values may be at least partially coincident but not directly related to our population.

Limitations

The main limitation of the present study is represented by subjective assessment of childhood nasaldifficulty. Other limitationsinclude children collaboration, especially those very young, the challenge to perform cardiorespiratory analysis during the sleep (i.e., sleep stages could not be examined and sleep time was only deducted from healthcare staff observation, so thatrespiratory polygraph recordings [25] were only indicative of the pattern of the childhood respiration during the night).

CONCLUSION

In conclusion, the nasal barrier test may be a useful, timewasting ambulatory assessment, that helps to assess the severity of SDB in children. However, this test should not be used alone because it is plagued by objective judgement and at risk of under or overestimation.

Key Points

- Sleep-disordered breathing due to upper

airway difficulty is frequent in pediatric patients.

- Clinical evaluation of upper airway difficulty is needed in the ambulatory setting.
- Children with clinical evaluation suggesting sleep-disordered breathing need further assessment with sleep respiratory actigraphy or polysomnography.
- Assessment of nasal difficultyshould be of clinical evaluation for sleep-breathing disorders.
- Nasal barrier test is a useful, timewasting ambulatory assessment, butpoorly predicts sleep breathing disorders severity in children.
- Nasal barrier test should not be used alone since it is plagued by objective judgement, being sensitive to the risk of under or overestimation.

Abbreviations

AHI = apnea-hypopnea index, OSA = obstructive sleep apnea, ODI = oxygen desaturation index, OSAS = obstructive sleep apnea syndrome, SDB = sleep disordered breathing.

Contribution of each co-authors

Study conception and design: MZ, LN, GP; Acquisition of data: MZ, EG, LT, SB, LS; Analysis and interpretation of data: MZ, GL, LS, LT, LN, MP, SB; Drafting of the manuscript: MZ, GL, EG, LT, LN, MP, SB; Critical revision: GP, GL, LN, LS.

Ethical approval

The study was approved by the Institutional Ethical Committee of Verona (University Integrated Hospital of Verona), and all parents signed the informed consent form.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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