

Correlation of Radiological and Polysomnographic Indicators of Obstructive Sleep Apnea in Children with Adenoid Hypertrophy

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ABSTRACT:

Adenoid inflammatory cytokines can facilitate accurate diagnosis and treatment. The adenoidal nasopharyngeal ratio (ANR) is a noninvasive simple tool to evaluate the adenoid size. Our study aimed to assess the correlation between ANR and obstructive sleep apnea (OSA) severity in children with adenoid hypertrophy based on inflammatory markers. This case-control study included 25 children with confirmed adenoid hypertrophy and 25 healthy children as controls (aged 3–13 years). ANR was determined using lateral nasopharynx radiography. Sleep-disordered breathing was evaluated using a sleep habit questionnaire and polysomnography. Clinical and polysomnographic data were correlated to ANR. 68% of children with adenoid hypertrophy had OSA. ANR was significantly higher in children with OSA than those without OSA. ANR has a significant positive correlation to the Apnea/Hypopnea Index and a significant negative correlation with sleep efficiency%, and sleep habit scores. At a cut-off point of ≥ 0.755 , ANR has 76.5% sensitivity and 87.5% specificity to predict OSA in children with adenoid hypertrophy. Snoring (OR 26.667; C.I.95%:2.242 - 317.147) and ANR ≥ 0.752 (OR 22.75; C.I.95%:2.114 - 244.868) are predictors for OSA in children with adenoid hypertrophy. ANR is well correlated to sleep habit questionnaire scores and polysomnographic indicators of OSA. ANR and inflammatory cytokines can be used for screening of OSA in children with adenoid hypertrophy, helping identify those who need a referral for polysomnography. In children with adenotonsillar hypertrophy, instead of treatment, appropriate treatments for other factors are required as OSA.

Keywords: Obstructive sleep apnea; echocardiography; brain natriuretic peptide; adenotonsillar hypertrophy

Introduction

Sleep-related disordered breathing and obstructive sleep apnea (OSA) are common sequels of adenoid hypertrophy in children that impair the quality of life of those children leading to both short and long-term morbidities including right ventricular dysfunction, pulmonary hypertension, stunted growth, insulin resistance, cognitive impairment, and nocturnal enuresis [1].

Such morbidities should be taken into consideration during the decision for surgical intervention. Despite emerging evidence demonstrating the long-term sequels of obstructive sleep apnea [2], still there is insufficient awareness of both parents and physicians about such hazards leading to delays in surgery decision that exposes such children to more complications. So, identification of those at greater risk for OSA is mandatory to allow early referral for adenoidectomy.

Hypertrophied adenoid tissue interferes with the patency of the airway, especially during sleep. The severity of upper airway obstruction predicts those at high risk for OSA. [3]. Obstructive sleep-disordered breathing includes primary snoring (>3nights/week), upper airway resistance (snoring with labored breathing causing recurrent arousals), obstructive hypoventilation (snoring with hypercapnia but no apnea), and the most severe form is obstructive sleep apnea (cessation of airflow with hypoxia and/or hypercapnia). [4]

The most reliable method to assess adenoid size is to determine adenoid nasopharyngeal ratio either radiologically or through nasal endoscopy which provides a 3-dimensional view but is an invasive procedure that needs sedation in children. [5]

Polysomnography (PSG) is the gold standard for diagnosing and assessing obstructive sleep apnea (OSA) severity. However, it is not widely available and expensive. [6] There is a need to get a simple bedside screening tool that could reflect the severity of upper airway obstruction.

Medical history of snoring, mouth breathing, and excessive daytime sleepiness in addition to airway narrowing detected in lateral nasopharynx X-ray

provides a strong prediction for obstructive sleep apnea. [7]

Sleep habit questionnaires represent a simple cost-effective widely available tool for the detection of sleep problems in children. The subjective nature of the sleep questionnaire represents a major limitation of its use for the assessment of obstructive apnea. [8]. Our study aimed to evaluate the correlation between ANR and polysomnographic parameters in children with adenoid hypertrophy.

Methods

The current study is a comparative study that was carried out on 25 children who were selected consecutively from the pediatrics and otorhinolaryngology outpatient clinic. Another healthy 25 children of matched age and sex were selected consecutively from the outpatient pediatric clinic. Inclusion criteria were children with confirmed adenoid hypertrophy aged 3-13 years. Children were excluded from the study if they had allergic rhinitis, nasal septum deviation, hypertrophic turbinate, obesity, or any neuromuscular, cardiorespiratory, craniofacial, or skeletal malformation or those who received medications affecting the sleep or those refused to be included. Informed consent was obtained from all parents before involvement in the study under the guidelines of the local ethics committee of Al-Azhar University.

All children were subjected to detailed history taking with stress on manifestation suggesting sleep-disordered breathing (snoring, nasal tone, sleep apnea, mouth breathing, noisy breathing, daytime sleepiness). Complete general and systemic examination including neurological, respiratory, cardiac, and otorhinolaryngology assessment .

Between May 2021 and May 2023, the study was conducted at Al-Zahra University Hospital, Cairo, Egypt, in partnership with the Department of Pediatrics.

Al-Azhar University, Faculty of Medicine for Girls, Local Ethics Committee reviewed the study and approved it after informed consent was obtained from all parents before study participation.

Laboratory investigations: Routine investigations were done for all participants. Blood samples were collected and centrifuged to separate serum from all groups. The following parameters were assessed: complete blood count (CBC) (Sysmex KX21N, Kobe, Japan). ESR (Westergren method) Coagulation profile (Stago, France), liver function, and kidney function (Cobas c 311, Roche, Germany). IL-2 (Elabscience, cat. No. E-EL-H0099), TNF- α (Elabscience, cat. No. E-EL-H0109), IL-10 (Elabscience, Cat. No. E-EL-H0103), and IL-4 (Elabscience, cat. No. E-EL-H0101) were estimated using enzyme-linked immunosorbent assay (ELISA) technique and according to the manufacturer's recommendations.

Assessment of anthropometric parameters

Height (centimeter) was measured in standing posture, barefoot with an extended knee. Weight (kilograms) was measured using a digital scale while the child wearing light clothes and body mass index was calculated (weight in kilogram/ (height in meter)² and put on a percentile chart to exclude obesity. [9] All measurements were double-checked by 2 expert pediatricians and were adjusted to the nearest 0.1 value.

Assessments of adenoid hypertrophy

The adenoid size was evaluated using a lateral soft tissue X-ray of the nasopharynx using standard techniques. Adenoid hypertrophy was identified when the adenoid-nasopharynx ratio (ANR) exceeded 0.67. The adenoid depth to nasopharynx diameter ratio was determined according to Fujioka et al. [10]. The severity of nasopharyngeal obstruction was categorized into mild if ANR is between 0.60-0.69, moderate if ANR is between 0.70-0.79, and severe if ANR is between 0.80-0.89. [11]

Children's Sleep Habit Questionnaire (CSHQ)

An Arabic version of the parent-based questionnaire was used to assess sleep problems and habits in children over the past 1 month. It consists of 33 items that reflect sleep problems and 3 items for evaluation of time of wake up, bedtime, and sleep duration. The score is summed into 3 subcategories sleep habits at bedtime (10 questions),

sleep behavior (10 questions), and habits in the morning and waking during the night (10 questions). The CSHQ evaluates 8 items: Daytime sleepiness (8 questions), parasomnias (7 questions), bedtime resistance (6 questions), sleep anxiety (4 questions), sleep-disordered breathing (3 questions), night waking (3 questions), sleep duration (3 questions), and sleep onset delay (1 questions). The score for each question was rated on a 3-point scale: Rarely = 1 (0 to 1 time/week); sometimes = 2 (2 to 4 times/week); and usually = 3 (5 times or more /week). Higher scores indicate greater sleep problems. [12]

Polysomnography (PSG)

Overnight (at least 8 hours) PSG for one night was done for all involved children using PSG apparatus (model BWIII; Product of Neurovirtual USA) at the sleep laboratory of the pediatric neurophysiology unit at Alzahraa Hospital, Al-Azhar University. In literature, the apnea-hypopnea index (AHI) is a widely used polysomnographic parameter to evaluate sleep-disordered breathing severity. In the current study obstructive sleep apnea was categorized based on AHI into mild obstructive sleep apnea when AHI is 1-4.9/hour, moderate if AHI is 5-9.9/hour, and severe if AHI is 10 or more per hour [13].

Diagnosis of obstructive sleep apnea in children:

Confirmed diagnosis by the combination of A and B items of the following criteria [14]:

A. The presence of ≥ 1 of the following:

- Snoring
- Labored/obstructed breathing during sleep.
- Daytime sleepiness and behavioral/learning problems

B. Polysomnography showed either:

-One or more obstructive, mixed apneas, hypopneas per hour of sleep.

- Obstructive hypoventilation (hypercapnia ($paco_2 > 50$ mmHg) for at least 25% of total sleep duration with either snoring,

-flat inspiratory pressure waveform, or paradoxical thoracoabdominal movement).

Statistical analysis

Data analysis was done using the Statistical Package for Social Sciences (version 22; SPSS Inc., Chicago, IL, USA). Data were expressed as mean $\pm$ SD and percentages. The independent t-student test, chi-square test, and ANOVA test were used for the comparison of groups and the Pearson coefficients test for correlation correlations between parameters. Further analysis of differences between subgroups was done using post hoc analysis. Linear and stepwise logistic regression analyses were performed to evaluate the association between AHI and other variables. The receiver operating characteristic curve (ROC) was used to detect sensitivity and specificity and determine optimal

cut-off points of ANR that predict OSA in children with adenoid hypertrophy. P-values <0.05 were considered significant.

Results

Among 25 children with adenoid hypertrophy, OSA was detected in 17 children (6 were severe, 7 were moderate, and 4 were mild based on AHI) while none of the healthy children had OSA. Most of them (14/25) had moderate nasopharyngeal obstruction, 8/25 had mild obstructions, and 6/25 had severe obstructions. No statistically significant difference between the studied groups as regards age, sex, and body mass index. Children with OSA have significantly lower height, weight, sleep habit questionnaire scores and significantly higher ANR, AHI, arousal index, and NREM 1 than those without OSA as shown in Table 1.

Table 1 shows a comparison of the children's clinical data, sleep habit questionnaire scores, and polysomnographic parameters.

Variables	Children with OSA N=17	Children without OSA N=8	Control N=25	ANOVA/ chi square test		Independent T'-test/ chi-square test		
				F	p-value	I vs II	I vs III	II vs III
Age (year)	5.882 $\pm$ 0.857	6.125 $\pm$ 0.835	6.040 $\pm$ 0.790	0.298	0.744	0.512	0.550	0.804
Sex (male/female)	9(52.9%)/ 8(47.1%)	6(75%)/2(25%)	15(60%)/10(40%)	1.103	0.576	0.402	0.445	0.678
Snoring (n, %)	16 (94.1%)	3 (37.5%)	0 (0%)	69.121	$<0.0001^*$	----	----	----
Weight (kg)	18.900 $\pm$ 2.627	20.625 $\pm$ 4.033	21.760 $\pm$ 2.450	5.281	0.009*	0.210	0.001*	0.340
BMI	15.147 $\pm$ 1.037	14.812 $\pm$ 1.138	15.200 $\pm$ 1.089	0.399	0.674	0.494	0.875	0.415
Height (cm)	111.412 $\pm$ 6.653	117.375 $\pm$ 8.035	119.800 $\pm$ 8.078	6.192	0.004*	0.094	0.001*	0.472
ANR	0.744 $\pm$ 0.035	0.684 $\pm$ 0.008	----	---	----	$<0.0001^*$	----	----
Bedtime score	17.412 $\pm$ 3.658	26.750 $\pm$ 1.832	25.200 $\pm$ 1.780	57.127	$<0.0001^*$	$<0.0001^*$	$<0.0001^*$	0.059
Sleep habit score	21.294 $\pm$ 2.418	25.000 $\pm$ 2.390	24.840 $\pm$ 2.230	13.412	$<0.0001^*$	0.003*	$<0.0001^*$	0.870
Sleep problem score	21.177 $\pm$ 2.921	26.250 $\pm$ 2.765	26.480 $\pm$ 1.584	29.051	$<0.0001^*$	0.001*	$<0.0001^*$	0.828
Total score	59.882 $\pm$ 7.833	78.375 $\pm$ 3.114	76.640 $\pm$ 2.970	62.023	$<0.0001^*$	$<0.0001^*$	$<0.0001^*$	0.192
AHI	9.965 $\pm$ 4.627	0.375 $\pm$ 0.349	0.260 $\pm$ 0.348	71.317	$<0.0001^*$	$<0.0001^*$	$<0.0001^*$	0.433
Arousal index	7.759 $\pm$ 3.267	1.225 $\pm$ 0.797	1.152 $\pm$ 1.003	57.438	$<0.0001^*$	$<0.0001^*$	$<0.0001^*$	0.836
Sleep efficiency%	86.118 $\pm$ 3.120	92.250 $\pm$ 1.669	94.084 $\pm$ 2.098	54.812	$<0.0001^*$	$<0.0001^*$	$<0.0001^*$	0.023*
REM %	18.765 $\pm$ 2.223	22.375 $\pm$ 1.408	22.776 $\pm$ 2.097	42.189	$<0.0001^*$	$<0.0001^*$	$<0.0001^*$	0.546
NREM1 %	16.412 $\pm$ 6.974	5.875 $\pm$ 0.991	4.888 $\pm$ 0.767	0.424	0.657	$<0.0001^*$	$<0.0001^*$	0.028*
NREM2 %	49.529 $\pm$ 2.452	50.500 $\pm$ 1.852	50.136 $\pm$ 3.060	5.068	0.010*	0.287	0.481	0.689
NREM3 %	19.882 $\pm$ 2.736	21.375 $\pm$ 2.387	22.264 $\pm$ 2.108	20.463	$<0.0001^*$	0.184	0.005	0.367

*Significant. I: children with adenoid hypertrophy and obstructive sleep apnea; II: children with adenoid hypertrophy and no obstructive sleep apnea; III: healthy children (control group); OSA: obstructive sleep

apnea; BMI: body mass index; AHI: apnea-hypopnea index; REM: rapid eye movement sleep; NREM: non-rapid eye movement sleep; ANR: adenoid nasopharyngeal ratio

ANR has a significant positive correlation with AHI and a significant negative correlation with Sleep efficiency, deep sleep (NREM 3 stage), and sleep habit scores in children with adenoid hypertrophy as shown in Table 2.

Table 2: Correlation between neck height ratio, adenoid nasopharyngeal ratio, polysomnographic parameters, and sleep habit questionnaire in children with adenoid hypertrophy

Variables	ANR	
	r	p-value
BMI	0.244	0.240
AHI	0.909	<0.0001*
Arousal index	0.778	<0.0001*
Sleep efficiency %	-0.642	0.001*
NREM1 %	0.297	0.150
NREM2 %	0.013	0.949
NREM3 %	-0.401	0.047*
REM %	-0.373	0.066
Bed time score	-0.682	<0.0001*
Sleep habit score	-0.520	0.008*
Sleep problem score	-0.596	0.002*
Total score	-0.688	<0.0001*

*Significant. BMI: body mass index; AHI: apnea hypopnea index; REM: rapid eye movement sleep; NREM: non-rapid eye movement sleep; ANR: adenoid nasopharyngeal ratio

The levels of pro-inflammatory cytokines, TNF α , and IL-2 appear to be increased significantly in patient groups with OSA as compared to the non-OSA group (Table 3). An increase in the level of IL-4 and IL-10 was also observed in the OSA group as compared to the non-OSA group, yet this increase was not significant (P = 0.32, 0.82) respectively.

Table 3 : Table 6. levels of TNF α , IL2, IL4 and IL10 (ng/ml) in different studied groups*

Groups	Control	Children with OSA N=17	Children without OSA N=8
TNFα (pg/mL)	2.16 $\pm$ 0.44	7.713 $\pm$ 1.26	5.15 $\pm$ 0.3
<i>p1</i> value		< 0.0001	< 0.05
<i>p2</i> value		N.S.	< 0.0001
IL-2 (pg/mL)	1.41 $\pm$ 0.26	2.67 $\pm$ 0.35	1.82 $\pm$ 0.16
<i>p1</i> value		< 0.0001	N.S.
<i>p2</i> value		N.S.	< 0.0001
IL-4 (pg/mL)	1.09 $\pm$ 0.234	3.195 $\pm$ 0.46	1.93 $\pm$ 0.32
<i>p1</i> value		< 0.0001	N.S.
<i>p2</i> value		N.S.	< 0.0001
<i>p3</i> value			< 0.0001
IL-10 (pg/mL)	1.8 $\pm$ 0.23	9.2 $\pm$ 0.83	6.14 $\pm$ 0.62
<i>p1</i> value		< 0.0001	< 0.05

$p2$ value†		N.S.	<0.0001
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Data presented as mean $\pm$ SD.

p1 comparison of each group versus control

p2 comparison of group A versus without OSA

At a cut-off point of ≥ 0.755 , ANR has 76.5% sensitivity and 87.5% specificity to predict OSA in children with adenoid hypertrophy as shown in Table 4.

Table 4 shows the adenoid nasopharyngeal ratio's cut-off value, sensitivity, and specificity in children with adenoid hypertrophy in predicting obstructive sleep apnea.

	cut off value	area under curve	Std. Error	sensitivity%	specificity%	Asymptotic 95% Confidence Interval	
						Lower Bound	Upper Bound
ANR	≥ 0.752	0.849	0.004	76.50%	87.50%	0.715	1.000

ANR: adenoid nasopharyngeal ratio

The presence of snoring and higher ANR ≥ 0.752 increased the risk of OSA children with adenoid hypertrophy by 26.6 and 22.7 times respectively as shown in Table 5 and Fig 1.

Table 5: Odds ratio for snoring and adenoid nasopharyngeal ratio for predicting obstructive sleep apnea in children with adenoid hypertrophy

Variables	Odd ratio (95% Confidence interval)
Snoring	26.667 (2.242 - 317.147)
ANR (≥ 0.752)	22.75 (2.114 – 244.868)

ANR: adenoid nasopharyngeal ratio

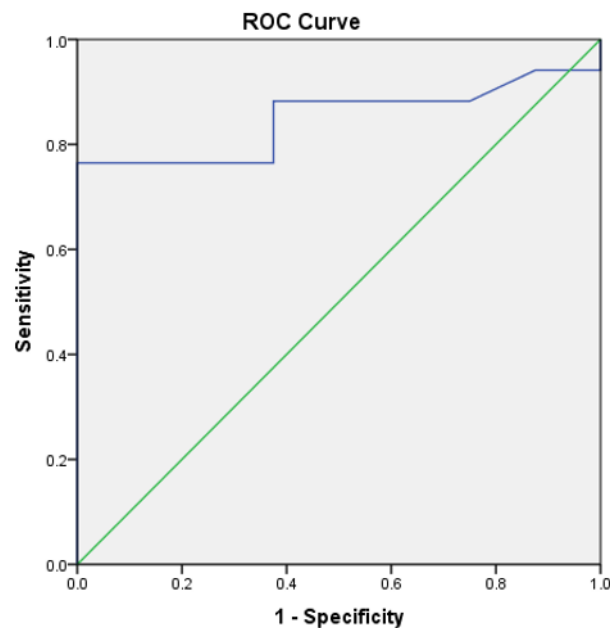


Fig 1: ROC curve evaluated model performance. ROC, receiver operating characteristic

Discussion

Adenoid hypertrophy is the most common cause of chronic upper airway obstruction in the pediatric age group [15]. Among our studied children, OSA was detected in 68% of children with adenoid hypertrophy. This high frequency of OSA among our studied children could be attributed to their young age as adenoid continues to increase in size with age to reach their maximum growth by age 7 to 10 years [16]. These findings are consistent with previous reports that untreated adenoid hypertrophy increases the risk of OSA by 3 folds [17]. Kang et al [18] demonstrated that Adenoidal hypertrophy significantly increases the risk of OSA (OR=1.89; 95% CI 1.19-3.00) with a significant positive correlation between adenoid size and AHI in young children than adolescents.

The severity of upper airway obstruction is a reliable tool to identify those at high risk for OSA. The current study demonstrated that ANR is significantly greater in children who developed OSA which was significantly correlated with sleep habit scores and polysomnographic parameters. In agreement with our findings, Wang et al [19] reported a significant positive correlation between adenoid size and AHI in normal-weight children. The greater ANR was associated with more severe

OSA (odds ratio: 1.55). The higher risk for OSA in our study is attributed to the involvement of children with documented adenoid hypertrophy (ANR>0.76) with most of them having moderate to severe enlarged adenoids. Hwang et al [7] demonstrated a significant correlation between adenoid but not tonsillar size with scores of the OSA-18 questionnaire. The greater airway obstruction adversely affects oxygen saturation which is suggested to be correlated to patient symptoms. The current study revealed disturbed sleep architecture in children with OSA that is significantly correlated with ANR which reflects the severity of airway obstruction. Under our findings, Yan et al [20] found a higher arousal index and prolonged NREM 1 in children with OSA. Lu et al [21] reported that higher snoring sound energy was significantly predictive of severe OSA (odds ratio 32.3; 95% CI: 2.6-396.6). Markkanen et al [22] concluded that snoring, adenoid size, and mouth breathing are associated with an increased tendency to develop OSA. Tagaya et al [23] reported a significant correlation between adenoid size and AHI; the degree of adenoid enlargement represents a significant predictor of the severity of OSA in preschool children. Adenoid hypertrophy is associated with more severe obstructive sleep apnea

and worse polysomnographic parameters than those without adenoid hypertrophy [24].

Our study revealed that ANR is positively correlated to the severity of OSA but not to BMI suggesting that airway obstruction is related to lymphoid tissue proliferation rather than fat deposition. Arens et al. [25] demonstrated that the size of the adenoid but not the BMI is significantly correlated with the severity of OSA. OSA severity is significantly related to the size of the nasopharyngeal space and the proliferation of nasopharyngeal lymphoid tissue. Magnetic resonance images showed that adenoid and retropharyngeal lymphoid tissues mainly contribute to upper airway obstruction and sleep apnea. Increasing the nasopharyngeal lymphatic tissue by 7.3 cm³ leads to the narrowing of the upper airway dimension by 1.4 cm³. The imbalance between nasopharyngeal cavity diameter and lymphoid tissue mass leads to excessive narrowing of the upper airway which increases the risk for OSA. So, the severity of sleep-disordered breathing is related mainly to the size of the airway cavity rather than the size of adenoids and tonsillar lymphoid tissue [26]. In the current study, we evaluated the airway narrowing caused by an enlarged adenoid using the simple non-invasive widely available radiological technique by calculating ANR. Measurement of nasopharynx width can be done either directly preoperative which is an invasive maneuver or radiologically by magnetic resonance imaging which is expensive not widely available and needs sedation for young uncooperative children [27]. Lertsburapa et al [28] demonstrated a good correlation between ANR, flexible nasopharyngeal endoscopy, and intra-operative mirror examination of adenoid size.

The small number of included children is considered a major limitation of the current study that interferes with the generalization of our findings; however, despite such a small number, our findings have statistical significance. Assessment of adenoid size using flexible nasopharyngoscopy provides direct visualization of a nasopharyngeal cavity that is more accurate, but it is an invasive procedure, so it was preferred to be done preoperative also it did not evaluate extra-luminal structures. Computed tomography and magnetic

resonance imaging allow 3-dimensional assessment of the anatomical structure of the nasopharynx however use is limited due to the long duration of the procedure that needs sedation for young uncooperative children and the hazard of ionizing radiation in addition to its high cost [29]. As most patients missed their follow-up reassessment after adenoidectomy could not be done. [30]

Conclusion

In conclusion, ANR is well correlated to sleep habit questionnaire scores and polysomnographic indicators of OSA. ANR can be used for screening of OSA in children with adenoid hypertrophy, helping identify those who need referral for polysomnography.

List of Abbreviations

ANR adenoidal nasopharyngeal ratio, OSA obstructive sleep apnea, PSG Polysomnography, CSHQ Children sleep habit questionnaire, AHI Apnoea-hypopnoea index, NREM nonrapid eye movement sleep, OR odd ratio & CI confidence interval.

Declarations: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

- **Ethics approval and consent to participate:** The study was conducted under the Declaration of Helsinki and approved by the Local Ethics Committee of Al-Azhar University, Faculty of Medicine for Girls
- **Consent for publication:** All participants provided informed consent.
- **Institutional Review Board Statement:** Informed consent was obtained from all parents before involvement in the study following the local ethics committee of Al-Azhar University .
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References

- Galvão CP, Tinano MM, Fontes Ferreira Nader CM, Franco LP, Gonçalves Becker HM. Evolution of obstructive sleep apnea syndrome, nasal flow and systolic pressure of the pulmonary artery in children with indication for adenoidectomy and/or tonsillectomy over 18 months. *Int J Pediatr Otorhinolaryngol*. 2019; 120:210-214.
- Chorney SR, Zur KB. Adenoidectomy Without Tonsillectomy for Pediatric Obstructive Sleep Apnea. *Otolaryngol Head Neck Surg*. 2020 Sep 22:194599820955172.
- Iwasaki T, Sugiyama T, Yanagisawa-Minami A, Oku Y, Yokura A, Yamasaki Y. Effect of adenoids and tonsil tissue on pediatric obstructive sleep apnea severity determined by computational fluid dynamics. *J Clin Sleep Med*. 2020;16(12):2021-2028.
- Kaditis AG, Alonso Alvarez ML, Boudewyns A, Alexopoulos EI, Ersu R, Joosten K, Larramona H, Miano S, Narang I, Trang H, Tsaoussoglou M, Vandenbussche N, Villa MP, Van Waardenburg D, Weber S, Verhulst S. Obstructive sleep-disordered breathing in 2- to 18-year-old children: diagnosis and management. *Eur Respir J*. 2016;47(1):69-94.
- Talebian S, Sharifzadeh G, Vakili I, Golboie SH. Comparison of adenoid size in lateral radiographic, pathologic, and endoscopic measurements. *Electron Physician*. 2018;10(6):6935-6941.
- Rundo JV, Downey R 3rd. Polysomnography. *Handb Clin Neurol*. 2019; 160:381-392.
- Hwang SH, Guilleminault C, Park CS, Kim TW, Hong SC. Usefulness of adenotonsillar size for prediction of severity of obstructive sleep apnea and flow limitation. *Otolaryngol Head Neck Surg*. 2013;149(2):326-34.
- Sen T, Spruyt K. Pediatric Sleep Tools: An Updated Literature Review. *Front Psychiatry*. 2020; 11:317.
- Ghali I, Salah N, Hussien F, et al. Egyptian Growth Curves 2002 for Infants, Children and Adolescents Ferring Publisher, Crescere nel mondo. 2008.
- Fujioka M., Young L.W., Girdany B.R. Radiographic evaluation of adenoidal size in children: adenoidal-nasopharyngeal ratio. *AJR Am J Roentgenol* 133 (1979), 401-404.
- Adedeji TO, Amusa YB, Aremu AA. Correlation between adenoidal nasopharyngeal ratio and symptoms of enlarged adenoids in children with adenoidal hypertrophy. *Afr J Paediatr Surg*. 2016;13(1):14-19.
- Owens JA, Maxim R, Nobile C, et al. (2000): Parental and self-report of sleep in children with attention-deficit/hyperactivity disorder. *Arch Pediatr Adolesc Med*, 154(6):549–55.
- Dehlink E., Tan H.L. Update on pediatric obstructive sleep apnoea. *J Thorac Dis* 8(2016),224-35
- Gipson K, Lu M, Kinane TB. Sleep-Disordered Breathing in Children. *Pediatr Rev*. 2019;40(1):3-13.
- Chang SJ, Chae KY. Obstructive sleep apnea syndrome in children: Epidemiology, pathophysiology, diagnosis, and sequelae. *Korean J Pediatr* 53(2010),863-71.
- Vogler RC, Li FJ, Pilgram TK. Age-specific size of the normal adenoid pad on magnetic resonance imaging. *Clin Otolaryngol Allied Sci*. 2000;25(5):392-5.
- Greenfield M., Tauman R., DeRowe A., Sivan Y. Obstructive sleep apnea syndrome due to adenotonsillar hypertrophy in infants. *Int J Pediatr Otorhinolaryngol* 67(2003),1055-60.

- Kang K.T., Chou C.H., Weng W.C., Lee P.L., Hsu W.C. Associations between adenotonsillar hypertrophy, age, and obesity in children with obstructive sleep apnea. *PLoS One* 8(2013), e78666.
- Wang, J., Zhao, Y., Yang, W. et al. Correlations between obstructive sleep apnea and adenotonsillar hypertrophy in children of different weight status. *Sci Rep* (2019) 9, 11455.
- Yan XH, Zhao Y, Wang J, Shen T, Yang W, Qiao Y, Cheng D, Chen M. Associations among sleep symptoms, physical examination, and polysomnographic findings in children with obstructive sleep apnea. *Eur Arch Otorhinolaryngol.* 2020 Feb;277(2):623-630.
- Lu CT, Li HY, Lee GS, Huang YS, Huang CG, Chen NH, Lee LA. Snoring sound energy as a potential biomarker for disease severity and surgical response in childhood obstructive sleep apnoea: A pilot study. *Clin Otolaryngol.* 2019 Jan;44(1):47-52.
- Markkanen S, Rautiainen M, Himanen SL, Satomaa AL, Katila M, Peltomäki T, Saarenpää-Heikkilä O. Snoring toddlers with and without obstructive sleep apnoea differed with regard to snoring time, adenoid size and mouth breathing. *Acta Paediatr.* 2021;110(3):977-984.
- Tagaya M, Nakata S, Yasuma F, Miyazaki S, Sasaki F, Morinaga M, Suzuki K, Otake H, Nakashima T. Relationship between adenoid size and severity of obstructive sleep apnea in preschool children. *Int J Pediatr Otorhinolaryngol.* 2012 Dec;76(12):1827-30.
- Valera FC, Avelino MA, Pettermann MB, Fujita R, Pignatari SS, Moreira GA, Pradella-Hallinan ML, Tufik S, Weckx LL. OSAS in children: correlation between endoscopic and polysomnographic findings. *Otolaryngol Head Neck Surg.* 2005 Feb;132(2):268-72.
- Arens, R. et al. Upper airway structure and body fat composition in obese children with obstructive sleep apnea syndrome. *Am J Respir Crit Care Med* (2011)183, 782–787.
- Lee SY, Kim JW. Nasopharyngeal Width and Its Association with Sleep-Disordered Breathing Symptoms in Children. *Clin Exp Otorhinolaryngol.* 2019;12(4):399-404 .
- Arens R, McDonough JM, Costarino AT, Mahboubi S, Tayag-Kier CE, Maislin G, Schwab RJ, Pack AI. Magnetic resonance imaging of the upper airway structure of children with obstructive sleep apnea syndrome. *Am J Respir Crit Care Med.* 2001 Aug 15;164(4):698-703 .
- Lertsburapa K, Schroeder JW Jr, Sullivan C. Assessment of adenoid size: A comparison of lateral radiographic measurements, radiologist assessment, and nasal endoscopy. *Int J Pediatr Otorhinolaryngol.* 2010 Nov;74(11):1281-5.
- Arens R, McDonough JM, Corbin AM, Rubin NK, Carroll ME, Pack AI, et al. Upper airway size analysis by magnetic resonance imaging of children with obstructive sleep apnea syndrome. *Am J Respir Crit Care Med.* 2003 Jan;167(1):65–70
- Afify, W., Arafa, T. M., & SHAHEEN, A. M. (2024). Respiratory distress in neonatal intensive care unit in Benha university hospital. *Benha Medical Journal*,41(Special issue (Pediatrics)), 1-7.

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