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THE IMPACT OF OBSTRUCTIVE SLEEP APNEA ON RIGHT VENTRICULAR FUNCTION IN CHILDREN WITH ADENOTONSILLAR HYPERTROPHY) A NOVEL FEATURE-TRACKING ECHOCARDIOGRAPHIC METHOD

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Abstract

Obstructive sleep apnea (OSA) is frequently caused by adenotonsillar hypertrophy (ATH), which may be harmful to cardiac health. Our goal was to assess how OSA affected the right ventricular function in kids with adenotonsillar hypertrophy (ATH) and assess different modalities of cardiac function with the help of echocardiography.

increased oxidative and nitrosative stress associated with disturbances in the antioxidant defense system has been implicated in the pathogenesis of several diseases.

This hospital-based randomized prospective case-control study was conducted on 52 kids with ATH and 25 healthy kids (5-12 years old) at Al-Zahra University Hospital. OSA was detected using polysomnography while right ventricular (RV) function was assessed using different modalities of echocardiography in addition to assessment of adenotonsillar hypertrophy, measurement of serum brain natriuretic peptide (BNP) and oxidative stress markers . OSA was detected in 64% of children with ATH. Particularly in those with OSA, there is a significantly elevated BNP level, myocardial performance index (MPI), and pulmonary artery pressure together with a significantly decreased RV

global longitudinal strain and tricuspid annular plane systolic excursion (TAPSE). The apnea/hypopnea score significantly correlates negatively with TAPSE and significantly positively with pulmonary artery systolic pressure, MPI, and BNP level. Regarding the biochemical results, there was oxidative stress evidenced by the measured parameters. Malondialdehyde and NO levels were significantly elevated in the blood samples of OSA patients as compared with the healthy controls. The antioxidant enzymes SOD and catalase were significantly reduced in the OSA group than in the control group

We have concluded that there can be subclinical cardiac dysfunctions that occur because of ATH. Routine cardiac screening in children presenting with sleep-disordered breathing associated with adenotonsillar hypertrophy may help identify and prevent the development of cardiopulmonary complications.

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

Introduction

Children with adenotonsillar hypertrophy (ATH) frequently experience sleep-related breathing disorders and obstructive sleep apnea (OSA), which reduces their quality of life and increases the risk for short- and long-term morbidities like stunted growth, cognitive, behavioral, and cardiopulmonary complications. Such morbidities should be taken into consideration during surgical intervention decisions. Despite emerging evidence that demonstrated cardiac sequences of OSA there is still insufficient awareness of both parent and physician about such problems leading to delay in surgery decision that further exposes such children to more myocardial impairment [1].

Airway obstruction is suspected via the history of snoring, sleep apnea, mouth breathing, and airway narrowing in lateral nasopharynx X-rays. Polysomnography (PSG) is the gold standard for detecting OSA [2]. Recent modalities in echocardiography including speckle tracking and 3D imaging Tricuspid annular plane systolic excursion (TAPSE), Myocardial Performance Index (MPI/Tei Index), and longitudinal strain are three parameters that provide a better evaluation of myocardial deformation allowing early detection of myocardial dysfunction [3].

On exposure to volume or pressure overload, the heart releases a 32-amino acid peptide called brain natriuretic peptide (BNP) that induces vasodilation, and diuresis and has an anti-hypertrophic effect on the myocardium. The combination of cardiac imaging and biomarkers allows better identification of the pathophysiological processes and early detection of cardiac dysfunction in asymptomatic high-risk subjects [4]. This study aimed to assess how OSA affected RV function in kids with ATH.

Materials and Methods:

Study design.

The study was conducted in the Department of ENT in collaboration with the Department of Pediatrics from May 2019 to July 2022 at Al-Zahra University Hospital, Cairo, Egypt.

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 after informed consent was obtained from all parents before involvement in the study.

Among the randomized 103 children who were presented with ATH, only 70 fulfilled our inclusion and exclusion criteria. 52 out of the 70 initially enrolled children completed all echocardiographic modalities assessment (6 refuse to do echocardiography, and 12 have technical difficulties due to being uncooperative children). Only 25 out of the 52 enrolled children completed the Polysomnography assessment (PSG) and agreed to do a laboratory investigation. The final study sample included 52 children with ATH who underwent echocardiographic assessment; 25 of them also completed PSG and laboratory measurement of BNP serum level. 25 age- and sex-matched healthy kids who did not meet any of the exclusion criteria for obesity or upper respiratory tract conditions (eg. allergic rhinitis) were enrolled as a control group.

Children with obesity, neuromuscular, cardiorespiratory, craniofacial, or skeletal malformations or those who took drugs that affected sleep, or refused to participate were excluded from the study. Each kid had a thorough medical history taken, general, ENT, and systemic examination with a focus on any symptoms that suggest sleep-disordered breathing (snoring, nasal tone, sleep apnea, mouth breathing).

Polysomnography (PSG)

At least 8 hours PSG for one night utilizing PSG equipment (model BWIII; Product of Neurovirtual USA) at the pediatric neurophysiology unit at Alzahraa Hospital, Al-Azhar University. AHI greater than 5 events/hours was used to identify obstructive sleep apnea [5].

Echocardiographic examination:

Echocardiography was done while the patient was in the left lateral decubitus position using Vivid E9 GE ultrasonography Horten, Norway with tissue Doppler and speckle tracking capabilities. Parasternal and apical positions were used to obtain 2D-, M-Mode-, and tissue Doppler echocardiographic procedures. Systolic diastolic functions and, pulsed wave TDI tests were evaluated based on the American Society of Echocardiography's guidelines [6]. RV Tei index was calculated from the trans-tricuspid and trans-pulmonary Doppler signals. (RV a time - RV b time)/RV b time. TR jet velocity was used to calculate the RV systolic pressure. Data were averaged across three consecutive cycles with associated ECG. 2D-STE analysis was carried out using Echopac Workstation Version 202 GE Healthcare software.

Two expert pediatric cardiologists independently perform an echocardiographic assessment for the included children during the same visit. All children were examined preoperatively.

Assessments of ATH

The adenoid size was evaluated using a lateral X-ray of the nasopharynx using standard techniques. Adenoid hypertrophy was identified when the adenoid-nasopharynx ratio exceeded 0.67. The adenoid depth to nasopharynx diameter ratio was determined according to Fujioka et al. [7]. Tonsillar hypertrophy was identified when tonsils extend outside the pillars according to Brodsky et al. [8].

Biochemical study of oxidative stress markers

Blood samples (5 ml) were collected from the subjects by venous arm puncture under aseptic precautions and transferred into sterilized EDTA vials. The collected blood samples were centrifuged at 3000 rpm for 10 min to separate plasma and erythrocytes. Plasma samples were used for NO analysis while erythrocyte samples were utilized for analysis of MDA, SOD, and catalase. For MDA 1:1 RBC hemosylate was used and for SOD and catalase, the hemosylate was diluted to 1:50 with 0.9% normal saline. Analysis was performed using UV visible spectrophotometer (Shimadyu Scientific Instruments, USA). Blood samples from the diseased children, and the normal controls were analyzed for malondialdehyde (MDA) and nitric oxide (NO) as indicators of oxidative stress and nitrosative stress respectively; superoxide dismutase (SOD) and catalase enzymes as indicators of antioxidant defense by UV visible spectrophotometer.

The levels of malondialdehyde (MDA) (Ohkawa et al., 1979), superoxide dismutase (SOD) (Nishikimi et al., 1972), and total antioxidant capacity (TAC) (Koracevic et al., 2001) were determined colorimetrically by the manufacturer’s instructions provided by Biodiagnostic Co, Egypt.

Measurement of serum brain natriuretic peptide (BNP)

3ml of venous blood samples from each subject and control were taken under strict aseptic conditions placed in a simple tube and allowed to clot for 10 to 20 minutes at room temperature then centrifugation at 2,000–3,000 rpm for 20 minutes. Human BNP level was assessed by Sandwich ELISA (Bioneovan Co.), and the kites were acquired from, and kept at -80°C until tests (Bioneovan Co Cata.N.: in-Hu3187).

The appropriate Micro ELUISA strip plate wells were filled with standards or samples, together with the designated antibody then filled with a Horseradish Peroxidase (HRP) conjugated antibody that was specific for BNP before being incubated. TMB substrate solution was added. Only the wells containing BNP and HRP-conjugated BNP antibodies showed a blue appearance before becoming

yellow upon the addition of the stop solution. At a wavelength of 450 nm, the optical density (OD) was measured spectrophotometrically.

Statistical analysis

Statistical Package for Social Sciences was used for data analysis (version 21; SPSS Inc., Chicago, IL, USA). Data were presented as mean, standard deviation, and percentages. For group comparison, an independent t-test, chi-square test, and ANOVA test were performed. Pearson coefficients test was utilized for correlations between parameters. Post hoc analysis was used to examine variations between subgroups. The relationship between the severity of OSA and the echocardiographic signs of RV dysfunction was shown by linear and stepwise regression analysis. P-values less than 0.05 were regarded as significant.

Result;

30 male and 22 female children with ATH and 25 healthy children (16 Male, 9 Female) of the same age and sex underwent echocardiographic evaluation. Children with ATH had worse systolic and diastolic RV performance, and higher peak pulmonary artery pressure and BNP blood levels as shown in Table 1 and Figures (1,2 &3).

Table 1: Comparison of echocardiographic data of initially enrolled children with adenotonsillar hypertrophy (n=52) and healthy controls

	Adenotonsillar hypertrophy N=52 Mean ± SD			Healthy controls N=25 Mean ± SD			Independent t-test/chi-square test	
							t/x²	**p-value**
IVS (mm)	6.000	±	1.143	6.660	±	0.800	-2.902	0.005
TV spg (mmHg)	29.480	±	4.599	19.120	±	2.048	13.479	<0.0001
Mean PAP (mmHg)	34.480	±	4.635	23.760	±	2.420	13.157	<0.0001
TV E	68.120	±	14.795	65.840	±	10.785	0.759	0.451
TV A	67.720	±	13.085	55.160	±	10.645	4.453	<0.0001
TV DT	118.560	±	30.729	184.480	±	32.891	-8.361	<0.0001
PV spg (mmHg)	4.028	±	1.201	3.468	±	0.605	2.685	0.009
PV AT	109.960	±	31.268	133.240	±	16.826	-4.189	<0.0001
PV E/A	254.440	±	27.424	272.000	±	24.478	-2.812	0.007
TV E/A	345.240	±	34.069	348.880	±	24.320	-0.532	0.597
RV MPI	0.380	±	0.103	0.249	±	0.067	6.627	<0.0001
Ta S	8.866	±	2.067	9.680	±	1.079	-2.239	0.028
Ta E	9.499	±	3.204	10.120	±	2.297	-0.962	0.340
Ta A	7.280	±	2.525	5.000	±	0.764	5.870	<0.0001
RVGLS	19.836	±	4.075	23.564	±	0.662	-6.305	<0.0001
TAPSE	18.840	±	2.486	20.160	±	1.281	-3.035	0.003
Age (year)	6.160	±	1.633	6.840	±	1.280	-1.972	0.053
Sex(male/female)	30/22			16/9			0.279	0.597

P-value< 0.05 is significant. IVS: intraventricular septum; RV: right ventricle; TVspg: tricuspid valve systolic pressure gradient; PV spg: pulmonary valve systolic pressure gradient; PAP: pulmonary artery pressure; TVDT: tricuspid valve deceleration time; RVGLS: right ventricle global longitudinal strain; TAPSE: tricuspid annular plane systolic excursion; MPI: myocardial performance index; A & E: early (E) and late (A) filling peak velocities; Ta S: tricuspid annular systolic velocity.

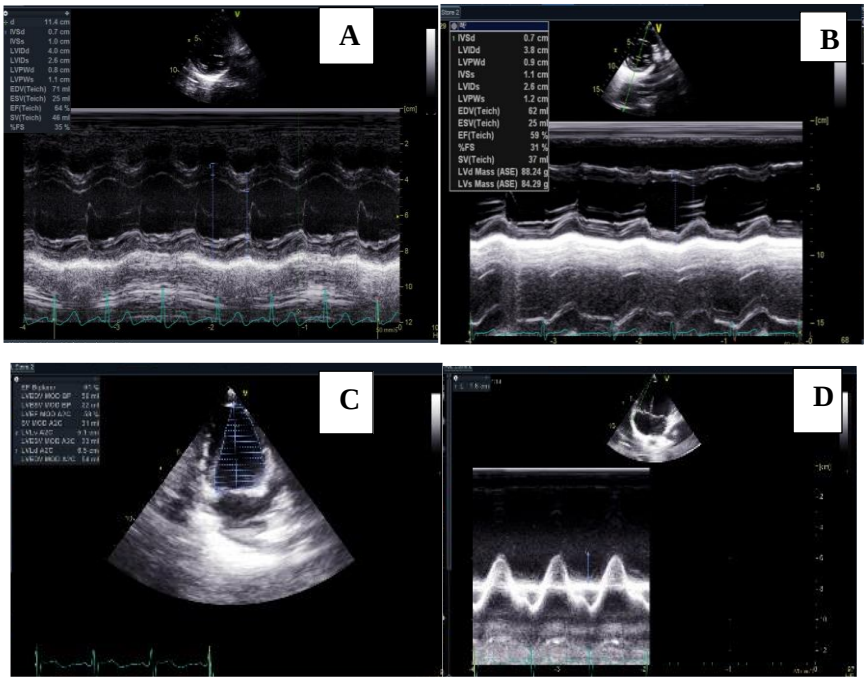

Fig. (1): A & B: represents: parasternal short axis view 2-D guided M-mode at the papillary muscle level to get the left ventricular end systolic and diastolic dimensions (LVEDd, LVESd), LV wall thickness (IVSd& LVPWd) and Left ventricular ejection fraction EF% by M-mode. C: EF by biplane method, D: 2-D guided M-mode on the right ventricle (RV) free wall at the tricuspid valve (TV) annulus to get tricuspid annular plan systolic excursion (TAPSE) for assessment of RV systolic function.

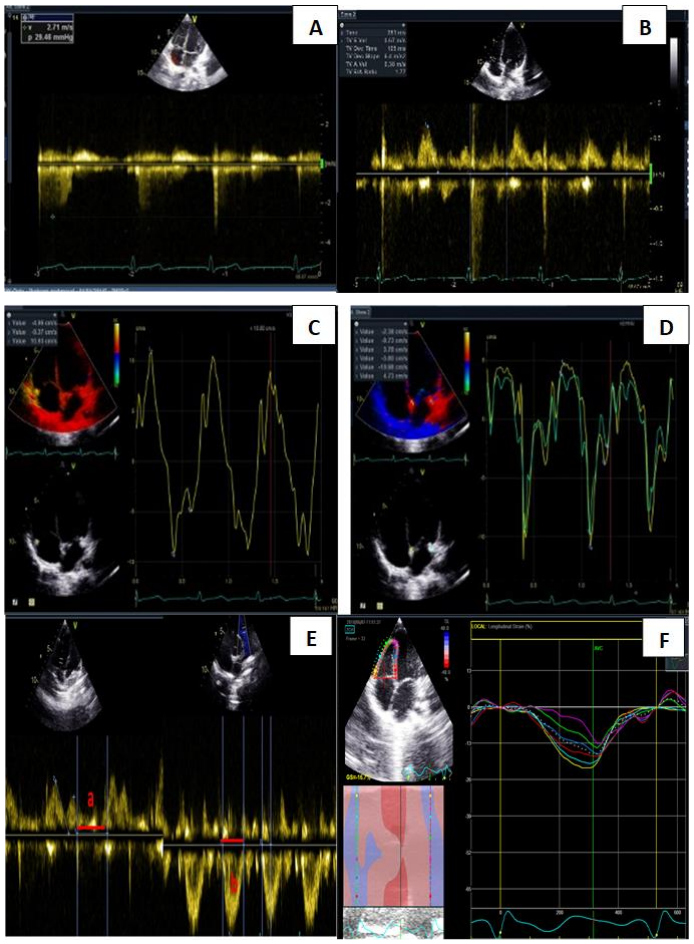

Fig.(2): A: spectrum of continuous wave of the Tricuspid valve (TV) flow at the level of the TV to get the TV regurgitant flow (TR maximum systolic velocity) to get the RV systolic pressure B: spectrum of the Doppler flow of the TV to get TV early and late diastolic flow (TV E, TV A velocities) for assessment of RV diastolic function. C&D: showed offline Tissue Doppler imaging analysis of the TV free wall annulus spectrum to measure the RV systolic peak velocity (Ta S) early and late peak diastolic velocities (Ta E & Ta A). E: illustrate the Pulsed Doppler of the TV inflow cursor just below the tip of the TV in the apical 4-chamber view and the pulmonary valve in the PV outflow view to get the myocardial performance index (MPI) or Tie index of the RV using the equation (RV a time – RV b time)/RV b, where RV a time = sum of isovolumic contraction time (IVCT) & isovolumic relaxation time (IVRT). RV b time =ejection time (ET). RV MPI=(a-b)/b. F: Right ventricular (RV) function by two-dimensional (2D) speckle tracking echocardiography (STE) global longitudinal strain (GLS) in apical4-chamber view.

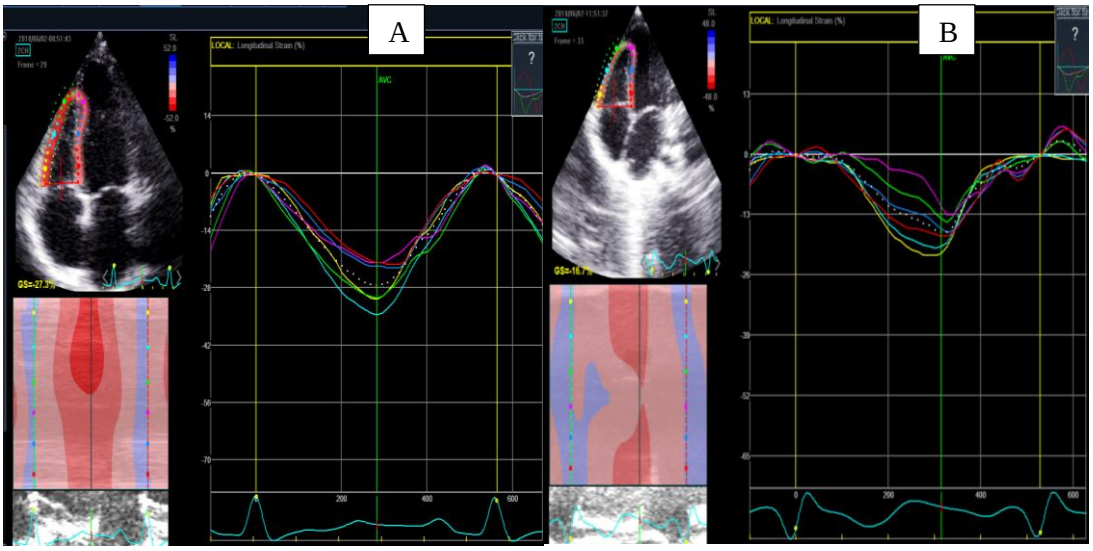

Figure (3): A: one of our patients 5 Ys old girl with normal RV peak global longitudinal strain (RV PGLS=- 27.3), B: 5 years old boy with impaired RV peak global longitudinal strain (RV PGLS =- 16.7)

In 25 children with ATH who underwent PSG and laboratory evaluation, OSA was found in 16 (4 of severe, 6 of moderate, and 6 of mild severity), but not in any of the healthy children. There was no statistically significant age or sex difference between the studied groups.

There is significantly impaired sleep efficiency, increased AHI, increased arousal index, and disturbed sleep architecture, in addition to impaired both systolic and diastolic RV function with elevated peak pulmonary artery pressure and increased BNP serum level in those with ATH than healthy controls especially those who had OSA as shown in table 2.

Table 2: Comparison of Echocardiographic, polysomnographic, and brain natriuretic peptide in the studied groups

	adenotonsillar hypertrophy with OSA N = 20	**adenotonsillar hypertrophy without OSA N = 32**	**Healthy Control N = 25**	ANOVA	**OSA vs non-OSA**	**OSA vs control**	**non-OSA vs control**
	Mean ± SD	Mean ± SD	Mean ± SD	P-value	P-value	P-value	P-value
IVS (mm)	5.941 ±1.297	6.125 ± 0.834	6.66±0.8	0.071	0.966	0.150	0.360
TVspg (mmHg)	31.117 ± 4.414	26.001 ± 3.023	19.12±2.047	<0.0001	0.009	<0.0001	0.001
Mean PAP	36.117 ±4.470	31.021 ± 3.023	23.76±2.420	<0.0001	0.009	<0.0001	<0.0001

(mmHg)							
TV A	67.647 ± 12.252	67.875 ±16.003	55.160 ±10.644	0.003	0.928	0.005	0.181
TV DT	116.412± 31.697	123.125± 31.197	184.48±32.891	<0.0001	0.947	<0.0001	0.001
PVspg (mmHg)	4.371 ± 1.151	3.300 ±1.063	3.468±0.605	0.004	0.108	0.021	0.968
PV AT	103.705 ±26.236	123.250 ± 39.391	133.24±16.825	0.002	0.544	0.001	0.879
PV EA	246.588 ± 23.893	271.125 ± 29.318	272±24.478	0.006	0.175	0.006	0.932
RV MPI	0.415 ± 0.099	0.302 ± 0.066	0.248±0.067	<0.0001	0.009	<0.0001	0.194
Ta A	7.452 ± 2.874	6.912±1.792	5.00 ±0.763	<0.0001	0.922	0.009	0.057
RVGLS	18.482 ± 4.141	22.712±2.237	23.564±0.661	<0.0001	0.009	<0.0001	0.688
TAPSE	18.705 ± 2.365	19.125±2.948	20.160 ±1.280	0.024	0.981	0.036	0.608
Age (year)	6.176 ± 1.704	6.125±1.642	6.960 ±1.485	0.214	0.967	0.350	0.538
AHI	14.588 ± 4.886	1.625±1.060	0.348 ±0.454	<0.0001	<0.0001	<0.0001	0.033
AI	10.776 ± 4.221	0.600±0.374	2.156 ±2.219	<0.0001	<0.0001	<0.0001	0.007
SE%	85.764 ± 3.072	92.250±1.669	94.048 ±2.097	<0.0001	<0.0001	<0.0001	0.023
REM%	18.588 ± 2.237	22.375±1.407	22.776±2.097	<0.0001	<0.0001	<0.0001	0.906
NREM1%	17.294±7.024	5.875±0.991	4.888±0.767	<0.0001	<0.0001	<0.0001	0.081
NREM2%	49.823±2.42	50.500±1.851	50.136±3.059	0.837	0.836	0.977	0.970
NREM3%	19.588 ± 2.647	21.375±2.386	22.264 ±2.108	0.003	0.301	0.005	0.746
BNP (ng/ml)	3.088 ±1.849	0.467±0.356	0.863 ± 0.688	<0.0001	<0.0001	<0.0001	0.056

P-value< 0.05 is significant. IVS: intraventricular septum; RV: right ventricle; TVspg: tricuspid valve systolic pressure gradient; PV spg: pulmonary valve systolic pressure gradient; PAP: pulmonary artery pressure; TVDT: tricuspid valve deceleration time; RVGLS: right ventricle global longitudinal strain; TAPSE: tricuspid annular plane systolic excursion; MPI: myocardial performance index; A & E: early (E) and late (A) filling peak velocities; Ta S: tricuspid annular systolic velocity; OSA: obstructive sleep apnea; BNP: brain natriuretic peptide; AHI: apnea-hypopnea index; AI: arousal index; SE: sleep efficiency; REM: rapid eye movement sleep; N

There is a significant correlation between echocardiographic indices of RV myocardial dysfunction, serum level of BNP, and the severity of OSA as demonstrated in Table 3

Table 3: Correlation of echocardiographic, brain natriuretic peptide and severity of OSA in the studied children

	AHI	
	r	p-value
BNP (ng/ml)	0.391	<0.0001
IVS (mm)	-0.331	0.020
TV spg (mmHg)	0.848	<0.0001
Mean PAP (mmHg)	0.842	<0.0001
TV E	0.262	0.069
TV A	0.236	0.103
TV EA	-0.053	0.717
TV DT	-0.574	<0.0001
PV spg (mmHg)	0.453	0.001

PV AT	-0.462	0.001
PV EA	-0.325	0.023
RV MPI	0.576	<0.0001
Ta S	-0.194	0.181
Ta A	0.342	0.016
Ta E	0.003	0.982
RVGLS	-0.687	<0.0001
TAPSE	-0.355	0.012

P-value< 0.05 is significant. IVS: intraventricular septum; RV: right ventricle; TVspg: tricuspid valve systolic pressure gradient; PV spg: pulmonary valve systolic pressure gradient; PAP: pulmonary artery pressure; TVDT: tricuspid valve deceleration time; RVGLS: right ventricle global longitudinal strain; TAPSE: tricuspid annular plane systolic excursion; A & E: early (E) and late (A) filling peak velocities; Ta S: tricuspid annular systolic velocity; OSA: obstructive sleep apnea; BNP: brain natriuretic peptide; AHI: apnea-hypopnea index; REM: non-rapid eye movement sleep.

Linear regression analysis and stepwise regression analysis demonstrated that increased AHI was significantly associated with elevated PAP, RV MPI (tie index), and RV GLS suggesting a direct effect of OSA severity on RV function and peak pulmonary pressure as shown in Tables 4 & 5. and figures 2 &3.

Table 4: Linear regression analysis for the association between AHI as the dependent factor with indicators of right ventricular dysfunction

Coefficients							
Model		Unstandardized Coefficients		Standardized Coefficients Beta	t	P-value	95.0% Confidence Interval for B
		B	Std. Error				Lower Bound / Upper Bound
	(Constant)	-1.109	4.341		-0.255	0.800	-9.864 / 7.646
	RV MPI	10.393	3.182	0.154	3.267	0.002	3.977 / 16.809
	RV GLS	-0.331	0.110	-0.159	-3.014	0.004	-0.552 / -0.110
	TAPSE	0.128	0.152	0.037	0.837	0.407	-0.180 / 0.435
	BNP	2.796	0.247	0.679	11.313	<0.0001	2.297 / 3.294
	Mean PAP	0.160	0.078	0.145	2.042	0.047	0.002 / 0.318
a. Dependent Variable: AHI							

P-value< 0.05 is significant. PAP: pulmonary artery pressure; RVGLS: right ventricle global longitudinal strain; TAPSE: tricuspid annular plane systolic excursion; MPI: myocardial performance index; BNP: brain natriuretic peptide.

Table 5: Stepwise regression analysis for the association between AHI as the dependent factor with indicators of right ventricular dysfunction

Model		Unstandardized Coefficients		Standardized Coefficients	t	p-value	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	0.939	0.464		2.023	0.049	0.005	1.873
	BNP	3.836	0.219	0.931	17.504	<0.0001	3.395	4.277
2	(Constant)	-3.617	1.001		-3.615	0.001	-5.631	-1.603
	BNP	3.441	0.196	0.835	17.524	<0.0001	3.046	3.837
	RV MPI	15.847	3.220	0.235	4.922	<0.0001	9.366	22.327
3	(Constant)	5.565	2.718		2.048	0.046	0.091	11.039
	BNP	3.098	0.200	0.752	15.512	<0.0001	2.696	3.501
	RV MPI	13.082	2.974	0.194	4.398	<0.0001	7.092	19.073
	RV GLS	-0.364	0.102	-0.175	-3.577	0.001	-0.569	-0.159

a. Dependent Variable: AHI

P-value< 0.05 is significant. RVGLS: right ventricle global longitudinal strain; MPI: myocardial performance index; BNP: brain natriuretic peptide

Regarding the biochemical results,. Malondialdehyde and NO levels were significantly elevated in the blood samples of OSA patients as compared with the healthy controls. The antioxidant enzymes SOD and catalase were significantly reduced in the OSA group than in the control group as shown in table 6

Table 6: Effect of oxidant/antioxidant biomarkers in studied groups

	adenotonsillar hypertrophy with OSA N = 20	**adenotonsillar hypertrophy without OSA N = 32**	**Healthy Control N = 25**	ANOVA	**OSA vs non-OSA**	**OSA vs control**	**non-OSA vs control**
	Mean ± SD	Mean ± SD	Mean ± SD	P-value	P-value	P-value	P-value
MDA (nmolg)	161.45 ± 24.15	158.09 ± 23.88	139.84 ±1.344	0.071	0.966	0.150	0.360
SOD ug	38.6 ± 5.48	35.75 ± 2.2	36.44 ± 1.15	0.052	0.830	0.001	0.210
NO imol	173.4 ± 48.3	170.3 ± 2.1	82.6 ± 0.95	0.005	0.021	0.002	0.001
catalase	1.48 ± 0.29	1.03 ± 1.1	1.05 ± 0.15	0.001	0.001	0.001	0.001

All values are presented as mean±SD, by ordinary ANOVA or Welch's ANOVA test followed by Tukey's test and Dunnett's T3 test post-hoc multiple comparisons tests, respectively, at P-value < 0.05. Abbreviations; SOD, superoxide dismutase; CAT, catalase; MDA, malondialdehyde

Discussion:

The most frequent cause of OSA in children is ATH which is thought to negatively impact the cardiac structure and function [1]. In our study 64% of the children with ATH had OSA. These results are in line with earlier studies that found untreated ATH tripled the risk of OSA [8]. ATH was a typical cause of OSA even in infants [9].

Our study revealed that children with ATH significantly reduced their ability to fall asleep, disrupted sleep patterns, RV dysfunction, elevated pulmonary artery pressure, and serum BNP levels, even in those who did not have OSA indicating that any degree of airway narrowing negatively impacts cardiac function and sleep effectiveness in such children. Cardiac impairment and sleep disturbance significantly correlated to the severity of OSA.

In agreement with our findings, Greenfeld et al [10] demonstrated that OSA induces morphological changes affecting both right and left ventricles that were significantly correlated to the severity of

OSA. Duman et al [11] found that the RV myocardial performance index significantly impaired in children with ATH that reversed after adenotonsillectomy. Children with ATH have higher mean pulmonary arterial pressure, according to Orji et al. [12]. Children with ATH are more likely to develop pulmonary hypertension, according to the findings of Naiboglu et al. [13], regardless of the severity of airway obstruction. According to Granzotto et al. [14], in children with ATH, a greater palatine tonsil width/depth was linked to a higher risk for cardiac problems and pulmonary hypertension.

Chronic airway obstruction causes hypoxia and hypercapnia, which mediate pulmonary vasoconstriction, increase pulmonary vascular resistance, and elevate pulmonary arterial pressure that in the long term induces RV dysfunction. Additionally, increased negative intrathoracic pressure against an obstructed airway leads to increased venous return and volume overload of the right ventricle that improved after adenotonsillectomy reflecting the role of early intervention on long-term comorbidities in children with ATH [15].

The complicated geometry of the right ventricle, which is crescent-shaped in cross-section and triangular in lateral view, makes it difficult to accurately assess its structure and function. A conventional echocardiogram is a useful tool for evaluating ventricular dysfunction, but more sophisticated techniques such as Tissue Doppler echocardiography, speckle tracking, and 4D echocardiography offer more precise quantitative data that enable early detection of myocardial dysfunction. Doppler echocardiography has a perfect correlation with cardiac catheterization for early detection of elevated pulmonary pressure in high-risk populations [16].

Children with OSA in the current study had significantly worse RV MPI/Tie index, TAPSE, and RV GLS than OSA-free or healthy children, which indicates subclinical RV impairment. Regression analysis revealed that RV MPI and RV GLS were sensitive indicators for the severity of OSA. Cincin et al [17] found that children with OSA due to ATH had higher pulmonary artery pressure and impaired RV function (lower MPI, TAPSE) and significantly lower tricuspid isovolumic acceleration and pulmonary acceleration time than the control group. Ehsan [18] systematic review and meta-analysis demonstrated that the baseline of PAP and RV dimensions were within normal limits in many studies that evaluated children with ATH. According to Maripov et al. [19], participants with OSA exhibited a considerably larger RV internal diameter and wall thickness, as well as a higher RV myocardial performance index, lower RV S', and more TAPSE. In children with ATH, Abdel-Aziz [20] found higher PAP, decreased RV diastolic filling characteristics (E/A), and increased RV end-diastolic diameters. In children with ATH compared to the control group, Kocabaş et al [21] found that RV ends diastolic dimension, RV MPI, and mean PAP were significantly higher, while E/A ratio at both mitral and tricuspid valves and E0/A0 ratios at the tricuspid lateral and mitral septal segments were significantly lower. This suggests myocardial diastolic dysfunction. Lee et al [15] reported higher plasma NT-proBNP levels in children with ATH despite no discernible variation in echocardiographic characteristics. This discrepancy may be explained as all children were assessed for snoring, and none of them had OSA.

According to our findings, AHI significantly correlates to RV dysfunction indices including RV MPI, TAPSE, and RV GLS, which is consistent with earlier studies [22]. This suggests a negative impact of OSA on both systolic and diastolic RV functions that were closely correlated to AHI. Tavil et al. [23] discovered decreased RV systolic and diastolic functions (TAPSE, peak systolic myocardial velocity at tricuspid lateral annulus (S-vel), and RV MPI) in those with OSA. Children with OSA caused by ATH showed higher systolic and mean PAP, pulmonary vascular resistance, and poorer MPI of both the right and left ventricles than healthy controls, according to research by Attia et al. [24].

Our study's findings supported those of earlier research, showing that OSA significantly affects pulmonary pressure. Furthermore, our research showed a substantial association between pulmonary pressure and the severity of OSA. Even in those without OSA, PAP was greater than in healthy subjects. These results imply that any change in airflow, even if mild and inadequate to cause OSA may negatively impact pulmonary vascular tone, leading to an increase in pulmonary pressure. According to Cho [25], even brief episodes of apnea/hypopnea lasting 10 seconds were linked to

desaturation, which occurred more frequently than OSA.

BNP has been utilized to assess early myocardial remodeling induced by either pressure or volume overload. In this study, heart function was assessed using a variety of techniques, such as a combination of biochemical and echocardiographic indicators. Even in individuals without OSA, BNP levels were considerably greater in children with ATH, indicating that cardiac biomarkers can be used to assess heart function early on, even before alterations to the echocardiogram.

The small number of children included in the study is seen as a significant constraint that prevents generalizing our findings; despite this, our findings have statistical significance. Reassessment after adenotonsillectomy was missed because most patients skipped follow-up appointments.

Conclusion:

Long-term comorbidities associated with persistent upper airway obstruction were not included in the adenotonsillectomy guidelines. Pairing circulating cardiac biomarkers and advanced echocardiographic modalities, as opposed to standard echocardiography, can define subtle RV dysfunction leading to early surgical decision-making.

Echocardiography which is a simple, cheap, and non-invasive modality may be helpful in identifying earlier cardiovascular changes. Early detection and timely management can prevent the development of late sequelae of cardiac complications which is more important in children with known cardiac elements.

As a result, otolaryngologists should take cardiac considerations into account while managing children with ATH.

If a child presents with adenotonsillar hypertrophy causing obstructive sleep symptoms, we recommend sleep study by polysomnography and cardiac screening in the form of echocardiography as a part of the pre-operative workup.

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Declaration of interests

☒ 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.

☒The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Conflicts of Interest: The authors declare no conflict of interest.

Data Availability Statement: Data will be provided upon reasonable request.

Declarations:

- Ethics approval: 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

-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.

-Informed Consent Statement: All participants provided informed consent.

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Author's contributions: All coauthors attended the initial meeting and participated in the discussion of topics and in the design of the consensus paper. Eman faruk wrote the initial draft of the manuscript which was then circulated to all coauthors. Comments and annotations of all coauthors were included in subsequent drafts. The final version of the manuscript was approved by all coauthors.

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