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Original Research Paper

Incidence of Cardiopulmonary Manifestations in Patients with Adenotonsillar Hypertrophy

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ABSTRACT:

Background: Adenotonsillar hypertrophy (ATH) is a common clinical problem in the pediatric age group. The treatment is primarily through oral medications and precautionary measures. In case of persistent and refracting cases causing significant airway obstruction, adenotonsillectomy is advised. In severe ATH and longstanding obstruction of airway, patient is prone to develop apneic spells and cardiopulmonary compromise. It then becomes essential to perform cardiac evaluation in such cases for effective management of the disease. **Objective:** To evaluate the incidence of cardiopulmonary complications in children with longstanding adenotonsillar hypertrophy and significant airway obstruction. **Study Design:** This is a tertiary hospital based observational prospective study at the Otorhinolaryngology, Department of Children Hospital and Institute of Child Health, Lahore, from October 2021- November 2022. **Results**: Total 110 patients were enrolled in this study with male to female ratio of 1.6:1. According to Brodsky classification, 82 (75%) had grade 3+ whereas 28 (25%) had grade 4+ tonsillar hypertrophy. All the patients had symptoms of moderate or severe snoring and apnea. ECG and Echocardiography of all the 110 patients showed cardiac manifestations which was completely resolved in 107 patients after 6 months of adenotonsillectomy, 2 patients were having remitting features and only one patient had persistent cardiac anomaly which was referred to cardiology dept. for further investigation. **Conclusion:** Cardiac complications are found common in children suffering from severe adenotonsillar hypertrophy with OSAS for a prolonged period. In patients with significant (>60%) airway obstruction, pre-op cardiac evaluation and post operative cardiac monitoring is essential.

Keywords: Obstructive sleep apnea syndrome (OSAS), adenotonsillar hypertrophy, electrocardiography, ECG changes, adenotonsillectomy.

INTRODUCTION:

Sore throat is the most common cause of ambulatory outpatient visits in childhood, worldwide [1]. Acute tonsilitis among pre-teens (5yrs-14yrs) accounts for approximately 2% and 1.3% of total pediatric outpatient visits in United States and worldwide, respectively [2] whereas, 34% (Confidence interval 95%, 1.3%-50.6%) of sore throats are diagnosed as adenoiditis, annually [3]. The prevalence is recorded higher in Asia than in Africa and America (48.0%, 95% CI[-2.0%, 98.0%], 27.0%, 95% CI[17.0%, 38.0%] and 24.0%, 95% CI[1.0%, 46.0%]), respectively. [4,5] The prevalence of adenotonsilitis remarkably decreases with age [4]. Viral etiology is common in children under 5 however, in the

age of 5-15years, bacterial infection is more common [5] In most of the cases, conservative management effectively treats adenotonsilitis. Recurrent ATH is when a patient develops 5 or more episodes in a year. About 11.7% (confidence Interval 95%, 11.0%-12.3%) develop recurrent ATH that significantly increases morbidity and decreases functionality in school going children. [5] Approximately, 30% of the cases develop peritonsillar abscess requiring tonsillectomy. [6] Sore throat with Adenotonsillar hypertrophy (ATH) is a commonly occurring phenomenon in children. If the symptoms persist or recur, then it can lead to obstructive sleep apnea syndrome (OSAS). [7] This generally considered benign condition can often have cardiovascular manifestations. It has been reported in the literature that increased upper-airway resistance resulting from hypertrophied tonsils and adenoids can cause intermittent airway obstruction, chronic alveolar hypoventilation, and can even lead to severe cardiopulmonary complications such as right ventricular (RV) failure and cor-pulmonale, a near-lethal culmination of pulmonary artery hypertension (PAH). [8] Nasal obstruction, snoring, and upper respiratory infections are common symptoms of OSAS in pediatric age group. Localized inflammation of the upper airway tissue and repeated upper airway obstruction inflict continuous and periodic mechanical insult, tissue vibration and fluctuating intra-pharyngeal pressures which can lead to adenotonsilitis. The mechanical airway obstruction can lead to cardiopulmonary compromise associated with hypercarbia, hypoxemia, metabolic acidosis, and vasoconstriction of pulmonary artery. Normally the pulmonary artery has minimal resistance due to high distensibility of pulmonary vasculature. [9] In OSAS, hypercarbia and hypoxemia cause progressive pulmonary artery constriction which increases resistance. To maintain the outflow, the right atrium and ventricle compensates for the pulmonary artery resistance by the combination of dilatation and hypertrophy. When the PA resistance increases markedly, then RV's compensatory mechanism becomes insufficient resulting in right sided heart failure, meanwhile the PA resistance keeps on increasing. Direct catheterization of RV or PA is a gold standard modality for respective pressure measurements, but the procedure is invasive, expensive, and is associated with several possible complications. Doppler electrocardiography is considered safer, quicker, and cost-effective investigations to detect cardiac abnormality. [9, 10] The intermittent collapse and occlusion of airway causes snoring. Snoring promotes inflammatory process and nasal obstruction which further aggravates snoring. This vicious cycle of disease progression leads to persistent adenotonsillar hypertrophy resulting in an array of complications. The fluctuating phases of hypoxia and re-oxygenation produce free radicals via several intracellular pathways, ample enough to cause local and systemic inflammation. [11,12] This study was conducted to explore and examine the association of adenotonsillar hypertrophy and cardiopulmonary status in patients with complaints of upper airway obstruction below the age of 14 years and to analyze the effect of adenotonsillar enlargement on cardiac aberration reflected in the electrocardiography (ECG) changes. This study also aims to highlight the potential severity of the resultant cardiopulmonary complications of ATH, the significance of cardiac evaluation in severe ATH related OSAS, along with special care and cardiac monitoring during and after the surgical intervention.

METHODOLOGY:

This prospective observational study was conducted at the pediatric otorhinolaryngology department, Children Hospital and Institute of Child Health, Lahore. The study included the patients who visited the outpatient department with long-standing adenotonsilitis along with its complications. The patients with severe respiratory distress were managed accordingly and adenotonsillectomy was scheduled for them after fulfilling the prerequisites which included cardiac evaluation. Detailed history and examination were done to diagnose the adenotonsilitis with OSAS. After taking the informed consent, the information was obtained with an interviewer assisted questionnaire based on patients' biodata and symptomatology. Then a careful ear, nose, and throat examination was performed. Palatine tonsils were examined for their size and signs of infection (erythema, exudates). The enlarged tonsils were assessed by using Brodsky grading method [13].

- Grade 0: Tonsils were resting in the tonsillar fossa and not visible behind the anterior tonsillar pillar or post-tonsillectomy
- Grade 1+: Tonsils were visible behind the anterior tonsillar pillars, occluding less than 25% of the oropharyngeal airway
- Grade 2+: Tonsils occupying more than 25% but less than 50% of the oropharyngeal airway
- Grade 3+: Tonsils occupying more than 50% but less than 75% of the oropharyngeal airway
- Grade 4+: Tonsils occupying more than 75% of the oropharyngeal airway or meeting in the midline
- Snoring was classified as mild, moderate, and severe.
- Mild: If present only in supine position and doesn't occur every night
- Moderate: If present every night but diminishes with change in position

- Severe: If present every night and not affected by change in position

Plain Xray Postnasal Space (PNS) lateral view of every patient was requested in erect position, with neck extended and mouth closed to assess the palatal airway and relative size of the adenoid gland. The size of adenoid is graded based on the degree of resultant airway obstruction which is in turn determined by the ratio of diameter of adenoid shadow on the radiograph to the nasopharyngeal tract diameter.

- Mild: Less than 50% nasopharyngeal airway obstruction
- Moderate: More than 50% but less than 100% nasopharyngeal airway obstruction
- Severe: Complete nasopharyngeal airway obstruction and no air column is seen in the postnasal space at the level of adenoid shadow.

The cardiothoracic ratio was measured by the plain chest radiograph (anteroposterior view) inspiratory film with lungs fully expanded and diaphragm pushed down. This is the ratio of the transverse diameter of the cardiac shadow to the transverse diameter of the chest (limited to the inner sides of the ribs). The normal cardiothoracic ratio is <0.5. Ratio greater than 0.5 indicates cardiomegaly and necessitates ECG/Echocardiography for further investigation. Electrocardiography (ECG) of all the patients was performed. The recorded ECG parameters included heart rate, heart rhythm, characteristics of ECG wave (P, QRS, and T wave), evidence of atrial/ventricular hypertrophy, and axis deviation. The ECG strips of all the patients were analyzed and reported by cardiologist and for all the abnormal ECGs, echocardiography was advised. The valuable parameters recorded on echocardiography were dimensions of Left atrium (LA), right ventricle (RV), posterior wall (PW), and Interventricular septum (IVS), left ventricle and end diastolic diameter (LVEDD), Isovolumetric relaxation time (IRT), left ventricle and systolic diameter (LVESD), Deceleration time (DT), fibre shortening (FS), peak late ventricular filling velocity (VA), peak early ventricular filling velocity (VE), and ejection fraction. The echocardiography was also performed post-operatively to rule out cardiac issue once the ECG became normal.

The saturation monitoring (SaO_2) of the patients was also documented for apnea and categorized into 3 groups.

- Mild apnea: $SaO_2 \geq 85\%$
- Moderate apnea: $SaO_2 = 65\text{-}84\%$
- Severe Apnea: $SaO_2 \leq 64\%$

In the adenotonsillectomies, firstly the enlarged adenoid gland was indirectly visualized by post-nasal mirror and palpated by the index finger. Then the adenoid curettage was done with Negus adenoid curette. The volume of the adenoid gland was measured by using an improvised test tube. The test tube was first filled with 10ml water and then the curetted pieces of adenoid gland were placed in it. The amount of displaced water was noted and the readings in milliliters were taken as the volume of the adenoid gland. The water displacement was noted by two different observers at a time, to eliminate human error. The average of the two readings was taken as a final reading for each case. After that, the enlarged palatine tonsils were cauterized by using bipolar cautery. Prior to the surgery, baseline investigations were done to call for anesthesia fitness. During and after the surgery, hemostasis was ensured.

Inclusion Criteria:

- Both male and female children of age 4 years to 14 years
- Children with the history of recurrent throat infections, long-standing snoring, and obstructive sleep apnea
- Children with enlarged adenoid gland and bilateral tonsils (≥Grade 3)
- Patients with cardiothoracic ratio more than 0.5
- Children fit for general anesthesia and adenotonsillectomy

Exclusion Criteria:

- Patients whose parents were not willing to enroll their child for the study
- Patients with other chronic diseases causing symptoms like OSAS such as morbid obesity, endocrine disorders, septal deviation, or craniofacial deformities in children with small sized palatine/lingual tonsils and adenoid tonsils (<Grade 2)

Data Analysis:

The results were tabulated, and the statistical analysis was performed using Statistical Package for Social Sciences Version 25 (SPSS v25). The Quantitative data analysis e.g., Age, Echocardiography and ECG features etc., of the patients was done by means and standard deviations. The Qualitative data analysis has variable outcomes e.g., Gender of the patient, components of clinical history and physical examination, etc. which were calculated by percentages and frequencies. The level of significance was determined at $P < 0.05$ and two-tailed level at 95% Confidence interval.

RESULTS:

By taking the inclusion and exclusion criteria into consideration, 110 patients were enrolled in this study. The results showed male predominance with male to female ratio of 1.6:1 comprising of males (n=68, 62%)

and females (n=42, 38%). However, gender did not correlate with the incidence of ATH ($P < 0.25$). Their age ranged from 4.7 years to 14 years with the mean age of 9.2±2.4 (mean ± SD). For ease, the patients are divided into 2 groups, 4-9 years (n=68, 62%), and 10-14 years (n=42, 38%). The indicator for the surgical correction of adenotonsillar hypertrophy was obstructive sleep apnea syndrome (OSAS) with recurrent mucopurulent nasal discharge (n=82, 75%, 95% CI), nasal blockage (n=102, 93%, 95% CI), and snoring (n=107, 97%, 95% CI). The symptoms of the patients on presentation are summarized in table 1.

Symptoms	Frequency	Percentage
Recurrent mucopurulent nasal discharge	82	75%
Mouth breathing	64	58%
Snoring	107	97%
Noisy breathing	48	44%
Cessation of breath during sleep	52	47%
Nasal blockage	102	93%
Recurrent cough	49	45%
Excessive daytime somnolence	10	9%
Restlessness during sleep	25	23%
Recurrent ear discharge	7	6%
Impairment of hearing	9	8%
Failure to grow like other children	2	2%
Recurrent otalgia	5	5%
Failure to thrive	3	3%
Impairment of speech	12	11%

Table 1. Summary of symptomatology of adenotonsillar hypertrophy associated with obstructive sleep apnea syndrome

According to Brodsky's classification, 82 (75%) of the study subjects were having enlarged tonsils of grade 3+ while the rest of the 28 (25%) patients were having grade 4+ tonsillar hypertrophy. Almost all the patients were having complaints of snoring, graded moderate in 73 (66%) and severe in 34 (31%) patients. Moderate apnea was documented in 27 (24.5%) and severe in 25 (23%) patients. There was no patient with mild snoring and mild apnea. (Table 2)

Brodsky classification for tonsils	Frequency	Percentage
Grade 3	82	75%
Grade 4	28	25%
Snoring	**Frequency**	**Percentage**
Moderate	73	66%
Severe	34	31%
Apnea	**Frequency**	**Percentage**
Moderate	27	25%
Severe	25	23%

Table 2. Findings of clinical examination and evaluation of the patients

The cardiothoracic ratio ranged from 0.89-1.72 with a mean value of 1.27 and SD ± 0.09. The adenoid and nasopharyngeal ratio ranged from 1.3 to 1.65 (mean=1.46, SD=±1.2). All the patients were having cardiac complications of various severity with or without functional abnormalities (systolic or diastolic dysfunction). The abnormal ECG was followed by echocardiography for the elaborative description of cardiac anomaly. The abnormal features of ECG in 110 patients are elaborated in table 2 and 3.

Figure 2. Pre operative chest xray of a patient (8 yrs old/male) showing cardiomegaly with cardiothoracic ratio of 0.9.

Figure 1. Post operative (after 6 months of adenotonsillectomy) Chest xray of the same patient with cardiothoracic ratio of 0.45.

Age Range	Leads	T-wave Inversion		R-wave Amplitude		S-wave Amplitude	
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
4-9 years	V4R	4	4%	7	6%	22	20%
	V4R-V1	3	3%	11	10%	25	23%
	V4R-V2	8	7%	13	12%	4	4%
	V4R-V3	5	5%	21	19%	14	13%
	V4R-V4	35	32%	4	4%	5	5%
	V4R-V5	2	2%	3	3%	10	9%
	V4R-V6	6	5%	2	2%	3	3%
10-14 years	V4R	3	3%	11	10%	9	8%
	V4R-V1	5	5%	8	7%	13	12%
	V4R-V2	10	9%	18	16%	17	15%
	V4R-V3	18	16%	21	19%	5	5%
	V4R-V4	32	29%	25	23%	3	3%
	V4R-V5	4	4%	32	29%	4	4%
	V4R-V6	3	3%	15	14%	31	28%

Table 3. ECG abnormalities in T-wave, R-wave, and S-wave in age groups of 4-9 years and 10-14 years

Age Range	Variables	Frequency	Mean ± SD		P-value
			Normal	OSAS	
4-9 years	Heart rate (bpm)	68	95.0 ± 10.0	105.2 ± 15.3	0.07
	P wave axis (˚)	68	53.0 ± 5.0	45.8 ± 13.7	0.09
	P duration (ms)	68	79.0 ± 8.0	92.4 ± 14.8	0.00
	PR interval (ms)	68	114.0 ± 15.0	129.0 ± 15.6	0.00
	QRS duration (ms)	68	56.0 ± 6.0	76.9 ± 5.2	0.00
	QRS axis (˚)	68	76.0 ± 6.0	75.2 ± 12.6	0.00
	QT duration (ms)	68	320.0 ± 18.0	331.0 ± 25.7	0.68
	QTc interval (ms)	68	402.0 ± 15.0	432.0 ± 22.5	0.00
	T-wave axis (˚)	68	46.0 ± 7.0	42.9 ± 15.7	0.10
10-14 years	Heart rate (bpm)	42	77.0 ± 6.0	97.5 ± 13.7	0.01
	P wave axis (˚)	42	45.0 ± 4.0	49.5 ± 10.5	0.56
	P duration (ms)	42	82.0 ± 9.0	95.2 ± 15.6	0.15
	PR interval (ms)	42	130.0 ± 15.0	131.8 ± 12.7	0.81
	QRS duration (ms)	42	78.0 ± 7.0	75.2 ± 9.7	0.25
	QRS axis (˚)	42	56.5 ± 8.0	47.2 ± 30.7	0.53

10-14 years	**QT duration (ms)**	42	334.0 ± 10.0	334.5 ± 15.3	0.21
	QTc interval (ms)	42	400.0 ± 20.0	420.0 ± 13.5	0.11
	T-wave axis (˚)	42	32.0 ± 4.0	32.5 ± 9.2	0.40

Table 4. Comparative analysis of ECG features of OSAS patients and normal, standardized values

According to the collected data, all the patients with persistent symptoms of OSAS were having structural as well as functional cardiac issue. Significant correlation between the ECG abnormalities and duration of symptoms was noted ($P < 0.002$) Most of the patients had overlapping cardiac problems of various degrees so the cumulative percentage could not be calculated. The pre-operative ECG of the patients showed impending right heart failure with right axis deviation (n=54, 49%), right atrial hypertrophy (n=37. 34%), and right ventricular hypertrophy (n=35, 32%).

Pre-operative ECG	**Frequency**	**Percentage**
Right ventricular hypertrophy (RVH)	35	32%
Left ventricular hypertrophy (LVH)	16	15%
Biventricular hypertrophy (BVH)	24	22%
Right atrial hypertrophy (RAH)	37	34%
Right axis deviation (RAD)	54	49%
Pre-operative Echocardiography	**Frequency**	**Percentage**
RAD	38	35%
RVD	24	22%
RVH	10	9%
PAH	32	29%
LVDD	46	42%
RVSD	43	39%
LVH	37	34%
LAH	23	21%
Cor pulmonale	21	19%

Table 5. The Abnormal Pre-operative ECG and Echocardiographic Changes in the selected subjects.

On monthly post-op follow-up for 6 months, the patients were evaluated for cardiac anomalies with ECG. Echocardiography was done after 6 months to confirm the ECG findings. Out of 110 patients, in 107 patients the structural and functional abnormality completely resolved. Two patients had remitting cardiac issues which were suspected to get resolved in next 2-3 months. Only one patient had echocardiographic and ECG changes that remained unchanged after adenotonsillectomy.

DISCUSSION:

In the diagnosed cases of adenotonsillar hypertrophy (ATH) with significant airway obstruction, adenotonsillectomy is the procedure of choice. The objective of immediate and effective treatment is to prevent recurrent upper respiratory tract infections and remove nasal obstruction caused by persistently enlarged adenoid gland and palatine tonsils. [14] Medical treatment is the first-step management of adenotonsilitis. If the child is refractory to oral or intravenous antibiotics, then timely surgical intervention can remarkably reduce morbidity such as stented growth, failure to thrive, recurrent/persistent otitis media, OSAS, and risk of associated mortality. [15] Multiple studies have shown the relationship between neglected OSAS and cardiopulmonary complications. Cardiac evaluation is seldom performed in patients with adenotonsilitis,

however this study mainly focused on the cardiac abnormalities in moderate-severe cases of adenotonsilitis/ATH and resultant OSAS induced cardiac abnormalities. [16, 17] Polysomnography is widely recognized screening tool for the suspected cases of OSAS [18] but due to lack of facilities and funds, this test was not performed in this study, The suspected cases of OSAS were confirmed by the radiography with the visualization of enlarged adenoid and tonsils causing significant airway obstruction. For the oxygen saturation monitoring, pulse oximeter was used. According to the reports, pulse oximeter has sensitivity and specificity of 100% and 98%, respectively. Hence pulse oximeter proved to be a useful tool for accurate monitoring of SaO_2. [19] Multiple studies have shown that adenotonsillar hypertrophy doesn't have any racial or gender predominance. [19-21] So, the male predominance detected in the results is assumed coincidental with the admissions of male patients outnumbering the female patients during the period of this study. According to the literature, the symptoms of OSAS generally resolve after the age of 6-8years as the adenoid gland gradually regresses due to repeated inflammation and resultant fibrosis. Meanwhile the nasopharynx development accelerates exponentially during this period which further widens the airway that relieves OSAS. However, our study results show that most of the symptomatic patients were above the age of 6 years with the persistent and progressively worsening symptoms of OSAS. [22] In previous studies, there was no significant correlation between the size of the adenoid and palatine tonsils or the degree of obstruction of airway and the severity of the symptoms or co-morbidity. [23, 24] In our practice, more than 65% of airway obstruction with enlarged adenoid and tonsils on the PNS lateral view Xray necessitates adenotonsillectomy. Exceptions can be made for patients with less than 65% of airway obstruction if significant comorbidity is associated with it, refractory to oral/intravenous medication and lifestyle modifications. Our study also provided radiological evidence of cardiomegaly with cardiothoracic ratio more than the normal range for the pediatric age groups. The degree of cardiac enlargement is related to the unilateral or bilateral atrioventricular hypertrophy especially if it is associated with the peripheral vasoconstriction. All the subjects had ECG abnormalities of varying severity. (Table 2 & 3) Echocardiography confirmed and specified the cardiac lesions. For all the patients, cardiac issues were the incidental findings. On cardiac consultation, OSAS was the suspected cause of these cardiac manifestations. Patients were prepared for elective adenotonsillectomy through pre-anesthetic evaluation. Special cardiac and vital monitoring was done during and after the procedure keeping in mind the possibility of apneic attacks during extubation of the patients, postoperatively. [16-17] All the patients had severe ATH associated with cardiac anomalies, but most of the patients did not develop all the symptoms of OSAS. One possible reason for it is that some patients were able to mouth breathe even during sleep. This phenomenon significantly reduces the degree of hypoxemia and hypercapnia, but cardiac pathology would still be inevitable. It is a general perception that large volume of adenoid gland will produce more obstruction of nasopharyngeal airway. According to our results, adenoid volume was not significantly correlated with the OSAS symptoms and ECG abnormalities. The determinant of severity of OSAS is the degree and duration of nasal obstruction. The degree of nasal obstruction can be visualized on Xray PNS lateral view or can be calculated postoperatively by the ratio of adenoid volume to the nasopharyngeal airway volume. These results are in congruence with multiple similar studies. [15-22] The follow-up of these 110 post operative patients showed complete remission of OSAS and abnormal ECG features in 107 patients. Two patients had resolving symptoms perhaps requiring more than 6 months to get completely resolved. One had persistent cardiac issue which was referred to cardiology for further investigation. Overall, the results significantly established the relation between severe ATH with OSAS and cardiac manifestations. [23-25]

Limitations:

There are certain limitations while studying the pattern of development of cardiac abnormalities from OSAS. Firstly, multiple studies demonstrate systemic hypertension, subclinical RV dysfunction, pulmonary hypertension, and cardiac arrythmias associated with ATH and OSAS. However, those studies involved short follow-up periods, so the complete resolution of cardiopulmonary symptoms was not ensured. Secondly, RV function and pulmonary artery pressure are usually measured by doppler echocardiography whereas cardiac catheterization is the gold standard investigation for it. Thirdly, it is a well-known fact that the adenoid gland grows and may temporarily, partially obstruct the nasopharyngeal airway. But as the child grows the nasopharyngeal airway regains its full patency. So, the relationship between the size of the adenoid gland and the patency of the nasopharyngeal airway is still not well established. In other words, it is uncertain when the OSAS due to ATH should be conservatively managed and after how long a surgical intervention should be advised as last resort. Lastly, another determinant of adenotonsillectomy that is under-studied is how long does OSAS take to develop permanent, irreversible RV

dysfunction or PH and what is the window period for the adenotonsillectomy that ensures complete reversal of ECG abnormalities.

CONCLUSION:

ECG abnormalities and cardiac complications are not common in every patient of adenotonsilitis but in those with grade 3 or 4 tonsilitis and moderate to severe degree of OSAS, cardiac issues must be ruled out to plan surgery on urgent basis. As adenotonsillectomy is a routinely performed surgery, ECG is not usually performed pre-operatively. But in patients with significant airway obstruction for a prolonged period, the risk of cardiovascular complications should not be ignored. A patient with an abnormal ECG should be evaluated by a pediatric cardiologist and his adenotonsillectomy surgery should be prioritized with special care during induction and maintenance of general anesthesia. Usually, all the symptoms due to adenotonsillar hypertrophy are reversible after adenotonsillectomy.

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