The effects of obstructive sleep apnea syndrome due to adenotonsillar hypertrophy on the cardiovascular system in children

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Obstructive sleep apnea syndrome (OSAS) due to adenotonsillar hypertrophy (ATH) is a common and important problem in children. OSAS can lead to significant cardiopulmonary complications, poor growth and problems with learning and behavior. Many studies in the literature show that OSAS due to ATH causes pulmonary hypertension, ventricular hypertrophy and systemic hypertension in the pediatric population. In this review, we discuss the effects of ATH on cardiac function. It is well known that as a child grows, the nasopharyngeal passage becomes enlarged, helping to improve OSAS. Based on this, we discuss the possible positive effect of this age-related improvement on the obstruction of cardiovascular disturbances. Finally, the possible relationship between the duration of OSAS and the timing of surgery with the permanency of cardiovascular disturbances is discussed.

Key words: obstructive sleep apnea, pulmonary hypertension, cardiovascular changes, adenotonsillar hypertrophy.

More than 100 years ago, clinicians began to recognize the manifestations of sleep-related breathing obstruction in children. Sleep–disordered breathing (SDB) has an estimated prevalence of 11% in children[1]. Obstructive sleep apnea syndrome (OSAS) is the most severe form of SDB, occurring in about 1-3% of the pediatric population[2,3], Children with OSAS have increased upper airway resistance during sleep due to a combination of soft tissue hypertrophy, craniofacial dysmorphology, neuromuscular weakness, or obesity [4]. The main cause of OSAS in children is adenotonsillar hypertrophy (ATH); therefore, it can be frequently cured by adenotonsillectomy.

Sleep-related upper airway obstruction in children can lead to a variety of nighttime and daytime symptoms (Table I). Children with OSAS almost always present with a history of snoring and difficulty breathing during sleep. Parents often report nighttime sweating, restlessness and unusual sleeping positions in their affected children. Chest retraction, use of accessory muscles, and paradoxical rib cage motion during inspiration occur during episodes of upper airway obstruction. Daytime symptoms include mouth breathing, nasal obstruction, and hyponasal speech. OSAS due to ATH in children can lead to significant cardiopulmonary complications, poor growth and problems with learning and behavior [5–7].

Adenotonsillar hypertrophy (ATH) appears to be a key element in the compromise of airway patency during sleep in otherwise healthy children with OSAS. Thus, patient history and physical examination are the most important steps to indicate surgical intervention in children with OSAS due to ATH (Fig. 1). Routine ear, nose and throat examination, lateral nasopharynx graphy and direct visualization of adenoid tissue by nasopharyngeal endoscopy can be used to evaluate tonsil and adenoid size. Polysomnography is recognized as the most useful laboratory test to assess the presence and severity of OSAS. However, some researchers believe that children with

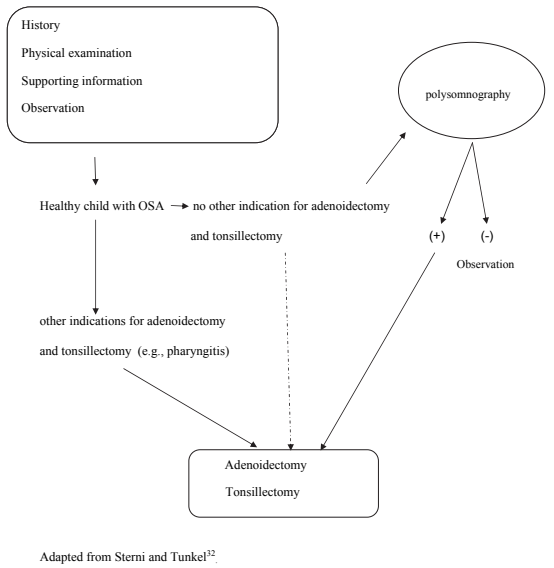

Fig. 1. Evaluation and management of obstructive sleep apnea syndrome in healthy children (i.e., children with no other disease).

sleep apnea can be diagnosed by skilled observation and that sophisticated monitoring may not be necessary[8,9]. Children who undergo adenotonsillectomy for recurrent pharyngeal infection may have obstructive symptoms as well. These children do not require polysomnography on a routine basis. Polysomnography is recommended if there is concern that the patient may also have severe OSAS that requires intensive postoperative monitoring. Patient history, presence of grade 3-4 ATH that causes airway obstruction according to Brodsky scale[10] and polysomnography are all important factors for the surgeon to determine the timing of the surgery.

Cardiopulmonary Effects of OSAS due to ATH

Mechanical airway obstruction due to ATH can lead to cardiopulmonary complications associated with hypercarbia, hypoxemia and pulmonary artery vasoconstriction. In its severe form, ATH can lead to right ventricular (RV) failure, cor pulmonale, growth retardation, or even death [11].

Cardiac effects of ATH in childhood have been investigated by many scientists using supplemental diagnostic modalities such as radionuclide ventriculography and echocardiography, chest radiography, and electrocardiography (ECG). Amin et al.[12] and others have found that OSAS in children leads to structural changes and hypertrophy of both the right and left ventricles. Most notably, left

Table I. Common Symptoms and Management of Childhood Obstructive Sleep Apnea Syndrome

Presentation	
Excessive daytime sleepiness	Infrequent complaint
Associated obesity	Minority of patients
Underweight / failure to thrive	Frequent finding
Daytime mouth breathing	Frequent finding
Sex	Male / Female =1:1
Enlarged tonsils and adenoids	Frequent finding
Sleep patterns	
Obstructive	Obstructive apnea or obstructive hypoventilation
Arousal with obstruction	Not often seen
Disrupted	Not often seen
Management	
Surgical	Definitive therapy in most patients
Medical (positive airway pressure)	Only in selected patients

Adapted from Carrol and Loughlin[33].

ventricular (LV) hypertrophy seen in Amin et al.'s [12] OSAS patients was related to the degree of severity of the OSAS. Yılmaz et al.[13] reported that ATH causes higher mean pulmonary arterial pressure values in children. Lavrikainen and co-authors[14] showed that RV hypertrophy is more common in children suffering from upper airway obstruction. Brown and co-authors[15] divided their patients in two groups as mild and severe cor pulmonale based on abnormal chest X-ray and ECG findings. In the severely affected group, they detected multiple ECG abnormalities. The authors also noted that LV hypertrophy is a known risk factor for future cardiovascular disease in this population.

In a recent study, the width of the palatine tonsil/depth of the pharynx (T/P) determined by lateral neck radiography was well correlated with pulmonary arterial pressure in children with ATH and a surgical indication for SDB[16]. The same study found that children with T/P >0.66 can be at greater risk for cardiac complications and should be submitted to studies with Doppler echocardiography or given preference for surgery.

Duman and co-authors [17] reported that the RV myocardial performance index, which reflects myocardial function, was significantly impaired in pediatric patients with advanced ATH without evident cardiovascular disease compared with age-matched control subjects. These cardiac changes reversed following surgical intervention by adenotonsillectomy[17,18]. Miman and co-authors[19] documented full recovery of the symptoms of pulmonary hypertension (PH) patients; these patients had PH secondary to ATH and had undergone adenotonsillectomy. Görür and co-authors [20] investigated 33 children with ATH pre- and post-surgery and compared findings with control subjects. Six months after adenotonsillectomy, they observed significantly improved RV diameter, LV end-systolic diameter and interventricular septum thickness. They also detected decreased LV compliance.

Systemic hypertension, a frequent complication of adult OSAS, has also been reported in children with OSAS[21–23]. Kohyama and co-authors [21] showed that systolic and diastolic blood pressure values of children with ATH were increased and were positively correlated with the degree of SDB. Although an exact mechanism has not been fully explained, it appears that intermittent hypoxemia is the major contributor to this serious consequence of SDB, with lesser roles played by sleep fragmentation and episodic hypercapnia. Intermittent hypoxia during the night will lead to increased sympathetic neural activity, and the latter will be sustained and induce changes in baroreceptor function, leading to hypertension[24]. Increased surges in sympathetic activity have been reported in children with OSA[25–27], and elevation of arterial blood pressure has been documented[27,28]. It is also likely that the episodic nocturnal hypoxia associated with SDB will induce changes in the physical contractility properties of resistance vessel beds and contribute to the overall elevation of blood pressure[29,30].

To our knowledge, arrhythmia analysis has not been performed adequately in patients with ATH. Thus, the incidence and prevalence of arrhythmias in ATH, the type of arrhythmias seen, the prognostic significance of arrhythmias, and whether treatment of ATH consistently decreases arrhythmias and favorably impacts cardiovascular mortality and morbidity are unfortunately unknown. Yılmaz et al.[31] evaluated the prevalence of arrhythmias, heart rate variability (HRV), and heart rate turbulence (HRT) by means of 24-hour Holter ECG monitoring pre- and postoperatively in children with ATH. They found that although some ECG and Holter findings such as sinus tachycardia and Mobitz type 1 second-degree atrioventricular block improved after the operation, the prevalence of arrhythmias and HRV and HRT values did not change significantly in the postoperative period.

Pathophysiology of PH

Elevation of the pulmonary vascular resistance causing pulmonary arterial pressure is the first step of the sequelae leading to cor pulmonale and congestive heart failure. Because of the absence of cardiovascular-related symptoms in this period, changes in pulmonary arterial pressure do not draw attention. Silent progression of pulmonary vascular disease is a function of the unique physiology of the pulmonary vascular bed and the response of the cardiovascular system, primarily the

RV, finally leading to increased pulmonary vascular resistance. The normal pulmonary vascular bed has very low resistance. Due to decreased resistance, the pulmonary vasculature has high distensibility; therefore, increases in pulmonary blood flow may result in minimal to no change in pulmonary artery pressure. ATH can exacerbate PH due to the vasoconstrictive effects of hypoxia and hypercarbia. In order to maintain cardiac output, the RV compensates for the progressive increases in pulmonary vascular resistance through a combination of dilation and hypertrophy. However, when pulmonary vascular resistance is markedly elevated, the RV's compensatory mechanism becomes insufficient. As a result, the RV fails, with rapid and progressive diminution of cardiac output at a constant rate; consequently, pulmonary artery pressure may elevate.

A gold standard method for pulmonary vascular resistance measurement is by direct catheterization of the RV and pulmonary artery. However, this method is invasive and expensive, and may cause serious complications. Indirect pressure measurement can be done by Doppler echocardiography.

Management

Tonsillectomy and adenoidectomy remain the procedures of choice for OSAS in the majority of diagnosed children. Radiofrequency tonsil reduction is a new technique that has been introduced as a potential treatment for OSAS in children, in combination with surgical adenoidectomy[32]. Intracapsular subtotal tonsillectomy using different surgical methods has also been introduced as an approach to reduce perioperative morbidity in children being treated for OSAS[32]. The long-term efficacy of these techniques as compared with conventional adenotonsillectomy needs to be demonstrated in future studies.

In conclusion, nearly all studies in the literature show that OSAS in children due to ATH causes PH and RV hypertrophy. Other clinical studies have reported systemic hypertension, subclinical RV dysfunction and cardiac arrhythmias in patients with ATH. However, these studies have many limitations. Small study groups were assessed, and follow-up periods were relatively short. Additionally, RV function and pulmonary artery pressure of the patients with ATH were evaluated using Doppler echocardiography but not cardiac catheterization, which is the gold standard to assess these cardiac abnormalities. Subtle RV impairment and a mild increase in pulmonary artery pressure were reported in these studies.

It is well known that as a child grows, the nasopharyngeal passage is enlarged, which helps to improve obstruction. Therefore, OSAS may improve after nasopharyngeal passage enlargement, and these subtle cardiovascular disturbances may recover spontaneously without surgery. To our knowledge, there is no study in the literature that evaluates the fate of PH, ventricular hypertrophy and systemic hypertension in children with spontaneous resolution of the obstruction by enlargement of the nasopharyngeal passage with aging.

Another unresolved issue is whether there is a relationship between duration of the nasopharyngeal obstruction and permanent PH and ventricular hypertrophy. The same question applies to the timing of the surgery. In other words, does late surgery increase the risk of permanent PH and ventricular hypertrophy? Further longitudinal studies to evaluate patients who refused to undergo surgery or who could not be operated on for other reasons are needed to answer these questions.

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