Pathophysiology of childhood obstructive sleep apnea: current concepts

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Abstract

The obstructive sleep apnea syndrome (OSAS) is a common and serious condition during childhood. Its pathophysiology remains poorly understood. Although OSAS is related to adenotonsillar hypertrophy in children, adenotonsillar hypertrophy is not likely the sole cause of sleep-disordered breathing in this age group. Rather, large tonsils and adenoids appear to precipitate OSAS in children with underlying abnormalities of upper airway function. Normal children have a relatively narrow upper airway, but maintain airway patency during sleep because of increased upper airway neuromotor tone and an increased central ventilatory drive. We speculate that OSAS occurs in those children lacking the compensatory upper airway neuromotor responses. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

The childhood obstructive sleep apnea syndrome (OSAS) was described in the medical literature by William Osler more than a century ago (Osler, 1892). Nevertheless, the first scientific case series was published only a few decades ago (Guilleminault et al., 1976). Since that time, it has been realized that childhood OSAS is a common disease, estimated to occur in approximately 2% of young children (Ali et al., 1993; Gislason and Benediktsdottir, 1995; Redline et al., 1999). It can result in serious morbidity, including growth failure (Marcus et al., 1994a), cor pulmonale and neurocognitive deficits (Gozal, 1998). Death has been reported (Marcus and Carroll, 1994). Nevertheless, despite the frequency and severity of this disease, few systematic studies have been performed, and little is understood about its pathogenesis. This
article will review current concepts on the pathophysiology of childhood OSAS.

2. Polysomnographic differences between children and adults with OSAS

The many clinical differences between children and adults with OSAS are beyond the scope of this article. Of note, however, are the polysomnographic differences, which may shed light on the differing pathophysiology between the age groups.

2.1. Children appear to have clinical sequelae associated with milder forms of OSAS than adults; i.e. with fewer and shorter obstructive apneas

The reason for this is unclear, but may be due to the fact that significant desaturation may occur even with brief apneas. This is because children have a lower functional residual capacity and a faster respiratory rate than adults.

2.2. Children have less fragmented sleep than adults

Adults with OSAS have frequent arousals from sleep. As a result, sleep is fragmented, and slow wave and rapid eye movement sleep is decreased (Weitzman et al., 1980; Bradley and Phillipson, 1985). In contrast, children with OSAS have fewer arousals (see below) and hence, preserved sleep architecture (Frank et al., 1983; Marcus et al., 1994a). Thus, excessive daytime sleepiness, the cardinal symptom of OSAS in adults, is unusual in children (Carroll et al., 1995).

2.3. Children may show a pattern of persistent, partial upper airway obstruction associated with hypercapnia and/or hypoxemia, rather than cyclic discrete obstructive apneas

This has been termed ‘obstructive hypoventilation’ (American Thoracic Society, 1996). The decreased frequency of cortical arousals in response to obstructive apnea, and the presence of some upper airway reflexes, may permit this pattern of breathing to occur.

2.4. In children, obstructive apnea is predominantly a rapid eye movement (REM) phenomenon (Morielli et al., 1996; Goh and Marcus, 1998)

A recent study of children with severe OSAS showed that the majority of obstructive apneas occurred during REM sleep, although REM sleep accounted for less than a quarter of total sleep time (Goh and Marcus, 1998). Furthermore, apneas were longer and more numerous during later REM periods than during REM periods earlier in the night. This indicates a state-specific deficit in upper airway/central nervous system function.

3. Pathophysiology of childhood OSAS

3.1. Role of the tonsils and adenoids

Adenotonsillar hypertrophy clearly plays a role in the pathogenesis of childhood OSAS. Other causes of childhood OSAS include obesity, craniofacial disease and neuromuscular disease; however, these are less common, and will not be the focus of this paper. The vast majority of children with OSAS has large tonsils and adenoids, and improves after adenotonsillectomy (Suen et al., 1995). Isono and colleagues studied children with OSAS during anesthesia and skeletal muscle paralysis, and determined that the site of upper airway closure was at the level of the tonsils and adenoids, whereas in normal children, it was at the level of the soft palate (Isono et al., 1998). Nevertheless, childhood OSAS does not appear to be due to adenotonsillar hypertrophy alone. A number of facts suggest that a combination of structural abnormalities (such as adenotonsillar hypertrophy) and neuromotor abnormalities must be present for OSAS to occur. Most obvious is the fact that patients with OSAS do not obstruct during wakefulness, when the tone of the upper airway muscles is increased. Studies have failed
to show a correlation between upper airway or adenotonsillar size and OSAS (Fernbach et al., 1983; Mahboubi et al., 1985; Laurikainen et al., 1987). Furthermore, a small percentage of children with adenotonsillar hypertrophy but no other known risk factors for OSAS are not cured by tonsillectomy and adenoidectomy (Suen et al., 1995). In addition, Guilleminault and colleagues reported a cohort of children who were cured of their OSAS by adenotonsillectomy, but developed a recurrence during adolescence (Guilleminault et al., 1989). Thus, it appears that childhood OSAS is a dynamic process resulting from a combination of structural and neuromotor abnormalities, rather than from structural abnormalities alone. These predisposing factors occur as part of a spectrum: in some children (e.g. those with craniofacial anomalies), structural abnormalities predominate, whereas in others (e.g. those with muscular dystrophy (Khan and Heckmatt, 1994)), neuromotor factors predominate (Fig. 1).

The size of the tonsils and adenoids increases during childhood; thus, all children have some degree of adenotonsillar hypertrophy. The lymphoid tissue in the upper airway increases in volume from birth to approximately 12 years of age (Vaughn, 1983), with the greatest increase being in the first few years of life. Simultaneously, there is gradual growth in the size of the skeletal boundaries of the upper airway. Thus, between 3 and 6 years of age, the tonsils and adenoids are largest in relation to the underlying upper airway size, resulting in a relatively narrow upper airway (Jeans et al., 1981). This coincides with the peak incidence of childhood OSAS. However, considering the structural changes occurring in the upper airway during childhood, it is not so much surprising that 2% of children have OSAS (Redline et al., 1999), but that 98% of children have no sleep-disordered breathing at all! In fact, normal children have less snoring and fewer obstructive apneas than normal adults (Marcus et al., 1992).

How are normal children able to compensate for their narrower upper airway during sleep? Some potential mechanisms will be explored below.

3.2. Role of the central nervous system

Adults with OSAS are thought to have a decreased ventilatory drive during wakefulness (Garay et al., 1981; Kunitomo et al., 1989; Bayadi et al., 1990; Benlloch et al., 1995). These studies did not differentiate whether the decreased drive was due to changes in chemoreceptor input or motor output. The decrease in overall central ventilatory drive in adult patients is probably secondary to longstanding, nocturnal hypoxemia and hypercapnia, rather than being a primary cause of OSAS, as treatment of OSAS results in normalization of the ventilatory drive (Guilleminault and Cummiskey, 1982; Berthon-Jones and Sullivan, 1987; Lin, 1994). A confounding factor in many of the adult studies was the presence of obesity and/or lung disease. Studies of children with OSAS demonstrated normal hypoxic and hypercapnic ventilatory responses during both wakefulness (Marcus et al., 1994c) and sleep (Marcus et al., 1998b). This difference between children and adults may be due to the removal of the confounding factors: none of the children studied had lung disease, and most were of normal weight. Another reason for the difference between children and adults may be the decreased duration of the disease process in children. Although children with OSAS have no overall decrease in their ventilatory drive, subtle abnormalities may be present. Gozal et al. (1995a) performed repetitive hypercapnic challenges in
children with OSAS soon after wakening in the morning, and found diminished responses in the OSAS subjects, which improved later in the day.

### 3.3. Role of upper airway neuromotor tone

Although the overall ventilatory drive appears to be normal in children with OSAS, it is possible that central augmentation of upper airway neuromotor function is abnormal. The upper airway muscles are accessory muscles of respiration and, as such, are activated by stimuli such as hypoxemia, hypercapnia (Weiner et al., 1982) and upper airway subatmospheric pressure (Widdicombe, 1986; Aronson et al., 1989). Previous studies have shown that, when upper airway muscle function is decreased or absent, e.g. in post mortem preparations (Brouillette and Thach, 1979), the airway is prone to collapse. Conversely, stimulation of the upper airway muscles with hypercapnia (Hudgel et al., 1988; Schwartz et al., 1993a) or electrical stimulation (Schwartz et al., 1993b) results in decreased collapsibility. These studies confirm that the tendency of the upper airway to collapse is inversely related to the level of activity of the upper airway dilator muscles. Therefore, increased upper airway neuromotor tone may be one way that patients can compensate for a narrow upper airway. Indeed, this has been shown in adults. Mezzanotte and colleagues demonstrated that adult patients with OSAS compensated for their narrow upper airway during wakefulness by increasing their upper airway muscle tone (Mezzanotte et al., 1992b). This compensatory mechanism was lost during sleep (Mezzanotte et al., 1996). Similar studies have not been performed in children, due to the invasive methods required.

Measurement of upper airway pressure–flow relationships provide a noninvasive means of evaluating upper airway function during sleep (Smith et al., 1988). In the living organism, the upper airway pressure–flow relationship is affected not only by mechanical and structural factors, but also by neural mechanisms. Thus, these measurements provide a useful tool for the comprehensive evaluation of upper airway function.

Upper airway pressure–flow relationships have been measured in children with OSAS associated with adenotonsillar hypertrophy (Marcus et al., 1994d). Pressure–flow measurements were obtained during natural, nocturnal sleep. The subjects breathed through a nasal mask. Inspiratory airflow was measured with a pneumotachometer. Nasal pressure ($P_N$) was measured from a mask port. $P_N$ was then gradually altered through a range of positive and negative (subatmospheric) pressures, using continuous positive airway pressure (CPAP) machines, one of which had been modified to provide subatmospheric pressure. Pressure–flow curves were constructed by plotting maximal inspiratory airflow ($V_{\text{Imax}}$) of flow-limited breaths against $P_N$. Only flow-limited breaths were used because, in the flow-limited condition, $V_{\text{Imax}}$ is determined solely by the upper airway properties, and is independent of the pressure downstream from the collapsible locus of the upper airway (Smith et al., 1988). $P_N$ versus $V_{\text{Imax}}$ curves were fitted by least squares linear regression. The critical airway pressure ($P_{\text{crit}}$) was defined as the X-axis intercept of the regression line ($V_{\text{Imax}} = 0$), i.e. the $P_N$ at which there was zero flow. It was found that the children with OSAS had $P_{\text{crit}}$ values in the positive range, similar to that of adults with OSAS (1 ± 3 in children vs. 3 ± 2 cm H$_2$O in adults, NS) (Gleadhill et al., 1991). In contrast, the control group of age-matched primary snorers had markedly subatmospheric $P_{\text{crit}}$ values, that were lower than those seen in adults with primary snoring. This indicated that snoring children had a less collapsible upper airway than snoring adults.

The fact that normal children snore less than adults, and rarely have any obstructive apneas, suggests that normal children have a less collapsible upper airway than normal adults. In order to understand the normal upper airway neuromotor mechanisms responsible for maintaining upper airway patency during sleep in children, we studied the pressure–flow relationships in normal children (aged 6–15 years) compared to adults (Marcus et al., 1999b). All subjects were non-snorers, and none was obese (body mass index $\geq 30$ kg/m$^2$). We found that the children had a markedly different configuration to their pressure–flow curve than the adults (Fig. 2). Many of the children did not demonstrate flow limitation.
Fig. 2. Maximal inspiratory flow ($V_{\text{Imax}}$) versus nasal pressure ($P_N$) is plotted for an adult (panel A) and a child (panel B). For the adult, as $P_N$ became more negative, $V_{\text{Imax}}$ decreased. $P_{\text{crit}}$ is $-21$ cmH$_2$O, and the slope of the pressure–flow curve is $22$ ml/sec per cmH$_2$O. For the child, $V_{\text{Imax}}$ was maintained despite increasingly subatmospheric $P_N$; thus, $P_{\text{crit}}$ could not be determined. The slope of the pressure–flow curve is $2$ ml/sec per cmH$_2$O. Reproduced with permission (Marcus et al., 1999b).

even at markedly subatmospheric pressures. Thus, as nasal pressure decreased, inspiratory flow was able to be maintained, presumably due to an increase in upper airway neuromotor tone. In these cases, the X-intercept of the pressure–flow curve could not be determined without extreme extrapolation, and consequently $P_{\text{crit}}$ could not always be determined. Therefore, the slope of the pressure–flow curve (SPF, the reciprocal of the resistance upstream to the collapsible locus in the upper airway) was used to characterize the upper airway response.

In contrast to the children, who maintained flat pressure–flow curves, most adults showed a progressive decline in inspiratory flow with decreasing $P_N$. The mean SPF for the children was $8 \pm 5$ ml/sec/cm H$_2$O, whereas for adults it was $30 \pm 18$ ml/sec/cm H$_2$O ($P < 0.002$). SPF increased significantly with age ($r = 0.62$, $P < 0.01$). Thus, children were better able to maintain upper airway patency when subjected to subatmospheric pressure.

What causes the upper airway neuromotor activation in children? Many factors regulate upper airway function, including central ventilatory drive, chemoreceptor afferents, upper airway pressure and flow receptors, pulmonary mechanoreceptors and sleep state. Several studies have confirmed that the central nervous system plays an important role in preserving upper airway patency. As stated earlier, the upper airway muscles are activated by stimuli such as hypoxemia, hypercapnia and subatmospheric pressure loads. The following facts suggest that the upper airway activation in response to pressure loading is centrally mediated: (1) Humans respond very differently to upper airway loading during sleep compared to wakefulness (Aronson et al., 1989; Henke et al., 1992), suggesting a role for the higher central nervous system centers. (2) Functional magnetic resonance imaging studies show activation of central nervous system centers in response to upper airway loading (Gozal et al., 1995b). (3) The EMG responses of the upper airway muscles to hypercapnia and inspiratory loading are similar (Mezzanotte et al., 1992a). These studies suggest a role for the central nervous system in modulating the upper airway response to subatmospheric pressure.

In order to further evaluate the role of the central nervous system in augmenting upper airway muscle tone, the occlusion pressure in 100 msec ($P_{0.1}$) was measured. $P_{0.1}$ is an index of ventilatory drive to the pump muscles, and there-
fore does not necessarily indicate drive to the upper airway muscles. However, it can be used as a marker for overall central ventilatory drive during sleep. We found a strong inverse correlation between SPF and $P_{0.1}$ asleep ($r = -0.80$, $P < 0.02$). Thus, those subjects with the greatest ventilatory drive (largest $P_{0.1}$) had the least collapsible upper airway (flattest SPF). Interestingly, there was no correlation between SPF and $P_{0.1}$ during wakefulness, indicating that deficits in ventilatory drive can be sleep-state specific. Several studies have shown that children have a higher ventilatory drive than adults (Gozal et al., 1994; Marcus et al., 1994b; Springer and Wasserman, 1988). Thus, normal children may compensate for their narrower upper airway by increasing upper airway neuromotor tone, via an increased central ventilatory drive.

The above study evaluated the developmental changes in the dynamic function of the intact upper airway, showing a tendency for upper airway collapsibility to increase with age. Studies of the mechanics of the passive (paralyzed) pharynx have shown similar results. Anesthetized, paralyzed children had a slightly lower passive closing pressure of the upper airway than adults ($-4 \pm 3$ vs. $-7 \pm 5$ cmH$_2$O) (Isono et al., 1997, 1998). This difference between the age groups appears smaller than the difference in dynamic $P_{\text{crit}}$ between children and adults, although differences in technique make direct comparisons difficult. As stated earlier, $P_{\text{crit}}$ could not be defined in normal children because closure of the upper airway could not be induced. However, $P_{\text{crit}}$ has been shown to be substantially lower in children with primary snoring than adults with primary snoring ($-20 \pm 9$ vs. $-7 \pm 3$ cmH$_2$O) (Marcus et al., 1994d). The greater difference in dynamic than passive closing pressure between children and adults supports the theory that upper airway neuromotor tone is important in maintaining upper airway patency in children.

Upper airway neuromotor responses have been further examined in preliminary experiments in normal children by: (1) inhibiting upper airway tone by using positive pressure; and (2) stimulating the upper airway using hypercapnia. The effect of inhibiting upper airway tone was evaluated in a group of normal children by having the children sleep while receiving continuous positive airway pressure (CPAP). CPAP has been shown to suppress upper airway tone (Strohl and Redline, 1986). The nasal pressure was rapidly dropped from the positive holding pressure to subatmospheric levels for several breaths, before being returned to the holding pressure (Fig. 3). The rationale for this experiment was that a hypotonic airway could be induced, in contrast to the previous experiments where nasal pressure was decreased gradually in a stepwise fashion, thereby allowing the subjects time to recruit upper airway muscles. The pressure–flow curves obtained from the intermittent protocol showed a steeper SPF and a measurable $P_{\text{crit}}$ in the children, when compared with the gradual, step protocol.

In the second set of experiments, pressure–flow measurements during sleep were obtained in a group of normal children under hypercapnic conditions compared to eucapnia, in order to assess the effects of stimulating upper airway neuromotor tone. In all cases, the hypercapnia resulted in increased flow for a given pressure (Fig. 4), demonstrating that hypercapnia has a dramatic effect on upper airway properties. Presumably, the hypercapnia resulted in increased upper airway neuromotor activity, resulting in a change in the upper airway collapsibility and/or upstream resistance. At mild levels of subatmospheric $P_N$ (e.g. $-4$ cmH$_2$O in Fig. 4) there was a marked increase in inspiratory flow when the subject breathed CO$_2$ compared to room air. As the subatmospheric pressure decreased (became more negative, e.g. $-15$ to $-17$ cmH$_2$O in Fig. 4), there was a persistent but much smaller effect of CO$_2$ on $V_{\text{Imax}}$. This suggests that, at high pressure loads, the upper airway muscles are maximally activated and cannot increase their tone further, despite persistent stimulation by CO$_2$. However, several caveats should be noted. First, this experiment evaluated the response of the upper airway during dynamic, changing conditions. With each drop in $P_N$, there is further activation of the upper airway muscles, with resultant changes in the upper airway properties (Aronson et al., 1989). Thus, upper airway collapsibility is not necessarily constant over a range of nasal pressures. Second,
it should be noted that the range of subatmospheric pressure used in these experiments were not within the physiologic range.

The above experiments have demonstrated the capability of the pediatric upper airway to modulate airflow in response to such stimuli as subatmospheric pressure and CO₂. Furthermore, the studies suggest that children not only have increased basal upper airway tone during sleep, but that the tone can be increased even further in response to a stimulus. Thus, pharyngeal muscle activity appears to play a prominent role in preserving upper airway patency in children during sleep, in order to compensate for an anatomically smaller upper airway.

While the dynamic upper airway responses have not yet been studied in children with OSAS, it can be speculated that these compensatory mechanisms are deficient in the OSAS population. However, it has been shown that breathing high levels of exogenous CO₂ during sleep will convert the breathing pattern of children with OSAS from a

Fig. 3. Pressure–flow responses were measured by dropping nasal pressure (Pₐ) in a gradual, stepwise fashion, or intermittently from a positive holding pressure. Maximal inspiratory airflow (V_{Imax}) is plotted against Pₐ. The intermittent technique (represented by triangles) results in a steeper slope than the step technique (represented by circles).
flow-limited to a nonflow-limited waveform, demonstrating that the upper airway muscles can be activated (Marcus et al., 1998b). It is therefore possible that children with OSAS have some preservation of their upper airway reflexes. This may allow them to partially compensate for increases in upper airway resistance, thereby preventing complete upper airway collapse. If they have an impaired arousal threshold to the increased upper airway load (see below), and to the resultant hypercapnia and hypoxemia (Marcus et al., 1998b), this may allow for persistent, uninterrupted partial upper airway obstruction, thus giving rise to the pattern of obstructive hypoventilation.

3.4. Role of arousal

The arousal response to obstructive apnea differs markedly between children and adults. In adults, obstructive apnea termination is almost always associated with cortical arousal, whereas in children, arousals frequently do not occur. McNamara and colleagues (McNamara et al., 1996) studied children with OSAS, and found that only half of nonREM and one third of REM obstructive apneas were terminated by EEG arousals. The number of respiratory-related arousals correlated with age; in infants, less than 20% of obstructive apneas were associated with arousal. This lack of cortical arousal in response to airway obstruction probably accounts for the lack of sleep fragmentation and resultant daytime somnolence in pediatric patients. It may also explain why children can go on to have extended, uninterrupted periods of obstructive hypoventilation.

In general, children have a higher arousal threshold than adults; the younger the child, the higher the arousal threshold. This has been demonstrated using both non-respiratory (acoustic) (Busby et al., 1994) and respiratory stimuli. However, age-related changes in the arousal threshold are not the sole reason for the lack of arousal in pediatric OSAS patients. Studies have shown that children with OSAS also have a specific arousal deficit in response to respiratory stimuli. This has been demonstrated using both hypercapnia and inspiratory resistive loading. The arousal response to exogenous hypercapnia and
hypoxemia was studied in school-aged, prepubertal children with OSAS compared to controls (Marcus et al., 1998b). It was found that hypoxemia (S\textsubscript{a}O\textsubscript{2} of 75%) was a poor stimulus to arousal in both children with OSAS and normal controls. Hypercapnia resulted in arousal in all subjects. However, the patients with OSAS aroused at a higher PCO\textsubscript{2} than controls. Those with the highest apnea index had the highest arousal threshold. The hypercapnic arousal threshold decreased following treatment, suggesting that the blunted arousal threshold was secondary to chronic nocturnal hypercapnia. Interestingly, hypoxic hypercapnia was a potent stimulus to arousal in this experimental setup, despite the fact that children with OSAS frequently have obstructive apneas associated with hypoxic hypercapnia and yet do not have cortical arousals.

The arousal response to an exogenous, inspiratory resistive load was measured in a group of school-aged, prepubertal children with OSAS, compared to controls (Marcus et al., 1999a). Overall, the children with OSAS aroused at a higher load than the controls (23 ± 8 vs. 15 ± 7 cm H\textsubscript{2}O/L/sec, \( P < 0.05 \)). The difference was most marked during REM sleep, which is the stage of sleep when children have the most obstructive apneas. Interestingly, the patients with OSAS had higher arousal thresholds during REM sleep than nonREM sleep, whereas normal subjects had lower arousal thresholds during REM sleep. REM sleep is thought to be important in young children in order to facilitate growth and maturation (Roffwarg et al., 1966). Thus, the increased arousal thresholds during REM sleep may be a protective response, enabling children to preserve REM sleep even in the face of increased upper airway obstruction.

It is not known whether the arousal deficit to inspiratory resistance loading is a primary contributing factor to childhood OSAS, or is secondary to the effort of continually breathing against an increased upper airway load. The arousal response to inspiratory loading during sleep has not been assessed in adults with OSAS. However, in adults, the depressed response to inspiratory loading during wakefulness is reversible following treatment of the OSAS (Greenberg and Scharf, 1993). Thus, it can be extrapolated that the arousal deficit to upper airway loading in children may be secondary.

Although apnea-related cortical arousals, as demonstrated on EEG, are less common in children than adults, subcortical arousals, as demonstrated by movement (Praud et al., 1989; Mograss et al., 1994) or autonomic changes (Aljadeff et al., 1997), occur frequently. These subcortical arousals probably do not cause daytime sleepiness. However, it is not known whether they can result in other neurodevelopmental consequences. The subcortical arousals may contribute to hypertension in children with OSAS (Marcus et al., 1998a).

3.5. Role of other structural factors

Structural factors other than adenotonsillar hypertrophy may play a role in the pathogenesis of childhood OSAS. There is no doubt that children with craniofacial anomalies are at risk for OSAS. However, it is unclear to what degree minor anatomical differences can contribute to sleep-disordered breathing. Few studies have attempted to correlate craniofacial measurements with polysomnographic characteristics, and the results of these studies are conflicting (Laurikainen et al., 1987; Guilleminault et al., 1989). Clearly, further study is needed.

3.6. Role of genetic factors

Genetic factors play a role in the pathophysiology of OSAS, as demonstrated by studies of family cohorts (Douglas et al., 1993; Guilleminault et al., 1995; Redline et al., 1997, 1999), as well as one study of human leukocyte antigen typing (Yoshizawa et al., 1993). It is unclear whether this is due to the modulating influence of genetic factors on ventilatory drive (Bayadi et al., 1990; Redline et al., 1997), anatomic features (Douglas et al., 1993; Guilleminault et al., 1995) or both. Ethnicity is also important, with OSAS occurring more commonly in African Americans (Redline et al., 1999).
4. Link between childhood and adult OSAS

This review has emphasized some of the differences between childhood and adult OSAS. Are these in fact two different disease processes, or are they manifestations of the same underlying physiologic abnormalities? Are the children with OSAS, who were successfully treated with adenotonsillectomies, at risk for recurrence of their disease during adulthood, or are these two diverse diseases affecting discrete populations? The frequency of adenotonsillectomies in the 50's and 60's, the under-recognition of childhood OSAS and the lack of natural history studies make these questions difficult to answer. It is intriguing to note that the prevalence of OSAS is similar in childhood and adulthood. OSAS occurs in approximately 1–3% of children (Ali et al., 1993; Gislason and Benediktsdottrir, 1995; Redline et al., 1999) and 2–4% of adults (Young et al., 1993). Are these the same patients?

Only one long-term study of childhood OSAS has been reported. Guilleminault and colleagues re-evaluated a group of adolescents who had undergone successful surgical treatment of OSAS during childhood (Guilleminault et al., 1989). Of 49 potential cases, 23 underwent polysomnography. Three patients, all of whom were male, were found to have OSAS. Cephalometric studies in these three indicated a small upper airway when compared to normative data. This study suggests that either some or all children with OSAS and adenotonsillar hypertrophy have additional subclinical abnormalities, be they structural or neuromotor, that can lead to recurrence of OSAS if additional risk factors (such as weight gain, or testosterone secretion at puberty) are acquired.

5. Conclusion

The pathophysiology of childhood OSAS remains poorly understood. However, it is thought to be caused by a combination of anatomic and neuromotor factors, i.e. by the superimposition of structural abnormalities upon an inherently more collapsible upper airway. Further study is needed to clarify the disease process.

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