Sarah is the bright and gifted daughter of two caring parents who maintain optimal health and fitness through diet and regular exercise. Her somatotype, like that of her parents, is slender and fit, with below-normal levels of body fat. Sarah has maintained an aggressive schedule of extracurricular activities to complement her academics, and she excels at almost everything that she attempts. Last year, however, Sarah’s parents noted a precipitous decline in their daughter’s physical, cognitive, and emotional performance. Fearing the worst, they had the child screened for a variety of potential disorders, and also had her examined for a panoply of affective disorders that may be responsible for her debilitations. As the assessments returned negative, Mom and Dad were ambivalent: they felt the conflict of encouragement regarding their daughter’s health together with the bewilderment over their daughter’s stunted development.

After inadvertently obtaining an audio recording of Sarah during her sleep, her father developed a concern for the loud, sonorous snorts that peppered the audiotape. Forwarding the tape to a qualified Sleep Specialist for analysis and interpretation resulted in the discovery that Sarah was suffering from severe sleep fragmentation, secondary to adenotonsillar hypertrophy. Her enlarged tonsils were impeding airflow into her lung, causing high levels of inspiratory flow limitation, or upper airway resistance. The chronic increase in breathing resistance during sleep was resulting in some compromise of arterial oxygen saturation, but the resultant sleep fragmentation was the primary culprit affecting her daytime functioning. Sarah was scheduled for and underwent the obligate surgery, after which her performance returned to normal, exemplary levels.

Sarah’s situation is not uncommon, yet her condition is often unrecognized and misdiagnosed. Many family practitioners and pediatricians are expert at discerning waking disorders, but remain unqualified to recognize disorders of sleep. Most of us in the health care profession realize that the field of sleep medicine is relatively new...a burgeoning clinical science with new facets revealed every day. And, adult sleep labs are proliferating at a rapid rate. Yet the evaluation of pediatric sleep disorders is practiced by only a select few and, as a result, the field is just beginning to mature. With the recent publication of the “Standards and Indications for Cardiopulmonary Sleep Studies in Children” in the American Journal of Respiratory and Critical Care Medicine (the official journal of the American Thoracic Society, Vol. 153. pp.866-878. 1996), interest in this area of clinical endeavor is expected to flourish.

In the scenario presented above, the child suffered from a sleep disorder affecting breathing. This category of sleep disorders includes the sleep apnea syndrome, sleep hypopnea syndrome (also called partial apnea in the pediatric sleep nosology), periodic breathing, and the upper airway resistance syndrome. Hallmark characteristics of the
breathing disorders during sleep include chronic arterial oxygen desaturation, sleep fragmentation and deprivation, and excessive daytime sleepiness, with or without snoring. These symptoms often result in the attendant deficits observed during wakefulness, like automatic behaviors, learning disabilities, attention deficit disorders, and excessive irritability. Children so afflicted are often labeled as recalcitrant troublemakers, or slow learners. Depending on the educational and psychological resources that are available to the child and the parents, the child may become ‘tracked’, or ‘phased’ into a socio educational category that constrains their true abilities...the true capacities of the child. The entire life course of the individual can thus be altered, unless the sleep disorder is recognized, properly diagnosed by a sleep specialist, and treated.

**Pediatric Sleep Disorders; Assessment and Methods**

Pediatric Sleep Labs must be able to accommodate a variety of physical, behavioral, and developmental challenges. The clinician conducting the history and physical examination should be aware of the basic symptomatology associated with sleep fragmentation and deprivation. Also, access to clinical polysomnography is required. The availability of appropriate treatment regimens is core to the success of the pediatric sleep testing service.

In order to assess the presence and impact of a pediatric sleep disorder, clinical polysomnography is performed, usually in a qualified sleep disorders center. Polysomnography is the measurement of multiple channels of biophysical signals during sleep. Many of the same signals recorded in adults are also collected on children during sleep.

**Sleep Staging**

EEG (electroencephalography), EMG (electromyography), and EOG (electrooculography) signals are typically gathered to determine sleep stages, and the scoring criteria employed for adults is recommended for children greater than 6 months of age. Alternate criteria is used for children < 6 months old (Anders, et.al). In some pediatric sleep labs, the electrophysiology channels are complemented by the analysis of respiratory rate, together with video monitoring of the sleeping patient, in order to appraise sleep/wake status, and the transitions between Rapid Eye Movement (REM) sleep and other stages of the sleep/wake cycle.
Cardio Respiratory Disorders Analysis

Respiratory airflow and movements are measured with a variety of transducers, and the associated EKG and arterial oxygenation status (SaO2) readings are inextricably linked to the ventilatory data. Nasal/Oral Thermistors, Thermocouples, and Respiratory Inductance Plethysmographs (RIP) are most frequently used to measure airflow and volume. For the assessment of ventilatory effort (a critical parameter to discern the type of respiratory abnormality), RIP is preferred in pediatric sleep testing centers over other, non-calibratable measures of ventilatory effort. End-tidal CO2 analysis is often used to determine ventilatory sufficiency.

Pure obstructive sleep apnea syndrome (SAS) is seen less in children than in adults. Children often present with chains, or strings of partial apneas, or hypopneas, that occur in stereotyped and periodic clusters throughout the night. Each event may last for but a few seconds (> 3 seconds), and each event may be separated by less than 20 seconds of intervening normal ventilation. The quantification of the occurrence of this Periodic Breathing is an important measurement in the pediatric sleep lab.

Other cardio respiratory parameters include inter-R interval analysis of the ECG for beat-to-beat rate variability, upper airway resistance assessment for 'subclinical hypopneas', breathing cycle parameters (Ti, Te, Tot), and the synchrony of ventilation (paradoxical breathing).

Treatment modalities for breathing disorders during sleep are essentially the same for children as they are for adults, with some exceptions. Continuous Positive Airway Pressure (CPAP) is frequently employed as a pneumatic ‘splint’, serving to buttress the airways open from the inside. Other interventions, like adenotonsillectomy, body position adjustments, and weight loss are also used to alleviate/palliate breathing disturbances during sleep. In small infants, significant increases in the inspiratory and/or expiratory upper airway resistance may be transiently realized simply as a function of neck flexion. During infant pulmonary function testing (often performed during sleep), for example, it is not uncommon to alleviate significant upper airway resistive load by simply reducing the amount of neck flexion by adjusting the body position of the baby.

Periodic Movements During Sleep (PMS)

While infants and pediatric patients do display a variety or normal and abnormal muscular movement patterns during drowsiness and sleep, periodic limb movements are often measured by classical adult criteria. Other movement/muscular conditions of interest in children include the following:

- Rhythmic Movement Disorders: Headbanging, Body Rocking, etc.
- Bruxism (Grinding/Gnashing of Teeth)
Parasomnias

Parasomnia is a category of sleep-related disturbances that are often, but not exclusively, associated with Rapid Eye Movement (REM) sleep. Some examples of parasomnia follow:

- Somniloquy (Sleep Talking)
- Sleep Paralysis
- Nightmares/Night Terrors
- REM Behavior Disorders (include kicking, screaming, punching activities during sleep)
- Enuresis (Bed Wetting)

The First Night Effect

Adults, especially those that exhibit sleep disturbances, usually experience little or no distress as they attempt to sleep in a laboratory environment. Children, on the other hand, often experience significant anxiety and trepidation when they are asked and expected to sleep in a foreign, clinical environment. This so-called “First Night Effect” can impede normal sleep onset, and in severe cases may compromise sleep efficiency to the point that the study is unscorable.

The sleep laboratory that is designed to accommodate pediatric and infant patients should be sensitive to the physiologic reactance associated with sleep in a foreign environments, and take appropriate steps to reduce or eliminate the first night artifacts. The sleep room should be comforting in its decor, with appropriate wall hangings, playthings, and other items to reduce the clinical feel of the room. Accommodations should be made within the room for the parent or guardian to sleep near the child. During the ‘hook-ups’, the actual preparation of the patient for the study, adequate time should be allowed for explanation of each of the electrodes and transducers, and the benign, noninvasive nature of its application. Allowing the children to touch the devices, run the chart copy recorder, or view their biophysical signals on a computer screen can serve to significantly minimize the first night effect.

Finally, the first night artifact can sometimes be eliminated when the study is performed in the patient’s home, where they are surrounded by a constant and comforting environment. Modern portable polysomnography equipment can be transported to the home for such recordings. Testing in the home, however, does not obviate the need for a videotape record of the child’s sleep study (see below). Sometimes, home studies are justified on a lower cost basis. It is unclear as to whether the test cost is actually less when testing in the home versus the established clinical lab.
**Video Recordings**

In the pediatric sleep lab, videotape recordings of the patient are required to correlate behavioral/positional data with the electrophysiology. Certain disorders (primarily the disorders of breathing) may only be manifest in the supine sleep position. Because of the limited EEG montage, seizure activity can be missed in the polysomnographic record if the associated video is not available for the observation of behavioral/motor movements that are displayed in response to the seizure event. Identification of sleep posture can assist in reducing neck flexion, improving sleep hygiene, and identifying more comfortable positions for sleeping. Finally, the video record should record actual clock time as verification that the study was performed during the appropriate bedtime period for the particular child under assessment. Even mild alterations in the sleep-wake cycle schedule of the child can significantly affect the quality of their sleep and, therefore, the clinical yield of the polysomnogram.

**Other Considerations**

Age-specific normal values for sleeping parameters are lacking or limited. Normal thresholds for these values need to be established to simplify the interpretation of the pediatric polysomnogram.

Which sleep abnormalities best correlate with disruptions of the activities of daily living? In our Sarah example, her cognitive performance decrements were exclusively tied to her upper airway resistance and the associated sleep fragmentation that it caused. In many other cases (Attention Deficit Disorder, for example), the association between sleep parameters and the daytime condition of the child may not be so straightforward, making the interpretation of the polysomnogram equivocal.

What is the most accurate and meaningful way of documenting desaturation during sleep?

Finally, educational opportunities in the field of sleep testing, both pediatric and adult, are expanding. Courses that are specifically designed for physicians, respiratory care practitioners, and EEG technologists are available in prestigious, established centers across the country. Contact the American Sleep Disorders Association (ASDA), or the Association of Polysomnograph Technologists (APT), for course details and availability. As well, many of the instructional programs are advertised in Respiratory/Pulmonary Medicine Journals.

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But I Have Promises to Keep.
And Miles to Go Before I Sleep,
And Miles to Go Before I Sleep*

-Robert Frost