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Polysomnography for the Diagnosis of Sleep Disordered Breathing in Children Under 2 Years of Age

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Summary. Objectives: To describe clinical polysomnography (PSG) results, sleep physicians' diagnosis, and treatment of sleep disorder breathing in children less than 2 years of age. Study Design: Retrospective clinical chart review at a pediatric tertiary care center, pediatric sleep laboratory. Subject Selection: Children less than 2 years of age who underwent clinical PSG over a 3-year period. Methodology: PSG results and physician interpretations were identified for inclusions. Children were excluded if either PSG results or physician interpretations were unavailable for review. Infants were classified in three age groups for comparison: <6 months, 6–12 months, and >12 months. Results: Matched records were available for 233 PSGs undertaken at a mean age 11.1 ± 7.0 months; 31% were <6 months, 23% were 6–12 months, and 46% were 12–24 months of age. Infants <6 months showed significant differences on sleep parameters and respiratory indicators compared to other groups. Compared to physician sleep disordered breathing (SDB) classification, current pediatric apnea–hypopnea index (AHI)-based SDB severity classification overestimated SDB severity. Age and obstructive-mixed AHI (OMAHI) were most closely associated with physician identification of SDB. Conclusion: Children <6 months of age appear to represent a distinct group with respect to PSG. Experienced sleep physicians appear to incorporate age and respiratory event frequently when determining the presence of SDB. Further information about clinical significance of apnea in infancy is required, assisted by identification of factors that sleep physicians use to identify SDB in children <6 months of age. **Pediatr Pulmonol. 2015;50:1346–1353.**

Key words: sleep disordered breathing; infants; diagnosis; treatment.

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INTRODUCTION

Polysomnography (PSG) is the accepted standard for measuring sleep disordered breathing (SDB) including obstructive sleep apnea (OSA) in both adults and children.[1,2] In children >1 year of age undergoing in-laboratory attended PSG, an apnea–hypopnea index (AHI) >1.5 events/hr of sleep is statistically abnormal.[3–6] However, the cut-off values that define clinically significant abnormalities, or level at which treatment is likely to alter outcome are yet to be determined. Therefore, PSG results, including but not limited to

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Conflict of interest: None.

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AHI, are part of the information used by clinicians to diagnose SDB and OSA.[7] PSG criteria used in research studies to define SDB and OSA vary and are based on cut-offs applied to AHI,[8] respiratory disturbance index (RDI),[9] obstructive AHI (OAHI),[10–13] or a combination of respiratory parameters on PSG.[14] Criteria used to determine SDB in infancy are less well-reported with no accepted criteria to define an abnormal AHI in children less than 1 year of age. In fact, infants <1 year of age are recognized to have unique issues with respect to SDB such that this group is excluded from practice guidelines.[2,15]

There are several reasons why applying the same criteria for an abnormal AHI in children to infants may not be appropriate. Prior to birth, the fetus does not rely on breathing for gas exchange and, therefore, there is considerable variability of both the amplitude and frequency of fetal breathing movements.[16] After birth, variability continues to decrease such that a more stable pattern of both breathing and heart rate develops. Apnea,[17] periodic breathing,[18,19] and oxygen desaturation[20–23] during sleep are normal events in healthy infants in the first few weeks after birth. Decrease in respiratory events with increasing age reflects greater stability in the respiratory control system.[20,23] Infants have more compliant upper airways and chest wall which increase the collapsibility of the upper airway and predisposes to paradoxical respirations.[24–26] Finally, infant arousal responses are immature with greater variability in the arousal response to stimuli such as hypoxemia and changes in upper airway resistance.[27,28] This variability in arousal response, along with greater variability of oxygen desaturation events, is likely to impact scoring of central apneas and hypopneas and, thus, alter the normal range of AHI in younger infants.

Previous studies in infants have used different cut-offs for defining an abnormal PSG respiratory event level, including a respiratory disturbance index (RDI) >5 events/hr of sleep,[29] mixed plus obstructive apnea index >2 events/hr of sleep,[30] AHI >2 events/hr unless >25% of events were central,[31] and obstructive mixed AHI >3 events/hr.[32] A recent review on OSA in infants suggests that an AHI >2 events/hr indicates the probable presence of OSA.[33] These criteria may represent the upper limit of normal in infants; whether they define a clinically significant cut-off or a threshold level where treatment should be considered to reduce the consequences of SDB is not known. The primary aims of this study are as follows: (1) to describe the results of PSG in a large cohort of children less than 2 years of age undergoing clinical PSG and (2) to determine the relationship between AHI, physician diagnosis, and treatment of SDB in children under 2 years of age. We hypothesize that infants less than 6 months of age will represent a distinct group with respect to PSG results and application of these results in treatment decisions.

METHODS

Sleep laboratory records were reviewed to identify all children less than 2 years of age who underwent clinical PSG over a 3-year period (2008–2010 inclusive). All children were referred by a physician to the pediatric sleep clinics at a single tertiary care center for review by one of three sleep physicians. All sleep physicians had completed training in pediatric sleep medicine and have been in active clinic practice for a minimum of 15 years. After a clinical review, the sleep physician determined that PSG was necessary and referred to the sleep laboratory. At the time of the study, no screening or other sleep measures were used prior to PSG. Demographic information, study indication, and PSG results were extracted from sleep laboratory records. Clinical diagnoses, physician interpretation, and treatment recommendations were extracted from medical chart review. Children were excluded from the final analysis if either PSG results or physicians' interpretation and recommendations were unavailable for review. Children were divided into three groups based on age at the time of study: <6 months, 6–12 months, and >12 months.

PSG was completed using the standard infant protocol of the sleep laboratory. This included the determination of sleep state using an electroencephalogram (EEG; C4-M1, C3-M2, O1-M2, O2-M1, F4-M1, F3-M2), electrooculogram (EOG; ROC/M1, LOC/M2), and submental electromyogram (EMG). Channels to evaluate respiratory status included pulse oximetry, nasal/oral air flow by thermistor, nasal pressure, chest, and abdominal wall movement using respiratory inductance plethysmography, and diaphragm and abdominal muscle activity by trans-diaphragmatic EMG. Carbon dioxide was monitored using transcutaneous CO_2 (T_cCO_2). Cardiac monitoring included the pulse signal from the oximeter and electrocardiogram (ECG). Following the standard laboratory protocol, infants <3 months of age may undergo daytime PSG. Both initial and follow-up diagnostic studies were included in the analysis.

Analysis of PSG data was completed by a single experienced scorer using the criteria of the American Academy of Sleep Medicine (AASM).[34] Although AASM sleep staging criteria can be applied starting at 2 months of age, sleep staging for infants <6 months of age was completed using the criteria outline by Anders et al.[35] as the standard protocol in the laboratory where the study was completed. For the purpose of analysis, active sleep (AS) in infants <6 months and rapid eye movement sleep (REM) in infants ≥6 months of age were combined as AS/REM and quiet sleep (QS) in infants <6 months and slow wave sleep (SWS) in

infants ≥6 months of age were combined as QS/SWS. Obstructive apnea was defined as the cessation of airflow (<10% of baseline level) for a minimum duration of two missed breaths with evidence of ongoing respiratory efforts. Central apnea was defined as the cessation of airflow (<10% of baseline level) for a minimum of two missed breaths if followed by an arousal, awakening or ≥3% oxygen desaturation, or for ≥20 sec in the absence of any associated events. Mixed apneas included central and obstructive components in the same event. Hypopneas were defined based on a decrease in airflow between 10–50% of baseline which was associated with an arousal, awakening, or ≥3% oxygen desaturation. Apnea–hypopnea index (AHI) was calculated based on the number of apneas and hypopneas during sleep divided by the total sleep time. The obstructive-mixed AHI (OMAHI) included obstructive and mixed apneas and hypopneas, while the central AHI (CAHI) included central apneas and hypopneas. Oxygen desaturation index (ODI) was calculated based on the number of oxygen desaturation events ≥3% during sleep divided by the total sleep time (TST). Classification of SDB severity by AHI was based on pediatric studies where AHI <1 event/hr is considered normal, AHI 1–5 events/hr indicates mild SDB, AHI 5–10 events/hr indicates moderate SDB, and AHI >10 events/hr indicates severe SDB.[36,37] Severity classification by physicians was obtained from the physician report for the PSG. This was either included in the PSG interpretation report or in the first clinic letter following the completion of the PSG. Treatment recommendations were also recorded. Where the physician classification crossed two categories (e.g., mild to moderate), the most severe category was assigned.

Statistical analysis was completed using SPSS 20 (SPSS, Inc., Chicago, IL). Frequency analysis and descriptive statistics were used to describe the demographics, PSG results, physician interpretation, and treatment recommendations. PSG variables with non-normal distribution were log transformed for statistical analysis. χ^2 analysis, γ, and one-way ANOVA, as appropriate, were used for group comparisons. Logistic regression was used to determine the contribution of multiple factors to physician classification of PSG results. Age was included in the model based on the hypothesis. To determine other variables for inclusion in multivariate regression analysis demographic, sleep, and respiratory parameters were tested in univariate analysis. All variables with a $P < 0.10$ on univariate analysis were included in the final model. Otherwise, a $P < 0.05$ was interpreted as demonstrating statistically significant differences. Bonferroni correction was applied in the analysis of post-hoc comparisons. The study was approved by the Research Ethics Committee.

RESULTS

A total of 300 matched physician reports and PSG data were available for inclusion. Among these, 68 were treatment studies and excluded from further analysis. The final analysis included 232 paired PSG results and physician reports from 205 children less than 2 years of age. Age at study ranged from 7 days to 24 months with a mean age at study of 11.1 ± 7.0 months; 71 children were <6 months (31%), 54 were 6–12 months (23%), and 107 were 12–24 months (46%) at the time of the PSG. Sex and syndrome/multiple anomalies had the same distributions across age groups (Table 1). Compared to children 12–24 months, infants <6 months had lower weight and head circumference z-scores while weight for length z-score was lower in infants 0–6 months and 6–12 months groups compared to infants 12–24 months.

The listed indications for PSG were exclusively related to sleep disordered breathing (SDB; Table 2); suspected OSA was the most common with (25, 10.8%) or without (72, 31.0%) a specific risk factor for OSA. Primary indications for PSG did differ by age group; for example,

TABLE 1— Description of the Sample by Age Group

	<6 months	6–12 months	12–24 months
N	71	54	107
Age (months; SD)	2.6 ± 1.4	9.2 ± 2.0	17.7 ± 3.2
Syndrome or multiple anomalies (%)	39.4%	31.5%	43.9%
% Male	52%	59%	65%
Length z-score	−0.30 ± 1.9	−0.24 ± 1.8	−0.28 ± 1.7
Weight z-score†	−0.82 ± 1.9	−0.23 ± 1.3	0.37 ± 1.3
Weight for length z-score*	−0.05 ± 1.7	−0.03 ± 1.4	0.67 ± 1.3
Head circumference z-score**	−0.33 ± 1.7	0.28 ± 1.7	0.53 ± 1.6

Syndromes include Aperts syndrome, Beckwith Wiedemann syndrome, brachio-oto-renal syndrome, Catel–Manzke syndrome, Down syndrome, Joubert syndrome, Opitz Frias syndrome, Prader–Willi syndrome, Trencher–Collins syndrome, and trisomy 21.
Weight: <6 months < 12–24 months†; Weight for length: <6 months < 12–24 months*; Head circumference: <6 months <12–24 months**;
*$P < 0.05$,
**$P < 0.01$,
†$P < 0.001$.

TABLE 2— Primary Indications for PSG by Age Group. Numbers Represent the Percentage (%) of Children Within the Age Group*

Primary indication	<6 months (%)	6–12 months (%)	12–24 months (%)
Suspected OSA with no specific risk	32.4	25.9	32.7
Suspected with specific risk	5.6	9.3	15.0
Non-syndromic palatal cleft or PRS	18.3	11.1	7.5
Cardio-respiratory disease	2.8	7.4	10.3
ALTE or family history of SIDS	15.5	9.3	0
Syndrome/multiple anomalies	5.6	0	8.4
Respiratory symptoms without snoring	4.2	5.6	0
Central apnea	1.4	1.9	0.9
Post-operative or follow-up study	2.8	20.4	16.8
No indication listed	14.1	11.1	13.1

*$\chi^2 = 45.6$, $P < 0.001$.

infants <6 months were more likely to have a PSG because of a family history of SIDS or ALTE while infants 6–12 months and 12–24 months were more likely to have a PSG because of cardio-respiratory disease.

Sleep parameters differed by age group as expected (Table 3). Respiratory parameters also differed by age group (Table 3). AHI, OMAHI, ODA, and minimum oxygen saturation were different in infants <6 months compared to other age groups. CAHI was higher in infants <6 months compared to infants 12–24 months.

Severity classification of SDB by AHI also differed by age group (Table 4). For example, severe SDB by AHI was identified in 82% of PSG results for infants <6 months and this accounted for 48.7% of severe SDB

TABLE 3— Sleep and Respiratory Parameters by Age Group

	<6 months	6–12 months	12–24 months
Total sleep time (TST; hr)†	5.5 ± 2.0	7.6 ± 0.8	7.6 ± 1.0
AS/REM (%)†	40.7 ± 14.1	27.6 ± 8.5	23.2 ± 7.7
QS/SWS (%)†	40.7 ± 11.3	27.9 ± 9.8	26.9 ± 8.3
Sleep efficiency (%)†	72.2 ± 13.8	83.8 ± 6.9	85.0 ± 9.4
Arousal index (events/hr)†	54.2 ± 19.4	12.2 ± 8.2	10.5 ± 5.2
AHI (events/hr)†	28.6 ± 21.8	12.4 ± 14.4	10.2 ± 9.7
OMAHI (events/hr)†	22.0 ± 25.2	8.4 ± 14.3	8.1 ± 10.4
CAHI (events/hr)†	8.3 ± 8.8	3.9 ± 3.5	3.0 ± 7.1
ODI (events/hr)†	33.4 ± 25.9	16.7 ± 17.8	11.8 ± 10.7
Minimum O_2 saturation (%)†	72.3 ± 13.2	81.5 ± 7.8	82.2 ± 8.2

TST, total sleep time; AS/REM, active sleep/rapid eye movement sleep; QS/SWS, quiet sleep/slow wave sleep; AHI, apnea–hypopnea index; OMAHI, obstructive mixed apnea–hypopnea index; CAHI, central apnea–hypopnea index; ODI, oxygen desaturation index.
Post-hoc: TST, QS/SWS, Sleep efficiency, Arousal Index, AHI, OMAHI, ODI, Minimum O2 saturation: <6 months < 6–12 months†; <6 months < 12–24 months†. AS/REM%: <6 months > 6–12 months†; <6 months > 12–24 months†; 6–12 months > 12–24 months**. CAHI: <6 months > 6–12 months**; <6 months > 12–24 months†; 6–12 months > 12–24 months*.
†$P < 0.001$, *$P < 0.05$, **$P < 0.01$.

TABLE 4— Severity Classification of SDB by Age Group Using AHI Criteria and Physician Classification

	<6 months		6–12 months		12–24 months	
	AHI Criteria* (%)	Physician (%)	AHI Criteria* (%)	Physician (%)	AHI Criteria* (%)	Physician (%)
Normal	0	28.2	0	34.3	0	19.4
Mild	1.5	35.9	16.7	45.7	32.7	41.8
Moderate	16.2	15.4	42.6	5.7	32.7	17.9
Severe	82.4	20.5	40.7	14.3	34.6	20.9

AHI Criteria, apnea–hypopnea index criteria. Normal, AHI <1 event/hr; Mild, AHI 1–5 events/hr; Moderate, AHI 5–10 events/hr; Severe, AHI >10 events/hr.
*Comparison of distribution of severity between age groups differed for AHI criteria ($\gamma = 0.58 \pm 0.068$, $P < 0.0001$) but not for physician classification ($\gamma = 0.12 \pm 0.11$, $P =$ ns).

TABLE 5— Physician Management Recommendations Across Age Groups*

Treatment recommended	<6 months (%)	6–12 months (%)	12–24 months (%)
No treatment	21	35	25
Repeat PSG	30	25	20
Medication	1.8	2.5	2
Surgery (including adenotonsillectomy)	1.8	2.5	30
Non-invasive ventilation (NIV)	41	18	16
Surgery and NIV	3.6	17	7

*$\chi^2 = 43.1$, $P < 0.0001$.

TABLE 6— Result of Binary Logistic Regression With Physician Classification of SDB Results as the Outcome Variable and PSG Variables as Predictors. PSG Variables Were Log Transformed for the Analysis

	Univariate analysis			Multivariate analysis		
	B ± SE	β	*P*	B ± SE	β	*P*
Age (days)	0.02 ± 0.026	1.02	ns	0.14 ± 0.063	1.14	0.031
AHI	2.20 ± 0.50	8.99	<0.001	−1.18 ± 1.71	0.31	ns
OMAHI	2.51 ± 0.61	12.32	<0.001	3.87 ± 1.10	48.03	<0.001
Mean S_pO_2	−70.77 ± 31.45	0.000	0.024	−50.89 ± 66.52	0.000	ns
ODI	1.80 ± 0.51	6.04	<0.001	1.32 ± 1.08	3.77	ns
Constant				98.85 ± 133.30	8.53E + 042	ns

across the whole cohort. In contrast to classification by AHI, there was no difference in severity classification by age group using physician categorization of SDB severity.

Physician management recommendations were documented for 192 PSG results (83%; Table 5). Treatment recommendations did differ by age group; for example, the most common recommended management was NIV in infants <6 months, no treatment for infants 6–12 months, and surgery for infants 12–24 months. Binary logistic regression with the physician SDB classification (absent/present) as the outcome variable showed that age and OMAHI were the strongest determinants of physician identification of SDB (Table 6).

DISCUSSION

The results from this study highlight that children <6 months are a distinct sub-group with respect to the diagnosis and treatment of SDB. Applying the pediatric criteria for classification of SDB to children <2 years of age results in higher severity rating of SDB compared to physician classification, especially in children <6 months of age. SDB treatment choices made by physician differ with age for infants <2 years. Experienced sleep physicians used both age and OMAHI when determining SDB classification.

There is limited published information regarding the role of PSG for the diagnosis of SDB in infancy. Recent guidelines with respect to PSG in children from the American Academy of Pediatrics exclude infants under 1 year of age and include this group in those considered complex.[2] Clinical practice guidelines aimed at otolaryngologists exclude infants <2 years of age when considering the role of PSG prior to tonsillectomy for SDB.[15] A range of criteria have been used for defining SDB by PSG in infants,[29–33] but none of these criteria have been investigated with respect to clinical decision making. The present study shows that physician assessment of SDB severity incorporates both age and respiratory events. In addition, for respiratory event parameters associated with physician classification of SDB, the discrepancy between AHI and physician severity classification was greatest for children <6 months of age.

Different methods used for determining SDB severity demonstrate different relationships with outcomes. For example, OSA severity predicts post-operative adverse events following adenotonsillectomy in children >1 year of age.[38,39] Physician assessment of severity may be a better predictor of post-operative outcomes than AHI based severity alone; one study using AHI-based severity criteria showed that even children with mild OSA were at risk of adverse events,[39] while a similar study using physician assessment of severity (which included PSG results) showed no adverse events in children with mild or moderate OSA.[38] Factors outside respiratory events, such as insufficient sleep, sleep disruption, and social or genetic factors are likely to affect the relationship SDB severity and neurocognitive outcomes.[13,40] Based on the present study, it appears that experienced sleep physicians

take into account both age and the number of obstructive respiratory events when determining the severity of SDB in children under 2 years of age. However, the resulting model supports that these factors alone do not fully explain physician severity classification which means that physicians incorporate factors outside PSG results when determining SDB severity.

SDB appears to follow a different trajectory in infancy than other age groups, likely reflecting developmental changes in sleep and breathing. For example, there is a dramatic change in sleep architecture over the first 6 months of life with the appearance of sleep spindles,[41–44] K-complexes,[45,46] and the emergence of an adult pattern of SWS.[45,47] Breathing patterns show decreased variability and slowing of the respiratory rate over the same time period.[48,22,49] Studies of healthy infants show a decrease in both obstructive and central respiratory events in early life.[17,27] A cluster analysis of over 10,000 children with seven repeated parent reported measures from 6–81 months defined five distinct symptom patterns relating to important clinical characteristics including growth parameters[50] as always normal (47%), always SDB (10%), early marked snoring with resolution (10%), early marked apnea with resolution (11%), and late snoring and mouth breathing (22%). Longitudinal studies of infants are needed to understand the combined impact of normal developmental changes and SDB through infancy. Studies to date suggest that at least a portion of infants with SDB are likely to have early resolution of disease.

In the present study, none of the standard measures of sleep fragmentation were predictive of physician assessment of SDB. Respiratory events are the primary PSG criteria used to define SDB despite the fact that sleep disruption is also analyzed as an important component of disease. Strong arousal response, leading to sleep fragmentation, is an important mechanism to protect against obstructive apnea during sleep in infants and potentially prevent catastrophic events such as sudden infant death syndrome (SIDS).[51–55] SDB, including snoring, has been shown to disrupt sleep in infants including a reduction in REM sleep[56] and a higher number of respiratory related arousals.[57] Further work is needed to determine whether evidence of sleep disruption influences physician assessment and management of SDB in younger children.

Limitations of this study must be acknowledged. The data were collected retrospectively from sleep laboratory records and medical charts. This meant that physician classification of PSG results and treatment decisions were missing for 12% and 17% of PSGs, respectively. No attempt was made to fill in this information with post-hoc review by physicians to ensure that the data collected best represented prospective clinical practice decision making. The data collected are from a single tertiary care center where PSG was a first-line test and where results are reviewed and interpreted by pediatric sleep physicians. The results may not generalize to centers where screening measures are used prior to PSG or where PSG results are reviewed by non-sleep or adult sleep physicians. Finally, this study examined only PSG variables to determine factors that influence physician assessment of SDB severity. Clinical diagnosis of SDB in any age group will incorporate multiple clinical factors, one of which is PSG results. Additional clinical factors, such as comorbidities, current symptoms, and physical examination findings, are likely important determinants of physician determinations of SDB and management decisions.

In summary, the results of the present study demonstrate differences in sleep and respiratory parameters by age group in a clinical cohort of infants <2 years of age. Infants <6 months of age appear to represent a distinct population with respect to the diagnosis and management of SDB. These results support the need for separate criteria to define abnormal PSG results in young children. Further work is needed to determine the relationship between PSG results, outcomes, and the impact of SDB treatment in infants <2 years of age.

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