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Original Article

Reference values for respiratory events in overnight polygraphy from infants aged 1 and 3 months

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ABSTRACT

Objective: We aimed to determine reference values for respiratory indices in polygraphies (PGs) performed in infants aged 1 and 3 months.
Methods: Healthy full-term neonates were recruited on the maternity ward. They were followed up by overnight PG at the age of 1 month and again at the age of 3 months. Indices of respiratory events, such as apneas, hypopneas, and percentage of periodic breathing were determined in each PG. Interpretation of PGs was performed blinded to the subject's data and the time of measurement. PG indices at 1 and 3 months of age were compared.
Results: PG recordings were obtained for 37 healthy infants (22 boys). At the age of 1 month, the median (minimum–maximum) central, obstructive, and mixed apnea index was 5.5 (0.9–44.3), 0.8 (0.1–6.7), and 0.3 (0–1.2), respectively. The same figures at the age of 3 months were 4.1 (1.2–27.3), 0.8 (0–2.3), and 0.1 (0–0.8), respectively. Mixed obstructive apnea–hypopnea index (MOAHI) was 1.5 (0.2–7.0) and 0.9 (0.2–4.4) at the first and second measurements, respectively ($P = .017$). Only 1.2% of central apneas lasted longer than 20 s. Periodic breathing was present in more than 90% of subjects studied.
Conclusions: The infants in our study aged ⩽3 months had respiratory event indices that were different from older children or adults. MOAHI showed a significant decrease during the first 3 months after birth. We recommend that scoring of PG in infants of 3 months or younger should consider age-specific reference values.

1. Introduction

Obstructive sleep apnea (OSA) affects close to 2% of children [1]. The reference standard for its diagnosis includes a full-night sleep laboratory-based polysomnography [2]. Standard polysomnographic indices such as the apnea–hypopnea index (AHI) or the oxygen desaturation index (ODI) have provided clear and internationally accepted criteria for diagnosing OSA and other sleep problems in children. There have been several studies investigating samples of healthy school-aged children and also some studies in preschool-aged children to establish pediatric reference values [3–6]. A large German study [7] recently proposed reference values in individuals aged 1–18 years and investigated the effect of pubertal development on polysomnographic indices. Thus there are now reference values available, obtained with up-to-date technology, for adults and children older than the age of 3 months.

In contrast, reference values for young infants are sparse, most of which are from the 1980s and 1990s [8–10] and used one or two channel-abbreviated cardiorespiratory monitoring instead of more advanced polygraphies (PGs). Another important limitation is that nasal pressure measurements were not used for determining hypopneas. Furthermore, there are only a few studies that have evaluated hypopneas in infants. One study investigated periodic and regular breathing in infants aged up to 6 months and found the former to be extremely frequent in the first weeks of life and was observed in up to 80% of recordings [8].

In possibly one of the largest of these studies, obstructive and mixed apneas were investigated in healthy infants aged 2–27 weeks [11]. This study added relevant information on the breathing pattern of infants and showed the rareness of mixed and obstructive apneas in this age group. However, only data on obstructive and mixed apneas were provided, but no data on central apneas were presented. Especially concerning central apneas, there might be a large discrepancy between infants and older children or adults. According to current guidelines [12], a central apnea should be scored if the event lasts 20 s or longer, or if the event lasts for the duration of two breaths during baseline breathing and is associated with an arousal or ⩾3% oxygen desaturation.

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In addition, a central apnea may be scored if the event is associated with a decrease in heart rate to less than 50 beats per minute for at least 5 s, or if the event lasts for less than 60 beats per minute for 15 s in subjects younger than the age of 1 year. These guidelines were recommended for scoring PGs of all children up to the age of 18 years, including infants [12]. However, the limited data on reference values in infants younger than the age of 3 months calls for a reconsideration of the appropriateness of adult-based recommendations in this age group.

Clearly, using consensus-based definitions seems reasonable. However, reference values should be thoroughly investigated in all age groups to apply these definitions. In infants, the few data currently available were either obtained using other definitions or monitoring techniques [8] or did not perform multichannel PG with nasal pressure measurements. Therefore, there is a lack of state-of-the-art analysis of respiratory events in this age group. This fact seems especially important considering age-specific phenomena like periodic breathing, which seems to be uncommon in children older than 1 year [7] but is extremely frequent in the first 3 months of life [8]. To expand the discussion on reference values to the first months of life, we launched our study on PG reference values for infants younger than 3 months of age.

2. Methods

2.1. Subjects

During 2006 and 2007, we recruited healthy-term neonates (i.e., $\geqslant$37 weeks gestational age) born at Tuebingen University Hospital, Tuebingen, Germany, and admitted to the maternity unit. Mothers were contacted on their infant's second day of life and invited to participate in the study. PG recordings were performed at 1 and 3 months of age. Only data from neonates who stayed in the maternity ward and were considered to be clinically healthy at the time of both enrollment and follow-up at the age of 3 months were included. Demographic and medical chart data (i.e., Apgar score, arterial umbilical pH, birth length, birth weight) were obtained for each subject at enrollment. Written informed parental consent was obtained for each subject. The study protocol was approved by the hospital's ethics committee.

2.2. Polygraphies

PGs were conducted using a portable, unattended, computerized polygraphic system (Embletta PDS, Broomfield, CO, USA) and interpreted according to standards published by the American Academy of Sleep Medicine [12]. The device was connected at home between 5:00 and 11:00 pm and recorded for the entire night. Parents were instructed how to check for the functioning of the device. Nasal flow was assessed with a nasal pressure transducer (via nasal cannula and built-in pressure transducer; Embla, Broomfield, CO, USA). The following channels also were recorded: chest and abdominal wall movements (inductance plethysmography, Embla), snoring (vibration sensor, New Life Technologies, Glen Burnie, MD), pulse oximetry–derived arterial hemoglobin oxygen saturation (SpO_2) (XPOD, Nonin Medical, Plymouth, MN, with 2–4-s averaging time), pulse waveform, and electrocardiogram. Recordings were analyzed using device-specific software (Somnologica for Embletta 3.3, Embla). Corrected estimated total sleep time (TST) was calculated according to published criteria [5]. Briefly, the first 10-min epoch without movement, artifact, or a distorted pulse waveform was defined as the sleep onset. The same criteria were applied to the last 10-min epoch for defining the end of the estimated sleep time. Recordings were manually analyzed for artifactual or non-interpretable periods on the nasal flow, thoracic effort, abdominal effort, or oximetry channel. Artifacts were defined as a distorted pulse waveform or the loss of nasal pressure or of thorax or abdominal effort for more than 1 min. These periods with artifactual data were subtracted from the estimated sleep time. Movement periods also were excluded from estimated sleep time and the corrected estimated sleep time was calculated [5]. Minimum required corrected estimated sleep time was 4 h.

Respiratory events were analyzed according to published criteria [12]. Obstructive apneas were defined as the absence of airflow with continued chest wall and abdominal wall movement lasting for at least two breaths. Central apneas were defined as an event lasting for >20 s, or as an event that lasted at least for the duration of two breaths during baseline breathing and was associated with an oxygen desaturation by $\geqslant$3% SpO_2, or if there was a decrease in heart rate to less than 50 beats per minute for at least 5 s or less than 60 beats per minute for 15 s [12]. Hypopneas were defined as a decrease in nasal flow by at least 30% with a corresponding decrease in SpO_2 by $\geqslant$3% or an arousal [18]. Periodic breathing was scored according to guidelines and defined as $\geqslant$3 episodes of central apnea lasting >3 s, separated by no more than 20 s of normal breathing [12]. The proportion of sleep time spent in periodic breathing was calculated. In addition to these standard criteria, central apneas after a sigh were separately marked and registered. The number of obstructive, mixed, and central apneas and hypopneas was divided per hour of TST and expressed as an index. The mixed obstructive apnea–hypopnea index (MOAHI) was defined as the sum of obstructive and mixed apneas and all hypopneas per hour of the estimated TST. The total AHI included central, mixed and obstructive apneas and all hypopneas. Indices of desaturation events by $\geqslant$3% and below 90%, 85%, and 80% SpO_2 were calculated. The nadir of the SpO_2 was manually determined and registered. The same montage was applied to the first and second PG (i.e., at 1 and 3 months of age). A pediatric sleep specialist (PEB) who was blinded to subjects' characteristics and the date of the measurement performed all PG analyses.

2.3. Statistics

Descriptive statistics as numbers and percentages, mean, and standard deviation (SD), or as median, minimum, and maximum, were used to summarize demographic, clinical, and PG characteristics. For each index, median, minimum, maximum, as well as the 75th and 95th centile, were calculated. The comparison of the indices between the two measurement points (i.e., at 1 and 3 months of age) was performed using the Mann–Whitney *U* test. A P value <.05 was considered statistically significant. All analyses were performed with statistical software (IBM SPSS, release 20.0 for Mac; IBM, Chicago, USA).

3. Results

PG recordings were obtained from 37 healthy infants (22 boys). Birth type was unassisted vaginal delivery in 26 infants (68%) and cesarean section in the remaining 11 (32%). Demographic and clinical characteristics are provided in Table 1. Race was predominantly white (i.e., >90%). Thirty-four infants (92%) completed the follow-up PG at 3 months. The mean ± SD duration of corrected estimated sleep time in the first and second measurement was 9.2 ± 1.9 and 10.0 ± 3.3 h, respectively (P = .038).

Median (minimum–maximum) values for central, obstructive, and mixed apnea index for the first and second measurement (i.e., at the age of 1 and 3 months) are provided in Tables 2 and 3. Based on the 95th centile, proposed reference limits at the age of 1 month for the central, obstructive, and mixed apnea index