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Original Article

Can the analysis of built-in software of CPAP devices replace polygraphy in children?

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ABSTRACT

Objectives: Polysomnography (PSG) is the gold standard for the scoring of residual respiratory events during continuous positive airway pressure (CPAP). Studies comparing PSG scoring with automatic scoring by the built-in software of CPAP devices have reported acceptable agreements except for the hypopnea index (HI) in adult patients, but no study has yet been conducted in children. The aim of the present study was to compare the automatic scoring by CPAP device and manual scoring using the software tracings of the CPAP device integrating pulse oximetry (SpO_2) with in-lab polygraphy (PG).
Methods: Consecutive clinically stable children treated with constant CPAP (ResMed) for at least one month and scheduled for a nocturnal PG were recruited. A pulse oximeter was connected to the CPAP device. The PG apnea-hypopnea index (AHI_{PG}), scored according to modified AASM guidelines, was compared with the automatic AHI reported by the CPAP device ($AHI_{A\ CPAP}$) and the manual scoring of the AHI on the CPAP software ($AHI_{M\ CPAP}$).
Results: Fifteen children (1.5–18.6 years) were included. Mean residual AHI_{PG} was 0.9 ± 1.2/hour (0.0–4.6/hour) vs. $AHI_{A\ CPAP}$ of 3.6 ± 3.6/hour (0.5–14.7/hour) ($p < 0.001$), and $AHI_{M\ CPAP}$ of 1.2 ± 1.6/hour (0.0–5.1/hour) ($p = 0.01$). Correlation between AHI_{PG} and $AHI_{A\ CPAP}$ was good ($r = 0.667$; $p = 0.007$), and improved when considering $AHI_{M\ CPAP}$ ($r = 0.933$; $p < 0.001$). Strong correlations were also observed between the PG apnea index (AI) and HI, and the manually scored AI and HI on CPAP, respectively.
Conclusions: Manual scoring of respiratory events on the built-in software tracings of CPAP devices integrating SpO_2 signal may be helpful. These results have to be confirmed in patients with higher AHI.

1. Introduction

In-lab overnight polysomnography (PSG) is considered the gold standard for continuous positive airway pressure (CPAP) titration and follow-up, both in children and adults [1,2]. However, there is considerable interest in validating alternative strategies to reduce the need for in-lab follow-up sleep studies, which are of limited access, costly and labor intensive [3].

Several studies have assessed the ability of different CPAP devices to identify residual respiratory events in adult patients with obstructive sleep apnea, and compared the data of the built-in software of CPAP devices with respiratory events simultaneously determined by in-lab PSG [4–14] or home type III polygraphy (PG) [15]. Despite the good correlation between the automatic apnea-hypopnea index (AHI) given by the built-in software of the CPAP device and the AHI scored by PSG/PG, the correlation was weaker for the hypopnea index (HI) alone. However, variable ranges of limits of agreement have been observed between the AHI scored by different CPAP devices and PSG/PG, which may lead to a misdiagnosis of residual respiratory events and, thus, inappropriate management. One explanation for the discrepancy between the AHI scoring by the CPAP device and that performed by PSG/PG is that the AHI automatically scored by the CPAP device depends entirely on the CPAP airflow signal, whereas the PSG/PG scoring takes in account the airflow signal and changes in arterial oxygen saturation

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(SpO_2) [9,15]. No study has yet assessed the residual respiratory events in pediatric patients by the different CPAP devices.

As one of the limitations of the CPAP built-in software is the scoring of hypopneas, the present study investigated the value of the adjunct of a SpO_2 oximeter to the CPAP devices to improve hypopnea scoring in children. Therefore, the AHI scored automatically by the built-in software of the CPAP device ($AHI_{A\ CPAP}$) was compared with the manual analysis of the CPAP built-in software tracings with the SpO_2 signal ($AHI_{M\ CPAP}$) and the AHI scored on an in-lab PG (AHI_{PG}).

2. Materials and methods

2.1. Patients

All consecutive stable patients treated with noninvasive constant CPAP for at least one month at home and with scheduled overnight PG between October 2015 and June 2016 were included. A dedicated noninvasive ventilation and sleep unit in a tertiary pediatric university hospital performed all sleeps studies. The study was conducted in agreement with the French regulations and received appropriate legal and ethical approval from the Ethical Committee CPP Ile de France II, n° 2015-11-3.

2.2. In-lab polygraphy

In-lab overnight PG (Cidelec, Saint Gemme sur Loire, France or Alice 6, Respironics, Carquefou, France) was performed with CPAP. Respiratory movements were recorded by respiratory inductance plethysmography, tracheal sound, body position, movements by actigraphy, heart rate, and SpO_2 (Nonin Medical Inc., USA) [16]. The SpO_2 signal was averaged on a four pulse-window and displayed with a sampling frequency of 1 Hz. Airflow was recorded using a pneumotachograph (pediatric/adult flow sensor, Hamilton Medical AG, Switzerland) placed on the single limb circuit next to the nasal/facial mask of the patient or a tubular flow sensor (Cidelec or Alice 6). The tubular flow sensor consisted of two connectors that were placed on the single limb circuit, one at the CPAP device exit and one next to the nasal/facial mask, which estimated airflow as the pressure difference between the two connectors [2]. The sleep study was recorded on videotape with an infrared video camera.

Respiratory events were scored according to 'modified' AASM guidelines, as electroencephalographic (EEG) arousals could not be scored on PG [16]. Obstructive apnea was defined as a drop in airflow amplitude by 90% of baseline for at least two respiratory cycles, with continued or increased inspiratory efforts. Central apnea was defined as a drop in airflow amplitude by 90% of baseline without inspiratory effort, duration of at least two breaths, and associated with an awakening, and/or a 3% oxygen desaturation (OD), or of a duration of at least 20 s. Mixed apnea was defined as a drop in airflow amplitude by 90% of baseline for at least two respiratory cycles with the absence of inspiratory effort during one portion of the event and the presence of inspiratory effort during another portion, regardless of which portion came first. Hypopnea was defined as a drop in airflow amplitude by 30% of baseline of a duration of at least two breaths, associated with an awakening, and/or an OD [16]. Recording time (Trec) was defined as the time between the reported sleep time and wakefulness. Total sleep time (TST) was defined as the Trec minus the wake periods recorded by actigraphy.

AHI_{PG} was calculated as the sum of the apnea and hypopnea events per hour of TST. The apnea index (AI_{PG}) and HI_{PG} were calculated as the number of apneas and hypopneas per hour of TST, respectively. Sleep study was considered normal in case of an AI_{PG} <1 event/hour and an AHI_{PG} <1.5 events/hour [17]. Mild sleep apnea was defined as an AHI_{PG} between 1.5 and 5 events/hour, moderate sleep apnea as an AHI_{PG} between 5 and 10 events/hour, and severe sleep apnea as an AHI_{PG} $\geq$10 events/hour.

2.3. CPAP device

Only devices with a fixed CPAP mode from the ResMed brand (S9 series, Airsense 10, Stellar) were used because of the necessity to have a cycle-by-cycle airflow display together with SpO_2 signal on the software (ResScan 5.6, ResMed Limited, Australia). A SpO_2 sensor (Nonin Xpod, Nonin Medical Inc., USA) was connected directly to the external port of the CPAP device. The SpO_2 signal was displayed on ResScan software with a sampling frequency of 1 Hz. In patients treated with another CPAP device, a ResMed device with the same CPAP pressure was used for the night.

According to information provided by the manufacturer, obstructive apnea was defined as a 75% reduction of baseline airflow, for at least 10 s, with upper airway closure. Central apnea was defined as a 75% reduction of baseline airflow, for at least 10 s, without upper airway closure. The distinction between obstructive and central apneas was performed by means of the forced oscillation technique that enabled detection of upper airway closure/opening. Unknown apnea was defined as apneas that could not be characterized precisely because of total air leak over 30 L/minute. Hypopnea was defined as a partial upper airway closure (ie, a 50% reduction of baseline airflow associated with inspiratory airflow limitation) for at least 10 s. This scoring did not integrate the changes in SpO_2.

2.4. Procedure

Expert staff manually scored PG, and the residual AHI_{PG}, AI_{PG} and HI_{PG} were reported. Two readers, who were blinded from the PG results, scored the respiratory events using the built-in CPAP software. Automatic AHI ($AHI_{A\ CPAP}$), AI ($AI_{A\ CPAP}$) and HI ($HI_{A\ CPAP}$) assessed by the built-in CPAP software were reported. Automatic AHI, AI and HI were also calculated as indexes per hour of polygraphic Trec ($AHI_{A\ CPAP}$ Trec, $AI_{A\ CPAP}$ Trec, $HI_{A\ CPAP}$ Trec) and per hour of polygraphic TST ($AHI_{A\ CPAP}$ TST, $AI_{A\ CPAP}$ TST, $HI_{A\ CPAP}$ TST).

All the respiratory events were then manually scored using the CPAP software as follows: (i) all the respiratory events following the AASM guidelines [16] were validated, (ii) all the events preceded by a sigh [18] or a movement (unstable airflow tracing), or central apnea lasting <20 s and hypopnea not associated with an OD, were removed, (iii) all the respiratory events scored according to the AASM guidelines but not scored by the CPAP software were added, (iv) all the respiratory events falsely scored by CPAP were modified. The AHI, AI and HI were calculated as the number of events scored using the CPAP software per hour of polygraphic Trec ($AHI_{M\ CPAP}$ Trec, $AI_{M\ CPAP}$ Trec, $HI_{M\ CPAP}$ Trec) and as the number of events per hour of polygraphic TST ($AHI_{M\ CPAP}$ TST, $AI_{M\ CPAP}$ TST, $HI_{M\ CPAP}$ TST). Periods with air leaks >24 L/min were discarded. Fig. 1 describes the different time periods to which the indexes of respiratory events refer.

2.5. Statistical analysis

The data were presented as mean and standard deviation (SD), or median and range. Comparisons between AHI_{PG}, AI_{PG} and HI_{PG} and automatic and manually scored events per hour of Trec and per hour of TST were performed using the Student *t*-test (parametric test) or the Mann–Whitney Rank Sum Test (nonparametric test). Pearson product moment correlation (parametric test) or Spearman rank order correlation (nonparametric test) coefficient (r) was calculated to assess the correlation between the respiratory events scored by PG, and CPAP software. Furthermore, agreement