Respiratory Physiology & Neurobiology 187 (2013) 183–189

Contents lists available at SciVerse ScienceDirect

Respiratory Physiology & Neurobiology

journal homepage: www.elsevier.com/locate/resphysiol

Emfit movement sensor in evaluating nocturnal breathing

Mirja Tenhunen[a,b,*], Ella Elomaa[c], Heli Sistonen[c], Esa Rauhala[d], Sari-Leena Himanen[a,c]

[a] Department of Clinical Neurophysiology, Medical Imaging Centre and Hospital Pharmacy, Pirkanmaa Hospital District, Tampere, Finland
[b] Department of Biomedical Engineering, Tampere University of Technology, Tampere, Finland
[c] Faculty of Medicine, University of Tampere, Tampere, Finland
[d] Department of Clinical Neurophysiology, Satakunta Central Hospital, Pori, Finland

ARTICLE INFO

Article history:
Accepted 21 March 2013

Keywords:
Respiratory effort
Sleep
Sleep-disordered breathing
Sleep-mattress
Emfit
SCSB

ABSTRACT

Obstructive sleep apnea (OSA) diagnostics by the movement sensors static charge-sensitive bed (SCSB) and electromechanical film transducer (Emfit) is based on dividing the signal into different breathing patterns. The usage of non-invasive mattress sensors in diagnosing OSA is particularly tempting if patient has many other non sleep-related monitoring sensors. However, a systematic comparison of the apnea–hypopnea index (AHI) with Emfit-parameters is lacking. In addition to periodic breathing, SCSB and Emfit visualize episodes of sustained negative increases in intrathoracic pressure (increased respiratory resistance, IRR), of which relevance is still ambiguous. Our aim is to compare Emfit-parameters with the AHI and to provide a description of the patients suffering from IRR.

Time percentage with all obstructive periodic Emfit breathing patterns (OPTotal%) showed the best correlation with the AHI. The OPTotal percentage of 21 yielded to excellent accuracy in detecting subjects with an AHI of 15/h or more. Patients with IRR received high scores in GHQ-12-questionnaire.

An Emfit movement sensor might offer additional information in OSA diagnostics especially if nasal pressure transducer cannot be used.

1. Introduction

Usually quantization of nocturnal sleep-disordered breathing (SDB) is based on the apnea–hypopnea index (number of respiratory events per hour of sleep), the arousal index (number of cortical microarousals per hour of sleep) and the oxygen desaturation index calculated from the polysomnography (PSG). The diagnostic sensitivity of the SDB analysis can be improved, for example, by calculating respiratory related arousals (RERAs) as is done when researching the upper airway resistance syndrome (UARS) (Iber et al., 2007). UARS patients have inspiratory flow limitation which leads to progressive increases in respiratory effort terminated by a sudden decrease in negative oesophageal pressure and arousal (Guilleminault et al., 1993). Repetitive respiratory events can also be detected with noninvasive movement sensors such as the static charge-sensitive bed (SCSB) and the Emfit (electromechanical film transducer) sensor, which are widely used in Finland in diagnosing SDB and periodic leg movements (Anttalainen et al., 2007b; Kirjavainen et al., 1996; Rauhala et al., 2009; Tenhunen et al., 2011). The suitability of SCSB movement sensor in sleep apnea diagnostics has been evaluated in many studies and it has been shown to identify obstructive apneas with high sensitivity (Anttalainen et al., 2010; Lojander et al., 1998; Polo et al., 1988; Polo, 1992; Salmi et al., 1989; Svanborg et al., 1990). In mattress scoring episodes of periodic apneas/hypopneas are named as obstructive periodic patterns (OP-patterns) by Polo et al. (1988).

Attention has recently been paid to another type of SDB; prolonged or sustained partial upper airway obstruction (Anttalainen et al., 2007a, 2010; Bao and Guilleminault, 2004). This phenomenon can be assessed either by sustained negative increase in oesophageal pressure or by prolonged flow limitation pattern in the nasal pressure transducer signal (Bao and Guilleminault, 2004; Hernandez et al., 2001). Also the SCSB and the Emfit can serve as non-invasive means to detect prolonged partial obstruction (Kirjavainen et al., 1996; Polo, 1992; Polo et al., 1991; Tenhunen et al., 2011). Increased negative intrathoracic pressure

Abbreviations: AHI, apnea–hypopnea index; AI, apnea index; CPB, central periodic breathing pattern; EDS, excessive daytime sleepiness; EEG, electroencephalography; Emfit, electromechanical film transducer; ESS, Epworth sleepiness scale; GHQ, general health questionnaire; HI, hypopnea index; IRR, increased respiratory resistance pattern; M, movement pattern; NB, normal breathing pattern; NREM sleep, non-rapid eye movement sleep; OP1-3, obstructive periodic breathing patterns, types 1–3; OPTotal%, percentage of time with obstructive periodic breathing patterns (OP1% + OP2% + OP3%); P1, periodic breathing pattern, type 1; PM, periodic movement pattern; PSG, polysomnography; REM sleep, rapid eye movement sleep; RERA, respiratory effort-related arousal; SCSB, static charge-sensitive bed; SDB, sleep-disordered breathing; TIB, time in bed; TST, total sleep time; UARS, upper airway resistance syndrome; W, Emfit wakefulness epoch based on sleep EEG.

* Corresponding author at: Department of Clinical Neurophysiology, Tampere University Hospital, Medical Imaging Centre and Hospital Pharmacy, Pirkanmaa Hospital District, Tampere, Finland. Tel.: +358 3 31164196; fax: +358 3 31164199.
E-mail address: mirja.tenhunen@pshp.fi (M. Tenhunen).

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http://dx.doi.org/10.1016/j.resp.2013.03.009

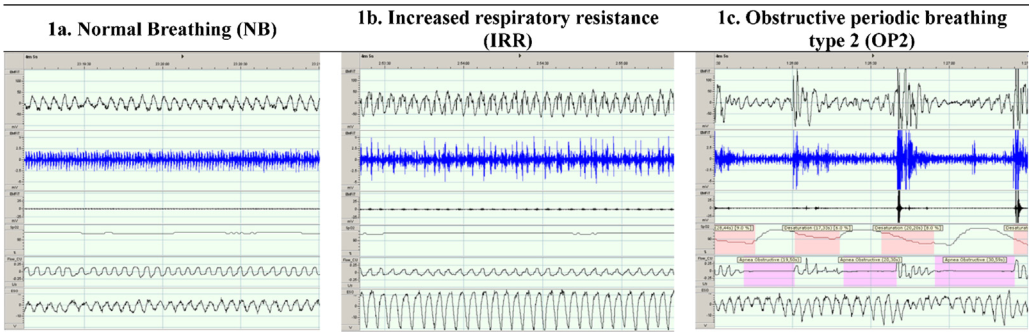

Fig. 1. Three examples of mattress breathing categories. (a) A 2-min period of normal breathing (NB). The uppermost channel represents regular respiratory movements measured by the Emfit. The second channel shows the Emfit high-frequency signal where only heart-related spikes are seen during unobstructed breathing. The third channel records large movements that are not present during normal breathing (raw Emfit signal). The following traces are the oxygen saturation percentage, airflow by the nasal pressure transducer and oesophageal pressure. (b) A 2-min period with increased respiratory resistance (IRR): respiratory-related spikes in the second Emfit channel. Breathing is regular, as assessed by the Emfit (trace 1) and by the nasal pressure transducer (trace 5) but negative oesophageal pressure has clearly increased (trace 6). (c) A 2-min episode of obstructive periodic breathing (OP2). Periodic respiratory amplitude variation in the Emfit (trace 1). In the high-frequency Emfit channel (trace 2), periodic bursts of respiratory-related spikes with large movements are seen. Movements appear also in the third Emfit channel (trace 3). Obstructive apneas in channel 5 (nasal airflow). Oesophageal pressure (trace 6) shows periodic negative swings. Scaling and order of the traces is kept the same in all of the figures.

induces respiratory-related spikes to the SCSB and the Emfit signal (Kirjavainen et al., 1996; Tenhunen et al., 2011), and the sustained partial upper airway obstruction with sustained spiking has been entitled "increased respiratory resistance, IRR" (Alihanka et al., 1981; Alihanka, 1987; Polo, 1992). IRR is clearly distinguishable from the OP-patterns (Fig. 1). In our recent work we discovered that during IRR there is a sustained negative increase in the oesophageal pressure but arousals and apneas/hypopneas are sparse. During OP-patterns oesophageal pressure is also increased, but apneas/hyponeas and arousals are frequent (Tenhunen et al., 2011).

The smaller Emfit bed sensor has replaced the SCSB in many laboratories, and because a systematic comparison between the AHI measured by the PSG and obstructive breathing periods measured with the Emfit has not been done, the main aim of the present study was to evaluate the feasibility of the Emfit-sensor in diagnosing obstructive sleep apnea (OSA) using the PSG with a nasal pressure transducer as a reference method. As there is only little epidemiologic data from prolonged partial obstruction, the other aim was to examine the prevalence of prolonged partial obstruction (IRR) among adult patients who were referred to a full polysomnography. The third aim was to compare polysomnographic and demographic parameters between obstructive sleep apnea syndrome–patients (OSAS) and patients with prolonged partial obstruction.

2. Materials and methods

We analysed retrospectively polysomnograms of adult patients (>18 years) that were recorded between 03/2005 and 03/2006 in the sleep laboratory of Pirkanmaa Hospital District in Tampere, Finland. The protocol was approved by the medical director of the Tampere University Hospital since the permission of the Ethical Committee of the Pirkanmaa Hospital is not needed for a retrospective analysis of recordings and recordings-related documents only. The total number of polysomnograms was 189. Due to technical problems with the nasal pressure signal or the mattress signal 32 recordings were excluded. One hundred and fifty-seven recordings were of sufficient quality and were further studied.

The polysomnography recordings were performed with the Embla N7000 and Somnologica Studio 3 software (Embla®, USA) and they consisted of six EEG channels (F3-A2, F4-A1, C3-A2, C4-A1, O1-A2, O2-A1), two electro-oculogram channels, submental and anterior tibialis muscle electromyography, thoracic and abdominal respiratory movements by inductive belts, electrocardiogram, pulse oximetry and position. Airflow was measured with a thermistor and nasal pressure transducer. In addition Emfit-sensor signal was acquired. The Emfit mattress is a moveable movement sensor, which consists of thin elastic light weight polymer layers separated by air voids and coated with electrically conductive, permanently polarized layers. Changes in the pressure acting on the film generate a charge on its electrically conductive surfaces and this charge can be measured as a current or a voltage signal (Paajanen et al., 2000). An Emfit sensor (32 cm × 62 cm × 0.4 cm) was placed under the thoracic area of the sleeping patient. A sampling rate of 2 Hz was used for pulse oximetry, 10 Hz for respiratory movements, 500 Hz for ECG, and 200 Hz for the Emfit-sensor and all the other signals.

Polysomnographies were classified into the sleep stages according to standard criteria (Iber et al., 2007). The apnea–hypopnea index (AHI) was calculated as the number of obstructive apneas and hypopneas (hypopnea rule 4b in (Iber et al., 2007) per hour of sleep. In addition, the apnea index (AI) and the hypopnea index (HI) were calculated. Arousals were scored according to the criteria of the ASDA (ASDA, 1992).

Conventional sleep parameters were gathered from polysomnographic recordings. Demographic data (age, sex, BMI, reason for sleep study, end-diagnosis, Epworth sleepiness scale (ESS) score (Johns, 1991), GHQ-12 score (Goldberg et al., 1997), subjective time in sleep as well as medications of the patients) were collected from the questionnaires, which are routinely used during sleep studies in our laboratory.

The Emfit signal was filtered into two different frequency bands. These filtered signals and the raw signal were used in visual scoring of the Emfit signal into nine Emfit categories as in our previous work (Tenhunen et al., 2011). Large body movements were analysed from the raw signal channel, the respiratory movements were analysed from the low-frequency channel (LF, 0.3–10 Hz) and the high-frequency channel (HF, 6–16 Hz) was used to visualize heart- and respiratory-related spikes (Alametsa et al., 2006; Kirjavainen et al., 1996). The scoring was performed in 3-min epochs from lights off-event to the final awakening. The mattress signal categories are presented in Table 1, and they were: normal breathing (NB), periodic breathing type 1 (P1), obstructive periodic breathing types 1–3 (OP1–3), central periodic breathing (CPB), increased respiratory resistance (IRR), large movements in the row signal lasting >40s (M), epochs with at least four short periodic movements in the channels without respiratory variation (periodic movements, PM), and wake epochs (W) with EEG-defined wakefulness more than 50% of time. Wake and REM sleep epochs were not included into