Respiratory Physiology & Neurobiology 230 (2016) 1–4

Contents lists available at ScienceDirect

Respiratory Physiology & Neurobiology

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

The utility of respiratory inductance plethysmography in REM sleep scoring during multiple sleep latency testing☆

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ARTICLE INFO

Article history:
Received 18 April 2016
Accepted 26 April 2016
Available online 30 April 2016

Keywords:
REM
Respiratory inductance plethysmography
MSLT
SOREMPs
REM-related erratic breathing pattern

ABSTRACT

Rapid eye movement sleep (REM) presents with a characteristic erratic breathing pattern. We investigated the feasibility of using respiration, derived from respiratory inductance plethysmography (RIP), in conjunction with chin electromyography, electrocardiography and pulse oximetry to facilitate the identification of REM sleep (RespREM) during nocturnal polysomnography (NPSG) and Multiple Sleep Latency Testing (MSLT).

The Cohen's weighted kappa for the presence of REM and its duration in 20 consecutive NPSGs, using RespREM and compared to the current guidelines, ranged between 0.74–0.93 and 0.68–0.73 respectively for 5 scorers. The respective intraclass correlation coefficients were above 0.89. In 97.7% of the Sleep-Onset-REM-Periods (SOREMPs) during 41 consecutive MSLTs with preserved RIP, the RespREM was present and in 46.6% it coincided with the REM onset, while in the majority of the remainder RespREM preceded conventional REM onset.

The erratic breathing pattern during REM, derived from RIP, is present and easily recognisable during SOREMPs in the MSLTs and may serve as a useful adjunctive measurement in identifying REM sleep.

1. Introduction

In 1957, Dement and Kleitman identified rapid eye movement (REM) sleep based on the presence of rapid eye movements and low voltage fast electroencephalographic (EEG) activity (Dement and Kleitman, 1957). It was subsequently observed that REM sleep was accompanied by a marked change in respiration (Aserinsky, 1965), characterised by an increase in frequency of breathing and a decrease in thoracoabdominal movement (Gould et al., 1988; Tusiewicz et al., 1977). This appears to be particularly the case with phasic REM, wherein chemoreceptor sensitivity to partial pressure of carbon dioxide ($PaCO_2$) is diminished compared to both tonic REM and slow wave sleep, while rapid eye movements and ponto-geniculo-occipital waves are associated with alterations in medullary respiratory drive (Orem, 1980; Sullivan et al., 1979).

REM related variations in the respiratory amplitude and frequency have previously been considered as a potential REM scoring rule, but were discarded due to concerns regarding their applicability when sleep disorder breathing is present (Silber et al., 2007). Currently, REM scoring rules (Berry RB et al., 2012) recommend that REM sleep onset should be scored if all of the following are present: low-amplitude mixed frequency (LAMF) EEG; low chin electromyography (EMG) tone; and rapid eye movements.

We aimed to investigate if the erratic breathing pattern during REM (RespREM), as derived from the respiratory inductance plethysmography (RIP) bands, could be an adjunctive tool for the identification of REM sleep during multiple sleep latency testing (MSLT), where any sleep disordered breathing is required to be under treatment.

2. Patients and methods

The onset of the characteristic breathing pattern in REM is identified predominantly by a significant drop in the chest wall RIP signal amplitude, occurring in parallel with, the REM-defining drop in chin EMG, with a lesser drop also observed in abdominal RIP signal. Similar drops in RIP signals, but without the relevant drop in the

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http://dx.doi.org/10.1016/j.resp.2016.04.009
1569-9048/

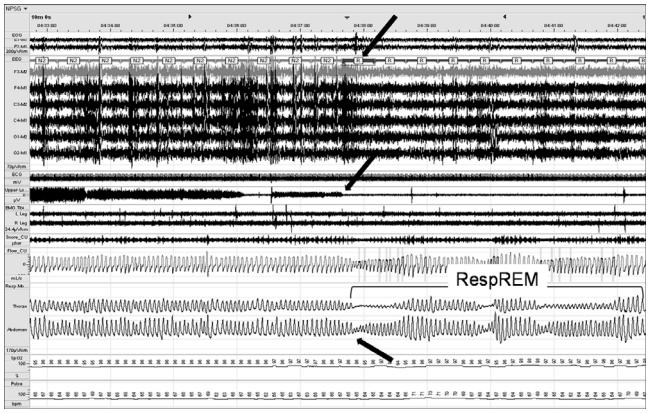

Fig. 1. A 10 min epoch of nocturnal polysomnography illustrating a NREM2 to REM transition and the REM-related erratic breathing pattern.
The upper arrow indicates the first REM epoch. The middle and lower arrows show the drop in chin EMG and the simultaneous drop in the chest wall signal with the initiation of the characteristic REM-related erratic breathing pattern (RespREM).

chin EMG can be observed following arousal events. To overcome scoring difficulties where the REM-defining lower chin EMG tone is not present (REM behaviour disorder, REM without atonia) or not clear we propose that this initial drop in RIP signal amplitude should be followed by a non periodical peak and trough pattern with a respective lower and higher breathing frequency, as seen in Fig. 1. To facilitate the identification of this pattern, the application of 10 min epochs is recommended based on our scorers' preference.

All the scorers participated in this study underwent an hour group standard-setting session reviewing examples of RespREM.

To test the reliability and feasibility of the RespREM tool, we applied it first to NPSGs, where occurrence of REM periods is greater than in MSLTs, and several sleep pathologies can be present. The modified NPSG of 20 consecutive patients, was scored by five experienced sleep scorers, blinded to the final diagnosis, using only chin electromyography, electrocardiography, pulse oxymetry and RIP for the detection of REM (RespREM), with subsequent assessment of accuracy against the current guidelines of the American Association of Sleep Medicine (AASM) for scoring REM. Intra-class correlation coefficient was used to assess reproducibility of measurement between different scorers. No exclusion criteria were applied to patients selection and all diagnoses were made in accordance with the International Classification of Sleep disorders 3 (ICSD3) criteria (AASM, 2014). Attended inpatient NPSGs were performed using the AASM recommendations (Richard Berry et al., 2013).

Following the completion of this part of the study, 41 consecutive MSLTs with sleep onset REM periods (SOREMPs) and RIP signal available, were analysed by one scorer seeking RespREM. Time difference between conventional REM onset and RespREM was recorded and analysed, taking into consideration the sleep stage sequence of the SOREMPs. Appropriate approval from the institutional review board on human research was obtained. The work described has been carried out in accordance with The Code of Ethics of the World Medical Association and informed consent was obtained from all subjects participated in this study.

2.1. Statistical analysis

Statistical analysis was performed using SPSS statistical analysis program (SPSS 21.0, IBM) and MEDCALC (v16.2). Data are reported as mean ± standard deviation (SD) unless otherwise indicated. Cohen's weighted kappa inter-correlation agreement was used for comparison between AASM rules and RespREM and intra-class correlation coefficient for the inter-observer agreement. Similarity of two means was compared using the Student *t*-test and the χ^2 test in case of normal distribution; otherwise, the Wilcoxon signed rank test was used. Significance level was assumed for p values < 0.05.

Table 1
Demographics and sleep diagnoses distribution in the two groups of patients participated in this study for RespREM rule validation.

Demographics	NPSG patients (n = 20)	MSLT patients (n = 41)
Male:Female	12:8	16:25
Age (mean ± SD)	43 ± 14.7	34 ± 13.0
BMI (mean ± SD)	30.4 ± 2.0	30.6 ± 2.3
Diagnosis (%)		
OSAS	8(40%)	1(2.44%)
NREM parasomnia	3(15%)	3(7.32%)
Insomnia	5(25%)	0%
Snoring	1(5%)	0%
PLMD	5(25%)	3(7.32%)
IH	2(10%)	6(14.64%)
NT1	0%	11(26.84%)
NT2	0%	12(29.28)
BIISS	0%	3(7.32%)
Shift Worker	0%	1(2.44%)
Isolated Sleep Paralysis	0%	1(2.44%)
DSPS	0%	2(4.88%)
Hypersomnia due to mental condition	0%	1(2.44%)

OSAS: obstructive sleep apnea syndrome, PLMS: periodic limb movements disease, NT1: narcolepsy with cataplexy, NT2: narcolepsy without cataplexy, BIISS: behaviorally induced inadequate sleep syndrome, DSPS: delayed sleep phase syndrome.

Table 2
Comparison agreement of RespREM rule against AASM recommendations in NPSGs. Average time difference between RespREM and REM onset is also reported.

	NPSG(98 REM periods)
Presence of REM periods	
ICC	0.89 (0.82–0.94)
REM duration	
ICC	0.95 (0.90–0.97)
Time difference in REM onset[a,*]	
Scorer 1	2.30 ± 0.01
Scorer 2	2.16 ± 0.01
Scorer 3	2.16 ± 0.01
Scorer 4	2.10 ± 0.01
Scorer 5	2.59 ± 0.03

Data are presented as Cohen's weighted kappa (95% confidence interval). ICC: intraclass correlation coefficient.
[a] Data are presented in epochs with mean ± SD.
[*] p > 0.05 (Anova).

3. Results

The demographic and clinical characteristics of the patients included in this study are presented in Table 1. The majority of subjects undergoing NPSG had findings consistent with either OSA or periodic limb movement disorder (PLMD), with central hypersomnias the most common diagnosis amongst those included in the MSLT cohort.

With regard to the NPSGs, our scorers using the RespREM rule identified most of the 98 REM periods (Berry RB et al., 2012), with a Cohen's weighted kappa ranging between 0.74–0.93. The results were similar when the total duration of REM sleep was assessed, with the weighted kappa ranging between 0.68–0.73, (Cohen, 1968; Kraemer, 1980). The inter-rater reliability was analysed by means of intraclass correlations, and the overall calculated level of agreement was κ = 0.89 (95% CI, 0.82–0.94) and κ = 0.94 (95% CI, 0.90–0.97) for the identification of REM sleep periods and their duration respectively, both considered as "very good" (Altman, 1991) (Table 2). The time deviation of RespREM from REM onset did not differentiate significantly between scorers (p > 0.05) (Table 2). Further case analysis identified that the lowest agreement was achieved in patients with obstructive sleep apnea and severe