Diagnosis of Sleep Related Breathing Disorder Based on Electrocardiogram Recordings

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Background

- Although OSAS has been recognized as an important contributing factor to increased cardiovascular morbidity and mortality, the disease remains under diagnosed and largely untreated due to the high costs/ reduced availability of whole night attended sleep studies. The need of alternative reliable and cost effective diagnostic methods is an imperative.
- The electrocardiogram (ECG) is an easy to acquire signal influenced by changes in the thoracic volume and posture. The quantification of changes in the geometry of the ECG waveforms allows estimating respiration. Based on this assumption we developed an algorithm that calculates ECG derived respiration (EDR) [1,2].
- Our goal was to evaluate the clinical applicability of ECG derived respiration.

Methods

- Retrospective data analysis from 13 adult subjects (6 females, 7 males; BMI=28+/-5; Age=37+/-8) referred to a sleep laboratory for a whole night PSG.
- PSG recordings included EEG, EOG, Chin EMG, Oronasal airflow and/or nasal pressure, abdominal and chest movement, SpO2 and pulse wave, and ECG sampled at 200 Hz at least.
- Inclusion criteria were: good quality PSG and ECG. ECG quality evaluation was based on signal-to-noise estimation, percentage of good quality signal, percentage of ECG with no movement artifacts, and the dynamic range of the signal.
- Sleep scoring was performed manually by an expert, according to R&K criteria.
- Respiratory events were separately obtained by two methods:
  - (1) Visual scoring (by expert) based on ASDA criteria
  - (2) Automatically by our algorithm
- The respiration signal obtained (EDR) was based on the continuous calculation of R wave amplitude and duration. The detection of respiratory events by our algorithm was performed for sleep time only; events were detected not only when they were followed by an autonomic arousal.
- Statistical analysis of the two result sets was performed……

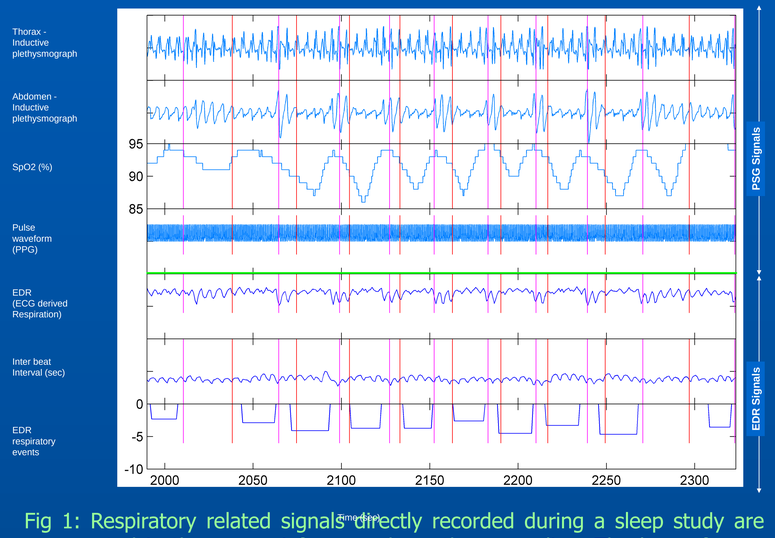

Fig 1: Respiratory related signals directly recorded during a sleep study are represented in the upper 4 frames, above the green line. The lower frames display parameters obtained by computation using our algorithms, namely EDR, inter-beat intervals and respiratory events. Vertical lines show the beginning (red) and end (purple) of respiratory event – as detected visually by an expert. Note the overlapping between the visually detected events and the EDR based ones as they appear in the bottom frame.

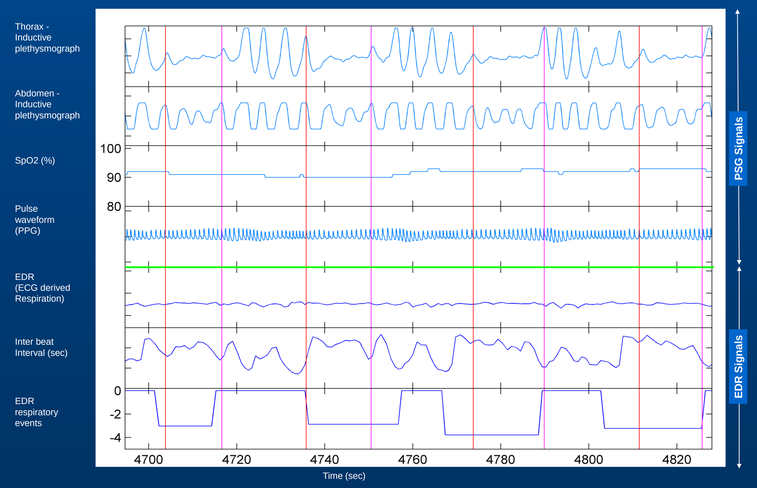

Fig 2: Same signals and frames as in Fig 1. Note that in this example, respiratory events were not followed by desaturations. Moreover, there were no autonomic arousals related to the respiratory events, either in the pulse wave signal or in the inter-beat interval.
EDR signal follows similar patterns as the abdomen respiratory inductive plethysmograph signal.

Results

✓A linear regression between the number of events per hour of sleep (RDI) resulting from the visual score and the RDI obtained by the EDR automated score showed a very good correlation with r^2=0.94, a=0.89 and b=-0.30 (see Fig 3).

✓EDR signal decreased during both central and obstructive events; however this change was significantly higher for central ones (p<0.027).

✓Bland Altman analysis showed mean difference in RDI value of 3.3 and standard deviation of 8.

Limitations

EDR captures the movement of the axis of the ECG electrodes relative to the electrical axis of the heart. Hence, it sums up movement of the thorax or abdomen or both – depending on the exact lead used. The limitations of this method are:

- It cannot be calibrated to tidal volume.
- It does not represent effort and cannot distinguish directly between central and obstructive apnea – although there are statistical differences between the quantitative EDR decrease during these events.
- The effective sampling of the breathing signal depends on the heart-rate – hence a low number of heartbeats per breath might adversely affect the quality of the signal.

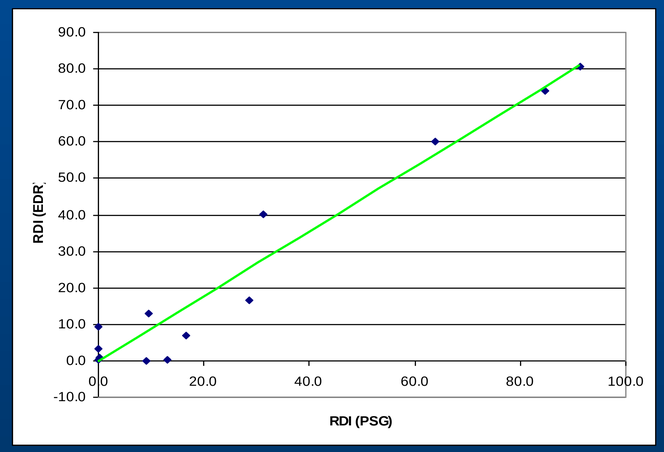

Fig 3: RDI obtained by EDR as a function of manually detected RDI from PSG. The line represents the correlation between the two measurements with R^2=0.094 and Y=0.89x-0.3

Conclusions

✓ Provided a good quality ECG recording respiratory events during sleep can be detected and quantified reliably.

✓ This novel method allows for multiple nights respiratory evaluation with obvious advantages in terms of comfort for the patient in the home environment and reduced cost per study.

ECG derived respiration may provide a cost effective diagnostic aid for sleep related breathing disorder

Refrences:
[1] Moody GB, Mark RG, Zoccola A, Mantero S. Derivation of Respiratory Signals from Multi-Lead ECGs. Comput. Cardiol. 1985. 12.pp113-116.
[2] Furman GD, Shinar Z, Baharav A, Akselrod S. Electrocardiogram Derived Respiration During Sleep. Compt. Cardiol.2005, 32.pp351-354.

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