Modern Methods in Cardiorespiratory Polysomnography

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Introduction

Studies of physiological processes in sleep not only involve the head related electrophysiological parameters of electroencephlalogram (EEG) electrookulogram (EOG) and electromyogram (EMG) but also have to take respiration, movement and the state of the cardiovascular system into account. While the recorded cardiac parameters used to be limited to the electrocardiogram (ECG), newer equipment also measures the pulsewave as well as aterial oxygenation via Photoplethysmography. Traditionally those cardiovascular parameters are mainly used as a means to monitor the vital stats of the patient under observation, even though they can be used to deduce the nightly variation of the relationship between sympathicus and parasympaticus and the general state of the autonomous nervous system (ANS) [1].

The large shifts impacting the ANS are not only due to the reduction in the activity of the metabolic system. It has even been argued that the observed changes co-occuring with the different sleep stages should be called a nightly stress test [2]. Today, characteristic changes of each sleep stage are known; symphathetic nerve activity is reduced in light sleep and especially deep sleep when compared to wake while showing a higher level parasympathetic activity. These changes are measurable using the classical methods based on heart rate variability (HRV) such as a spectral analysis of the beat-to-beat intervals (BBI) as seen in the ECG. The power over the low frequency band (LF; 0.04–0.15 Hz) is indicative of sympathetic activity while that in the high frequency band (HF; 0.15–0.4 Hz) mirrors *normal* repiratory processes and the parasympathetic activity. Care must be taken to correctly account for the respiration as an abnormally decreased breathing rate could easily be mistaken for sympathetic overactivation [3].

Heart Rate in Sleep Apnea

Shortly after sleep disordered breathing was first described by Guilleminault et al. [4], it was discovered that there are specific changes to the heart rate in parallel to the obstructive episodes. These cyclic variations, also known as verly low frequency oscillations, (VLF; < 0.04 Hz) are used by many diagnostic apparatus used in an ambulatory setting. Each apneic episoded is accompanied with a relative bradykardia followed by a tachycardic episode where the respiration has to compensate the reduced oxygen saturation.

Detection of Sleep Apnea from Heart Rate and ECG Morphology

Further cardiac features show promise in the diagnostics of apnea without requiring a complete cardiorespiratory polysomnography. The anual challenge held for the conference Computers-in-Cardiology 2000 in Boston was the detection of sleep apnea from a holter recording taken during the night [5]. Three groups of subjects with no, medium, or severe apnea were recorded and a total of 70 recordings were provided for the contest. 35 provided for training with the same amount held back as non-public evaluation data set. The top two groups scoring 92 and 95% respectively were using, in adition to the above mentioned cyclic variation of the heart rate, additional features such as the Amplitudes of the R-peak and T-wave.

Coupling and Synchronization of Heart Beat and Respiration

The coupling between the respiratory and the cardiac system, already mentioned in the context of HRV, is a long known effect, described as respiratory sinus arrhythmia in 1860 by Petr Einbrodt [6]. The study of phase synchronization of oscillators, especially in the context of complexity theory in the last decade of the last century, brought additional means to study this interrelationship of the regulatory mechanisms.

It was found that there was, under certain circumstances such as during deep sleep or other states of high relaxation, a tendency of heart beats to occur at certain phases of respiration. This synchronisation was significantly reduced on occurences of apneic events. Contrarily it has been found that another measure of coupling, the time based coordination, has a tendency to increase in hypertensive subjects and does not seem to be destroyed from these kind of events. [7]

Conclusion

Traditional cardiorespiratory polysomnography can be massivly enhanced, if not in some cases avoided, by the use of modern methods of cardiovascular physics. Parameters of heart rate as well as blood preassure variability can be combined with features derived from ECG morphology and coupling analysis to gain more detailed information of the physiology and pathophysiology of sleep wake regulation.

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