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Improving diagnostic ability of blood oxygen saturation from overnight pulse oximetry in obstructive sleep apnea detection by means of central tendency measure

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Summary

Objectives: Nocturnal pulse oximetry is a widely used alternative to polysomnography (PSG) in screening for obstructive sleep apnea (OSA) syndrome. Several oximetric indexes have been derived from nocturnal blood oxygen saturation (SaO_2). However, they suffer from several limitations. The present study is focused on the usefulness of nonlinear methods in deriving new measures from oximetry signals to improve the diagnostic accuracy of classical oximetric indexes. Specifically, we assessed the validity of central tendency measure (CTM) as a screening test for OSA in patients clinically suspected of suffering from this disease.
Materials and methods: We studied 187 subjects suspected of suffering from OSA referred to the sleep unit. A nocturnal pulse oximetry study was applied simultaneously to a conventional PSG. Three different index groups were compared. The first one was composed by classical indexes provided by our oximeter: oxygen desaturation indexes (ODIs) and cumulative time spent below a saturation of 90% (CT90). The second one was formed by indexes derived from a nonlinear method previously studied by our group: approximate entropy (ApEn). The last one was composed by indexes derived from a CTM analysis.

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Results: For a radius in the scatter plot equal to 1, CTM values corresponding to OSA positive patients (0.30 ± 0.20, mean $\pm$ S.D.) were significantly lower ($p \ll 0.001$) than those values from OSA negative subjects (0.71 ± 0.18, mean $\pm$ S.D.). CTM was significantly correlated with classical indexes and indexes from ApEn analysis. CTM provided the highest correlation with the apnea–hipopnea index AHI ($r = -0.74$, $p < 0.0001$). Moreover, it reached the best results from the receiver operating characteristics (ROC) curve analysis, with 90.1% sensitivity, 82.9% specificity, 88.5% positive predictive value, 85.1% negative predictive value, 87.2% accuracy and an area under the ROC curve of 0.924. Finally, the AHI derived from the quadratic regression curve for the CTM showed better agreement with the AHI from PSG than classical and ApEn derived indexes.
Conclusion: The results suggest that CTM could improve the diagnostic ability of SaO_2 signals recorded from portable monitoring. CTM could be a useful tool for physicians in the diagnosis of OSA syndrome.

1. Introduction

The obstructive sleep apnea (OSA) syndrome is characterized by repetitive reduction or cessation of airflow due to partial or complete airway obstruction [1]. This disease is usually associated with hypoxemia, bradycardia, arousals and fragmented sleep [2]. Nowadays, OSA is the most common respiratory referral in many sleep centers [3]. The estimated OSA prevalence varies from 1 to 5% of adult men in western countries [4]. OSA is associated with conditions that are responsible for the most important causes of mortality in adults: hypertension and cardiovascular and cerebrovascular diseases. Several neurobehavioral morbidities, which are of potentially great public health and economic importance, are linked with OSA [4]. The major behavioral symptoms include excessive daytime sleepiness (EDS), neurocognitive deficits like impairments in concentration and memory, and psychological problems like depression or personality changes [5]. Individuals with OSA are dangerous drivers with an increased risk of being involved in road and work accidents [3].

The standard diagnostic test for OSA syndrome is overnight polysomnography (PSG) [6], consisting in the recording of neurophysiological and cardiorespiratory signals subsequently used to analyze sleep and breathing. The apnea–hypopnea index (AHI) derived from the PSG is then used to diagnose the disease. Portable monitoring has been proposed as a substitute for PSG in the diagnostic assessment of patients with suspected sleep apnea [7]. Due to its noninvasive nature and simplicity, nocturnal pulse oximetry is widely used in many medicine areas to determine patient's blood oxygen saturation (SaO_2) and heart rate. The lack of airflow during apneic periods can lead to recurrent episodes of hypoxemia that can be detected on oximetry as fluctuations in SaO_2 records [8].

Several quantitative indexes derived from nocturnal oximetry have been developed to diagnose OSA. The most frequently used by physicians include oxygen desaturation indexes (ODIs), which measure the number of dips in the SaO_2 signal below a certain threshold [9–11], and the cumulative time spent below a certain saturation level (CT) [12,13]. However, these indexes have significant limitations. In general, CT indexes did not achieve high diagnostic accuracies [13,14]. On the other hand, there is not a universally accepted definition for oxygen desaturation. Moreover, there is not a consensus on a threshold to diagnose OSA based on ODIs [14,15]. Furthermore, correlation between oximetry indexes and AHI is not high [13]. In previous studies [16–18], our group has shown that nonlinear analysis could provide useful information in the diagnosis of OSA syndrome. A regularity measure from SaO_2 signals obtained applying approximate entropy (ApEn) improved the diagnostic accuracy of classical oximetric indexes [16]. ApEn was also applied to heart rate signals from nocturnal oximetry, obtaining promising results [17]. Moreover, additional nonlinear methods, central tendency measure (CTM) and Lempel–Ziv (LZ) complexity, were applied to SaO_2 records [18]. The results suggested that both CTM and LZ complexity could help physicians in screening for OSA syndrome. Particularly, a variability measure by means of the CTM provided the best diagnostic accuracy. The present study intended to go more deeply into the usefulness of the CTM to diagnose OSA. We assessed its advantages over classical oximetric indexes and other nonlinear methods: it is a simple parameter to estimate the signal variability with a low computational cost [19]. Furthermore, we studied the changes in the diagnostic accuracy when using different values of the input parameters.

Variability measures of ECG allow to distinguish between normal and chronic heart failure subjects