Detecting OSAHS from Patterns seen on Heart-Rate Tachograms

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Abstract

Objective: To determine the accuracy of a simple, visual heart rate (HR) tachogram-based method for identifying significant obstructive sleep apnea hypopnea syndrome (OSAHS). Method: N=35 HR tachograms, 10 min/line, 1hr/page, were generated from machine-generated beat-to-beat RR interval data provided by PhysioNet and extracted using the WFDB software package. Each tachogram was analyzed for the presence of cyclic variation of HR (CVHR), i.e., visible, cyclic, rapid increases and subsequent decreases in HR. Studies with >10 CVHR events in 1 hr and ≥100 minutes of CVHR during the entire night were scored as "severe," otherwise they were scored as "none." Results: Of the 30 studies that were known to have either severe OSAHS or none, 96.6% were correctly scored using this simple method. Conclusions: Results suggest that HR tachograms, which can easily be generated as a part of routine Holter scanning, may identify patients with previously undetected OSAHS, permitting two diagnostic tests for the effort and cost of one.

1. Introduction

Guilleminault et al [1], during the 1980's, were the first to show that the presence of "cyclical variation of heart rate (CVHR) can identify patients with sleep apnea. Despite the potential to use CVHR to screen for sleep apnea on routine Holter recordings, Guilleminault's findings were not applied.. This lack of enthusiasm may have resulted from the technical difficulties associated with generating the requisite R-R interval plots, or possibly because the prevalence and clinical significance of sleep apnea were yet not fully appreciated. Since then, it has become clear that the fragmentation of sleep due to obstructive sleep apnea hypopnea syndrome (OSAHS) has severe adverse consequences including poorer daytime cognitive performance, increased risk of motor vehicle and workplace accidents, as well as depression, diminished sexual function and memory loss [2]. Adverse physiologic effects of OSAHS , including increased activity of the sympathetic nervous system and abnormalities in peripheral chemoreceptor sensitivity persist into the daytime hours [3]. OSAHS is known to be associated with arterial and pulmonary hypertension [3], both left and right ventricular hypertrophy [3], and decreased daytime heart rate variability [4], increased risk of ventricular arrhythmias, myocardial ischemia, sudden cardiac death, myocardial infarction and stroke [5,6]. Most important, treatment can result in normalization of sleep, normalization of physiology [7], and improved outcome [5].

Even today, however, OSAHS is grossly under diagnosed, and referral rates to the Sleep Disorders Laboratory vary widely across physicians. It has been estimated that 93% of moderate to severe cases of sleep apnea in women and 82% in men escape clinical diagnosis [8]. Although the clinical sleep study is the gold standard, overnight polysomnography is expensive and inconvenient, resulting in a reduced likelihood of the test being performed. Furthermore, many sleep laboratories are already at capacity and have long waiting lists [5,7]. Holter monitoring is far cheaper and can be performed when needed. Thus, detection of OSAHS from CVHR seen on heart rate tachograms, generated in association with Holter scanning, could potentially identify many patients who would otherwise escape detection and treatment. This study tested the feasibility of this simple method.

2. Methods

2.1 Tachogram generation

Each R-R interval was converted to an instantaneous heart rate (60,000 ms per minute/R-R in ms) and the resultant heart rate series plotted against time using a program written in UNIX/C and gnuplot. The time of occurrence for each beat was derived by summing the prior R-R and noise intervals and adding that sum to the start time of the recording. Because the data were in the form of machine-generated QRS interval files in which normal beats, ectopy and noise were all labelled as normal beats, the time series was filtered by excluding all intervals <300 ms and >2500ms. In the current series, the start time was

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arbitrarily set to 00:00 for each patient. Plots were made in 10-minute segments such that 6 parallel 10-minute plots fit on an 8 ½" by 11" page in landscape mode. Thus, one hour of data was represented on each tachogram page. The y-axis for each plot was 0-100 bpm and the tick mark at 100 bpm was also 0 bpm for the next plot. Tachograms were printed and also saved as .pdf files. Figure 1 shows a representative 1-hour tachogram.

In most cases, the tachogram generated from the filtered time series was adequate for apnea detection. In a few cases, where the signal was too noisy, customized ECG-scanning software was used to generate a QRS file consisting of true normal-to-normal intervals derived from the raw ECG signal.

2.2 Tachogram analysis

Each tachogram was examined for the presence of cyclic variation of heart rate (CVHR). CVHR was considered to be present if there were at least 3 consecutive cycles of rising and falling HR. The rise in HR had to be at least 6 bpm. HR had to fall to baseline (or below). Each cycle had to be ≥10s duration. The start of one cycle and the start of the next had to be at least 20s but ≤ 2 min apart.

3. Results

Of the 35 patients in this study, 20 were classified as having severe sleep apnea (at least one hour with 10 apneas and at least 100 minutes with apneas), 10 with none and 5 with non-significant OSAHS. The tachogram method successfully identified 29 of the 30 with either severe or no OSAHS (96.6%). Data editing to eliminate noise and ectopy was necessary in only one of these cases. CVHR was clearly visible in every case and detailed quantification, as described above, proved to be unnecessary.

Figure 2 illustrates some of the different patterns of CVHR seen among patients with severe OSAHS in this study. What is notable in the figure, in addition to the obvious nature of the CVHR, is that despite the common belief that the "brady-tachy" HR pattern (i.e, a HR deceleration associated with the apnea followed by a HR acceleration during the subsequent arousal) is a hallmark of sleep apnea that is not the case. In fact, this pattern was seen in only 6 subjects in this study. Also evident is that the precise shape and frequency of the HR arousal pattern varies considerably across (and not shown) within subjects.

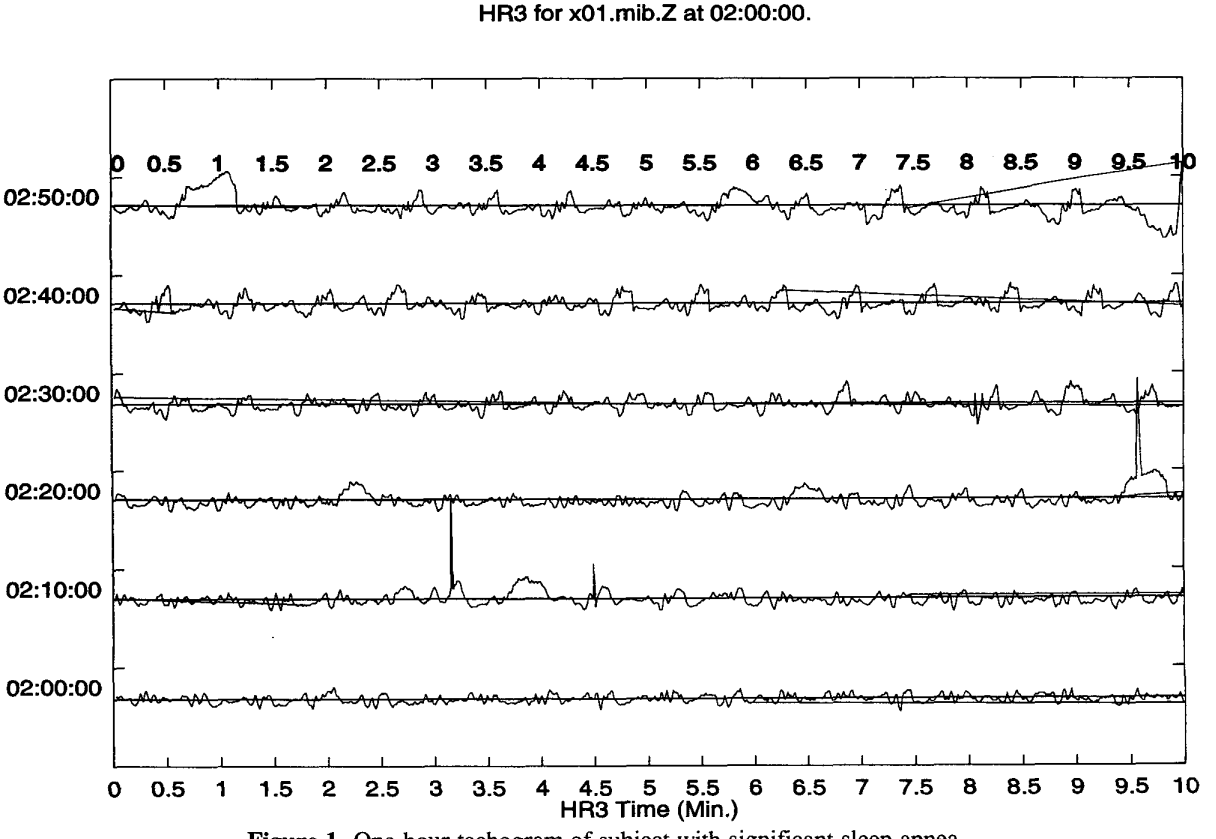

Figure 1. One-hour tachogram of subject with significant sleep apnea

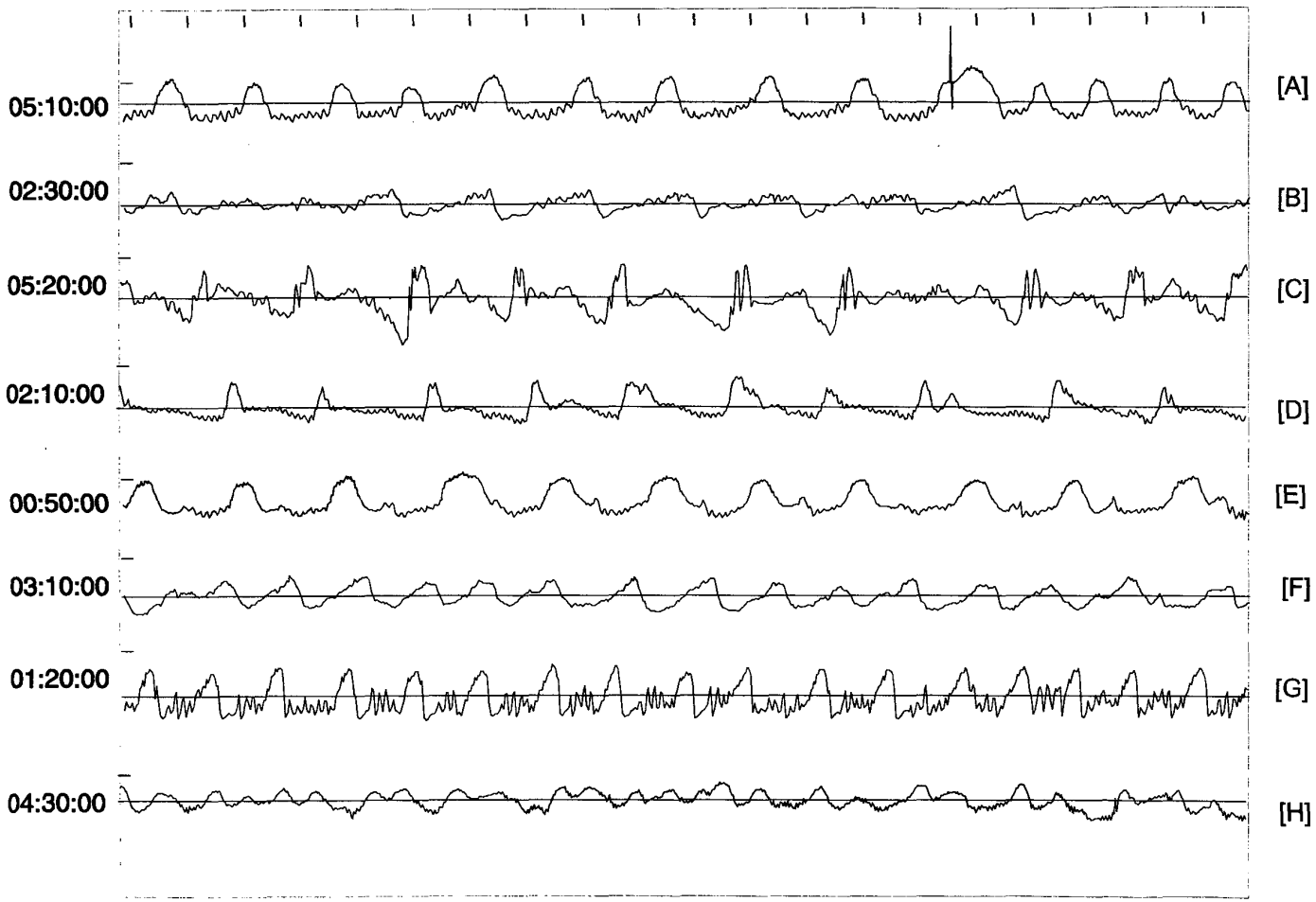

Figure 2. Ten-minute segments from tachograms for different subjects with severe sleep apnea. Tick mark above each represents 100 bpm but tick mark below is unrelated to the figure above. (A) no HR change with apnea, RSA (respiratory sinus arrhythmia) continues; (B) RSA ceases with apneas; (C) bradycardia with apneas; (D) bradycardia with apneas (E) slight tachycardia with apneas; (F) little RSA seen; (G) high RSA; (H) atypical CVHR.

4. Discussion

Results clearly support the potential of using heart rate tachograms to identify patients with severe OSAHS who might otherwise go undiagnosed. It is clear from the prior examples that when CVHR is severe OSAHS is readily recognizable. Holter scanner software could easily be modified to include HR tachograms as part of the final report. Thus, all patients in predominantly normal sinus rhythm undergoing Holter monitoring could automatically be screened for severe OSAHS. In addition, when severe OSAHS is discovered on Holter monitoring, patients could skip the split-night sleep study and have full night CPAP titration in the sleep lab. Holter monitoring could later be used to evaluate the effectiveness of CPAP in reducing HR arousals in these cases, without the patient needing to return to the sleep laboratory. Also, there are data sets, e.g., the Cardiovascular Health Study, where Holter recordings have been obtained on a large number of people who were subsequently followed for cardiovascular outcomes. HR tachograms could identify those with severe OSAHS and the relationship between their sleep disorder and outcome studied. There are also several large cardiac Holter data sets (e.g., MPIP, SOLVD, MUSTT, etc.) where the prevalence and effect on morbidity and mortality of severe OSAHS could be determined.

Limitations of this method must be noted. Patients with severe autonomic dysfunction (e.g. diabetics) are likely to have non-diagnostic tachograms. However, such tachograms are notable for the complete lack of the large movement-related HR arousals found in those without autonomic dysfunction. Also, this method is not usable for patients in atrial fibrillation, a group with a high prevalence of OSAHS. Similarly, detection of OSAHS may prove difficult in patients with a high proportion of non-respiratory sinus arrhythmia or ectopic beats. Finally, in some cases, the tachogram method may not distinguish between arousals due to sleep apnea and arousals due to other causes like periodic limb movements or frequent arousals for no apparent reason. However, the sleep of any person with significant CVHR, no matter what the cause, is significantly fragmented and that person, whether they suffer from sleep apnea or not, would be a candidate for a sleep study.

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