Analysis of the Influence of EEG Arousals from Nocturnal Sleep on Heart Rate

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Abstract

Heart rate changes during sleep due to several factors, like sleep stage, awakenings and body movements. This work investigates the influence of sleep arousal on heart rate changes. 586 arousals from seven polysomnographic recordings were analysed, and the mean frequency of the RR series was obtained every 5" from 20" before to 20" after the arousal. Results show that the mean heart rate decreases at least 15" before the arousal occurrence, and the original value is reached in the following 20" after the arousal.

1. Introduction

Arousals are transient EEG activities in nocturnal sleep, characterised by frequency increases of the signal, and they are related with daytime alertness or sleep quality. Their presence (possibly due to an increment of sympathetic nervous system activity), as well as changes in sleep stage, modify heart rate [1]. Muscular activity is another cause of heart rate variations, frequently associated to arousal presence, although some body movements may produce modifications in heart rate, even if they are not associated with the presence of EEG arousals [2].

Our objective is to analyse the influence of sleep arousal on heart rate changes in function of their different origins (types) and sleep stage of occurrence.

2. Materials and methods

Registers were obtained from the EEG Sleep Unit, La Fe Hospital (Valencia, Spain), using an acquisition system connected to a polysomnographic monitor. Eight channels (three EEG, two EOG, one EMG, one ECG and one of respiratory activity) were acquired with a 250 Hz sampling frequency and a 12-bit resolution.

For seven patients, nocturnal polysomnographic recordings were acquired and analysed by two experts in order to mark the presence, type and stage of EEG arousals. Sleep recordings were scored by Rechstchaffer and Kales criteria [3], and arousals were scored by ASDA criteria [4]. Four sleep stages of occurrence (S1 (N=18), S2 (N=484), S3 (N=62), REM (N=22)) and three types of arousal origins (T1: respiratory (N=377); T2: muscular (N=56); T3: others (N=153)) have been studied. For T1, an arousal occurrence was marked at the end of a respiratory apnea although no evidence was found on the EEG channels. For every recording, arousals marked in no valid segments were excluded from the study. Table 1 shows the final classification of every file used. In three cases (files 2, 3 and 6), patients had frequently apneic episodes.

File	T 1	T 2	T 3	S 1	S 2	S 3	REM
1	0,0	0,7	3,1	1,4	2,2	0,0	0,2
2	16,4	1,9	2,7	1,4	18,1	0,2	1,4
3	26,5	1,2	2,0	0,2	28,0	0,0	0,3
4	0,2	5,3	7,7	0,0	8,0	6,1	0,2
5	0,3	0,2	6,8	0,0	6,3	0,5	0,5
6	21,0	0,0	0,3	0,2	16,9	3,4	0,9
7	0,0	0,3	3,4	0,0	3,1	0,3	0,3

Table 1. Arousal percentage for every file in function of type (T1-3) and sleep stages of occurrence (S1-3, REM).

An algorithm based on adaptive threshold of the filtered and transformed ECG signal [5] was used to detect the QRS positions, and ectopic pulses were removed. In addition, the mean frequency (in beats per minute) of the RR series was obtained every 5" from 20" before to 20" after the arousal. The mean frequency at 20" before is used as the reference frequency, and is considered to be free from arousal influence.

For the register segmentation and mean frequency calculation of the heart rate, Matlab® 5.3 was used. Results are given as mean ± SD. Statistical analysis of results has been done using Student's t-test. Probability values $p<0.05$ have been considered statistically significant.

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Computers in Cardiology 2001;28:417-420.

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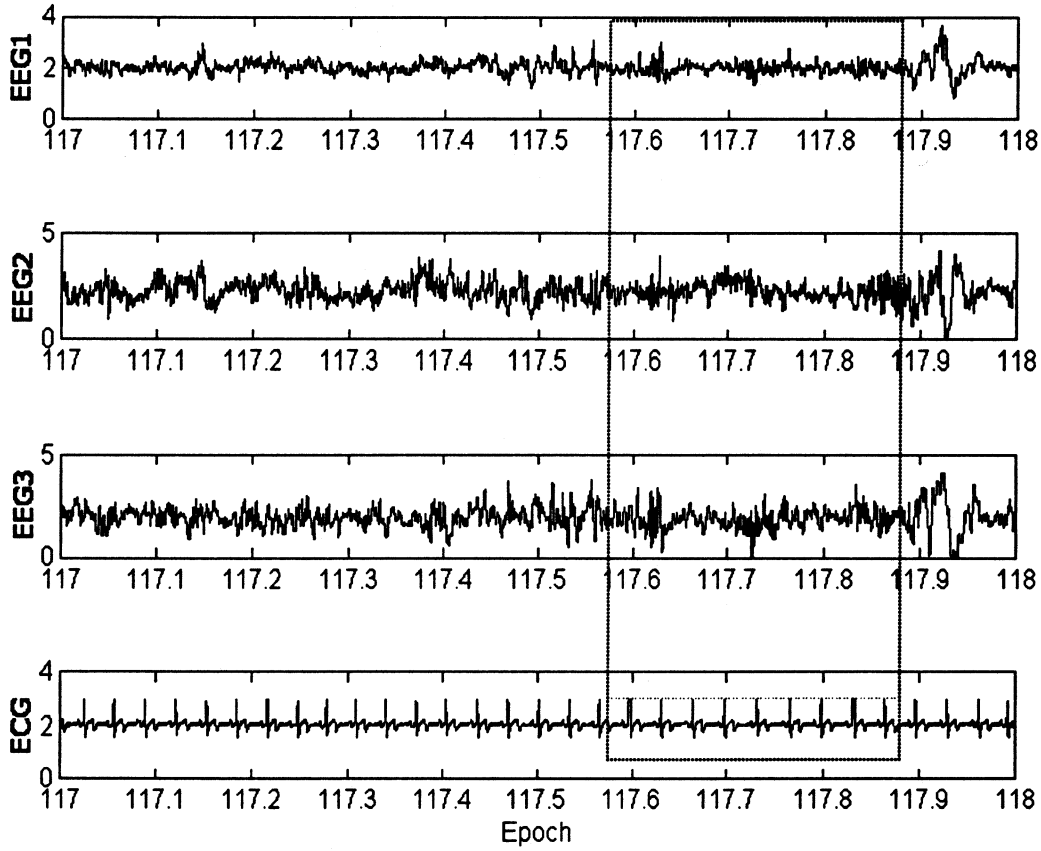

Figure 1. Example of EEG and ECG channels of a polysomnographic register. X-axis is represented in epochs (1 epoch = 30 sec.). Dot line marks the arousal presence.

3. Results

Figure 1 shows an example of EEG and ECG channels for a polysomnographic register. Dot line corresponds to the expert's mark of the arousal presence. Figures 2 and 3 show the average values obtained for the heart rate, normalized by the mean value in arousal presence, for the arousal types and for the four stages of arousal occurrence, respectively. Their corresponding mean heart rate frequencies values (in beats per minute) are represented in tables 2 and 3. Table 4 represents the statistical significance (p) for the paired test between the correspondent values of every 5" segment and the reference one (20" prior to arousal) for the corresponding types and stages.

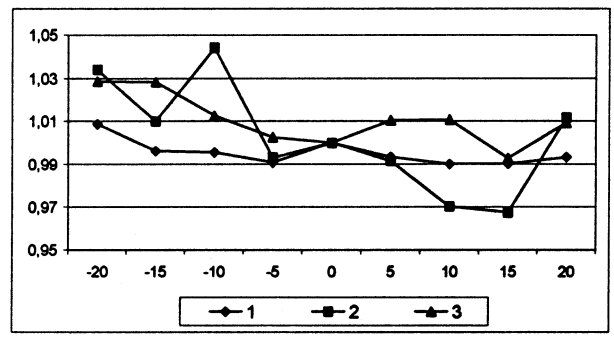

Figure 2. Average values obtained for the heart rate, normalized by the mean value in arousal presence, for the three arousal types. X-axis in seconds (0 represents the arousal presence).

Sec.	TYPE		
	1	2	3
-20	66,91± 10,89	73,08± 13,65	73,33± 13,93
-15	66,08± 9,78	71,39± 11,22	73,31± 10,90
-10	66,04± 9,75	73,81± 11,83	72,18± 10,83
-5	65,73± 9,23	70,20± 10,53	71,47± 10,03
0	66,34± 10,51	70,68± 10,91	71,29± 12,18
+5	65,91± 9,62	70,08± 10,57	72,02± 11,41
+10	65,68± 9,38	68,58± 9,50	72,05± 11,15
+15	65,69± 9,20	68,38± 9,06	70,78± 10,02
+20	65,89± 11,56	71,51± 13,59	71,95± 13,78

Table 2. Mean heart rate frequencies (in beats per minute) for the different types of arousals. Second 0 represents the mean frequency in the arousal window.

Sec.	STAGE			
	1	2	3	REM
-20	62,88± 7,13	68,53± 12,32	76,50± 11,73	67,88± 11,85
-15	62,38± 7,18	68,06± 10,59	74,33± 9,86	66,14± 12,34
-10	62,62± 8,17	67,54± 10,51	77,21± 8,38	66,92± 11,10
-5	63,55± 8,95	67,05± 9,58	74,11± 8,73	66,26± 13,84
0	61,90± 6,88	67,48± 10,92	74,91± 10,60	66,07± 14,88
+5	61,97± 6,03	67,37± 10,34	73,65± 10,10	68,23± 13,42
+10	62,55± 6,00	67,30± 10,28	72,24± 9,18	65,79± 11,38
+15	62,24± 4,55	66,55± 9,32	74,59± 8,25	66,74± 13,74
+20	64,55± 13,01	67,22± 12,10	75,42± 13,92	67,26± 14,80

Table 3. Mean heart rate frequencies (in beats per minute) for the different stages of the arousal presence. Second 0 represents the mean frequency in the arousal window.

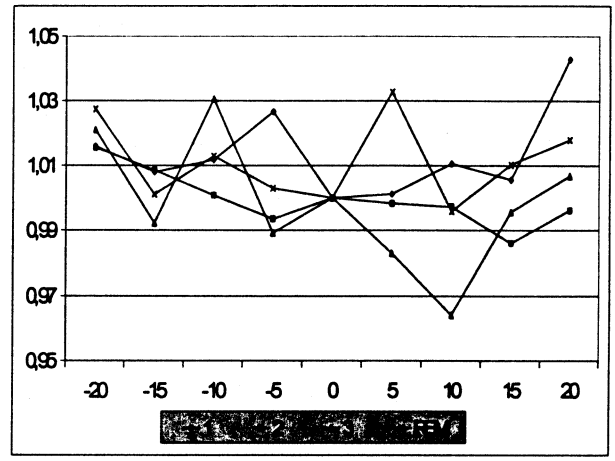

Figure 3. Average values obtained for the heart rate, normalized by the mean value in arousal presence, for the four stages of arousal occurrence. X-axis in seconds (0 represents the arousal presence).

TYPE	1	2	3
A-20 : A-15	0.037	0.150	0.493
A-20 : A-10	0.028	0.322	0.138
A-20 : A-5	0.008	0.027	0.031
A-20 : A	0.123	0.090	0.051
A-20 : A+5	0.019	0.044	0.135
A-20 : A+5	0.009	0.003	0.121
A-20 : A+15	0.008	0.004	0.013
A-20 : A+20	0.051	0.205	0.111

STAGE	1	2	3	REM
A-20 : A-15	0.126	0.139	0.123	0.286
A-20 : A-10	0.368	0.015	0.336	0.345
A-20 : A-5	0.277	0.001	0.079	0.295
A-20 : A	0.074	0.021	0.201	0.287
A-20 : A+5	0.096	0.010	0.072	0.446
A-20 : A+5	0.387	0.006	0.013	0.219
A-20 : A+15	0.282	0.000	0.142	0.317
A-20 : A+20	0.199	0.010	0.301	0.423

Table 4. Statistical significance (p) for the paired test between the corresponding values of every 5" segment and the reference one (20" prior to arousal).

Results show a heart rate decreasing at least 15" before the arousal occurrence, and the reference value is reached in the 20" period after the arousal. Although this evolution has been found for all the cases, significant differences have been mainly found for stage 2 and for respiratory and muscular types.

In contrast to published data, that show an increase in heart rate prior and during arousal occurrence, we found a similar variation pattern near arousals but with a decrement of the heart rate. Except for stage 2, there were no significant relationship between heart rate and sleep stage.

A possible reason for this result may arise in the characteristics of the data sets, generally healthy subjects in other studies, and constituted by patients with different pathologies in our case. In addition, some studies select segments without transition stages. We should conclude that there isn't an universal pattern of response of the heart rate to arousal occurrence, and the response is similar only in some grouped patients.

4. Conclusions

We have observed: 1) The mean frequency shows a decreasing at least 15" before the arousal occurrence, and the reference value is reached in the 20" period after the arousal. 2) Significant differences have been mainly found for stage 2 and for respiratory and muscular types.

Differences found among published data suggest the need of studying the response of the heart rate to arousal occurrence for different groups of patients.

Acknowledgements

This work was partially supported by project 01/0318 of the "*Fondo Investigación Sanitaria (FIS)*".

References

[1] Bonnet M, Arand D. Heart rate variability: sleep stage, time of night and arousal influences. Electroencephalography and Clinical Neurophysiology, 1997; 102:390-6

[2] Winkleman J. The evoked heart rate response to periodic leg movements of sleep. Sleep 1999;22:575-80.

[3] Rechstchaffen A, Kales A Eds. A manual of standardized terminology techniques and scoring system for sleep stages oh human subjects. Brain information service/Brain research institute. University of California at Los Angeles, 1968.

[4] Task Force of the American Sleep Disorders Association. EEG Arousals: Scoring rules and examples. A preliminary report from the Sleep Disorders Atlas. Sleep 1992;25:174-84.

[5] Pan J, Tompkins W. A real time QRS detection algorithm. IEEE Transactions on Biomedical Engineering 1985; 32:230-36.

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