CARDIAC FIELD ARTIFACT IN SLEEP EEG

K. C. Harke*, A. Schlögl*, P. Anderer**, G. Pfurtscheller*

*Department of Medical Informatics, University of Technology, Graz, Austria
**Department of Psychiatry, School of Medicine, University of Vienna, Austria

harke@sbox.tu-graz.ac.at

Abstract: Estimates of the cardiac field artifact were obtained for each EEG/EOG channel of all-night sleep EEG/ECG recordings by heartbeat-related averaging of the EEG. These estimates – so-called templates – can be used for minimization of the artifact, e. g. by heartbeat-synchronized subtraction of the template. The 3-dimensional nature of the cardiac field artifact is demonstrated by constructing vectorcardiograms from the templates and the corresponding electrode positions.

Introduction

The cardiac electrical field affects the surface potentials on the scalp. In EEG recordings, this leads to an artifact. In some cases, the QRS complex of the ECG can be visually recognized in the EEG waveform (Figure 2). For EEG analysis, it is desirable to minimize this artifact.

Several approaches to this problem can be found in literature. In this work, a basic technique is used, which was described e. g. by Barlow and Dubinsky [1] and Nakamura and Shibasaki [2]. The procedure works on EEG with one simultaneously recorded ECG signal. It consists of following steps:

1. A trigger signal is generated from the ECG by *QRS detection*. 2. An average ECG-artifact waveform (a template) for each EEG channel is obtained by *averaging* a certain period of the EEG signals around every detected QRS complex. 3. An estimate of the artifact is generated for each EEG channel by *repetition of the templates,* synchronized by the ECG-trigger. 4. These signals are *subtracted* from the raw EEG.

Fortgens and De Bruin [3] used four ECG derivations to model the cardiac dipole vector at each EEG electrode position as a linear combination of the ECG signals. Artifact removal is done by subtraction of this linear combination from the raw EEG under the condition, that the variance of the EEG becomes minimum after subtraction.

Artifact cancellation by adaptive filtering was described by Sahul et al. [4]. Strobach et al. [5] use both, templates and an adaptive filtering algorithm.

Dirlich et al. [6] investigated the topography of the scalp potentials of cardiac origin and the effects of head turns. They stated the 3-dimensional nature of the cardiac field artifact.

Materials and Methods

Data: The procedure was applied to 16 all-night sleep recordings from the SIESTA project, containing following signals: *EEG:* FP1-M2; C3-M2; O1-M2; FP2-M1; C4-M1; O2-M1; M2-M1; *EOG:* Pos8-M1 and Pos18-M1. (Pos 8 and Pos 18 according to [9] are Er5 and El6 according to [8], respectively.) *ECG:* One channel, right to left clavicle. Sampling frequencies are 100, 200, 256 and 400 Hz.

QRS Detection: An QRS detection algorithm that uses the squared envelope of the ECG as detection function [7] has been implemented in Matlab. The final result of the QRS detection procedure is a list of indices, which mark a fiducial point in every detected QRS complex.

Heart cycle related averaging of the EEG: Intervals of 3 seconds – 1 s before and 2 seconds after every fiducial point – from each EEG channel are averaged. All detected QRS complexes of an all-night recording - between 20454 and 38285 for the 16 recordings - are used in this procedure. This yields one 3 s period of averaged signal per EEG channel, in which all signal components uncorrelated with the heart rhythm have vanished and that contains a complete heart cycle (the template).

Heartbeat synchronized repetition of the templates: The templates are windowed by an asymmetrical (0.25 s rising and 0.5 s falling edge) hanning window. Heartbeat synchronized repetition is done by convolution of the windowed template with the index-list of QRS-complexes, which can be considered as a sequence of unit pulses in cardiac rhythm. Thus, an ECG in EEG is obtained. These signals are subtracted from raw EEG. An example can be seen in figure 2.

Construction of Vectorcardiograms: Nine EEG-/EOG-signals are given, where the desired solutions **x**[n] have only three components, i. e. the system of equations is overdetermined.

$$\boldsymbol{U}_{Nx9} = \boldsymbol{X}_{Nx3} * \Delta\boldsymbol{R}_{3x9} \qquad (1)$$

$\boldsymbol{U}$ is the matrix of templates, $\Delta\boldsymbol{R}$ describes the spatial differences between the two electrodes of each EEG-/ EOG channel [8] [9]; $\boldsymbol{X}$ are the 3 spatial templates that fit best to equation (1). Calculation and vizualization of the vectorcardiogram is also implemented in Matlab;

onset and end of the period used for the calculation has to be selected manually from the 3 s templates.

Results

Figure 2 shows (a) 9 seconds of raw EEG (channel M2-M1 of the recording b000101 rec. 1111-1113), (b) the repeated template and (c) the corrected EEG.

An example for construction of a vectorcardiogram can be seen in Figure 1: (a) ECG templates; (b) 3-dimensional vector loop with projections in the orthogonal planes.

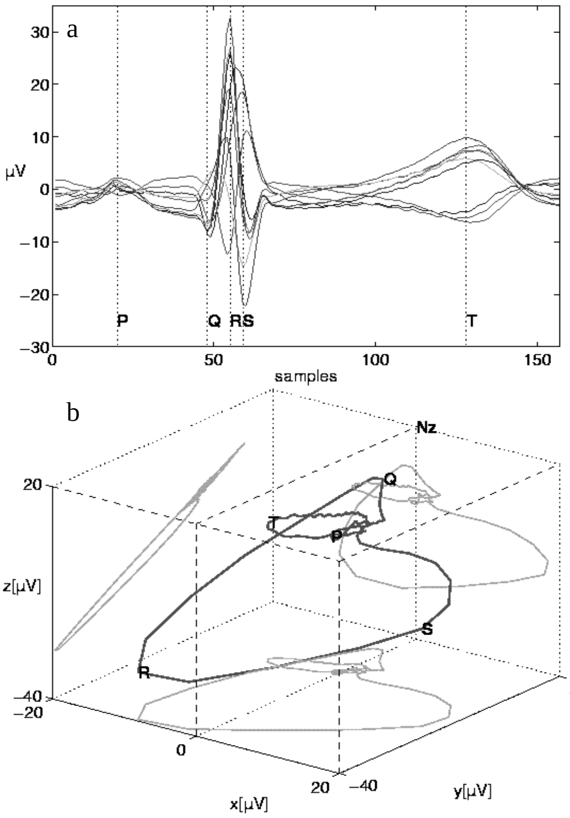

Figure 1: (a) Templates for recording n000401; (b) 3-dimensional vector-loop

Discussion

It has been demonstrated that the cardiac field artifact in EEG is due to an – unknown – 3-dimensional source, the cardiac dipole vector. Every body surface potential, EEG or ECG, represents a projection of the cardiac electrical field in a 2-dimensional subspace. As carried out before e. g. in [3] and [5], the spatial properties of the dipole vector have to be considered in correcting the cardiac field artifact. Methods, that use a single ECG channel as reference for correction, suffer from the lacking third dimension.

Some assumptions are inherent to the reported method of correcting the EEG: the artifact's variability has to be very small; a constant spatio-temporal relationship between ECG and the artifact in EEG is assumed. In reality, it is affected e. g. by head turns [6].

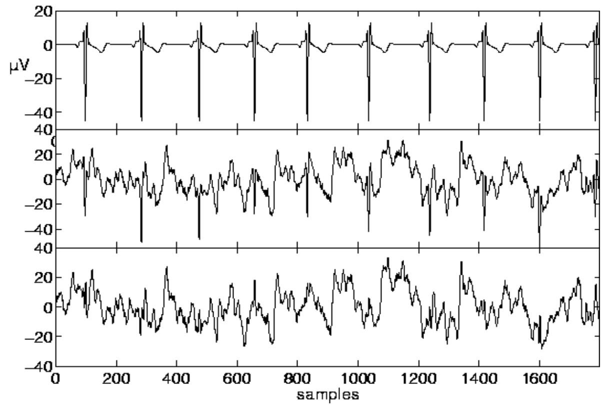

Figure 2: QRS cancellation procedure

Conclusion

Even the P- and the T-wave contribute to the ECG artifact in the EEG its waveform depends on spatial conditions. ECG artifacts in the sleep EEG can be removed by using the templates.

REFERENCES

[1] J. S. Barlow, J. Dubinsky, EKG-artifact minimization in referential EEG recordings by computer subtraction. *Electroenceph. clin. Neurophysiol.* 48 (1980): 470 – 472

[2] M. Nakamura, H. Shibasaki, Elimination of EKG artifacts from EEG records: A new method of non-cephalic referential EEG recording. *Electroenceph. clin. Neurophysiol.* 66 (1987): 89 – 92

[3] C. Fortgens, and M. P. De Bruin, Removal of eye movement and ECG artifacts from the non-cephalic reference EEG. *Electroenceph. clin. Neurophysiol.* 56 (1983): 90 – 96

[4] Z. Sahul, J. Black, B. Widrow, C. Guilleminault, EKG artifact cancellation from sleep EEG using adaptive filtering. *Sleep Research* 24A (1995): 486

[5] P. Strobach, K. Abraham-Fuchs, W. Härer, Event-Synchronous Cancellation of the Heart Interference in Biomedical Signals. *IEEE Trans. Biomed. Eng.* 41.4 (1994): 343 - 350

[6] G. Dirlich, L. Vogl, F. Plaschke, F. Strian, Cardiac field effects on the EEG. *Electroenceph. clin. Neurophysiol.* 102 (1997): 307 – 315

[7] M.-E. Nygårds, L. Sörnmo, L.: Deliniation of the QRS complex using the envelope of the e. c. g.. *Med. & Biol. Eng. & Comput.* 21 (1983): 538 – 547

[8] CEN, Vital signs Information Representation Version 1.2, Interim Report - CEN/TC251/WG5/N95-3, European Committee for Standardisation, Brussels, 1995

[9] Häkkinen, V., Hirvonen, K. et al.: The effect of small differences in electrode position on EOG signals: application to vigilance studies. *Electroenceph. clin. Neurophysiol.* 86 (1993): 294 - 300