Principal Component Analysis and Gabor transform in analysing burst-suppression EEG under propofol anaesthesia

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INTRODUCTION
The electroencephalogram (EEG) can be used in a variety of fields to examine the state and the dynamics of the human brain. The normal states of vigilance such as sleep and wakefulness, but also system disorders such as epilepsy and brain damage, and abnormal levels of vigilance such as coma and anaesthesia can be studied by the EEG.

A future application of the EEG in the field of anaesthesia could be monitoring of anaesthetised patients before, during and after surgery in order to establish the depth of the anaesthesia. This monitoring is now based on subjective scales of observation such as the OASA scale as reported by Chernik et al.1 Now there is only one device, the BIS-monitor, which gives an indication of the depth of anaesthesia based on EEG-parameters, but it is not completely known on which algorithm it is based. Bispectral (BIS) analysis in relation to anaesthesia is described by Glass et al.2

To gain more insight in the possibility to use the EEG during operative monitoring, an experiment was carried out with 20 patients to study the changes in the EEG during deepening of anaesthesia. Burst Suppression Pattern (BSP) is a characteristic signal, which can be recognised in the EEG during deepening of anaesthesia. It consists of high-voltage periods of bursts and low-voltage periods of suppression, both lasting from 1.5 to 6 seconds. This pattern occurs in different conditions ranging from brain damage, anoxia, coma and neonates ‘at risk’ to deep anaesthesia. In this study the focus is on BSP during propofol-anaesthesia in humans.

This article gives an preliminary view of two techniques used to analyse the EEG during BSP. The two techniques are the Principal Component Analysis and Gabor transform.
RESULTS

In the experiment BSP occurred at effect-site concentrations between 5.0 and 6.0 µg/ml propofol and at OASA-scores between 0 and 3 (range 0 till 7, deepest anaesthesia 0, no anaesthesia 7). PCA was done on three classes of EEG signals: burst-, suppression- and wake-EEG. The wake-EEG was taken from the first two minutes recorded at a steady-state effect-site concentration of 0.0 µg/ml propofol (before the infusion of propofol started). From each of the three classes, ten normalised spectra were taken and PCA was done on them. The total power for each spectrum was normalised at 1. The first component of each of the classes is shown in figures 1 to 3.

METHODS

Human subjects, 17 females and 3 males, aged 40 ± 15 years, participated in the experiment and gave their Informed Consent one day before surgery. All patients underwent plastic surgery. No pre-medication was given and they had no neurological deficits or psychoactive medication that might interfere with neurological processes. Only propofol was used for anaesthesia. There was no evidence that patients were extremely sensitive to propofol.

To induce propofol-anaesthesia, Target Controlled Infusion was used (Diprifusor TCI®). The propofol infusion rates were calculated based on estimated effect-site concentrations, taking into account known propofol pharmacodynamics as well as individual characteristics such as body weight, sex and age. Propofol infusion was stopped when the patient became hemodynamically unstable or showed signs of respiratory problems. A 9-channel EEG (Fz, C3, Cz, C4, P3, Pz, P4, O1, O2), using Neuroscan data acquisition software, was recorded during two minutes in a steady-state situation, that is on a stable estimated propofol effect-site concentration level. The sample frequency was 1000 Hz. The data were digitally post-filtered between 1 and 30 Hz.

As mentioned before, two techniques were used to analyse the data: Principal Component Analysis (PCA) and Gabortransform. PCA is based on the following principles. The normalised Fourier spectrum is used to detect whether there is any kind of mutual pattern in the spectra of selected EEG signals. If so, this pattern can be used to discriminate between several kinds of data sets. In this experiment the discrimination between burst patterns, suppression patterns and wake patterns was investigated. PCA is based on the following procedure: N signals (spectra) containing M samples are placed in a M x N matrix called X. This matrix is multiplied by the transposed matrix of X. Calculating the eigenvalues and the eigenvectors of this matrix gives the principal components (eigenvectors) and their weight (eigenvalues) in building the spectrum. The eigenvalue gives the relative weight of a component in comparison with the other components. The Gabortransform is described by Quian Quiroga. This transform is a transformation of the EEG signal to the frequency domain (spectrum) with a moving Gaussian window. In this experiment a Gaussian window of two seconds was used. This window is moved over the EEG signal by steps of 250 ms. The Gabortransform shows the development of the spectrum in time (dynamics of the signal). In the Gaussian window of 2 seconds a Fourier spectrum is made, the window is moved 250 ms in time over the EEG signal and again a spectrum is constructed. By this procedure the Gabortransform shows the successive spectra in time.
The first components comprise about 50% of the total power of the ten spectra per class. Based on this component the difference can be noticed between the burst-EEG on one hand and the wake-EEG and suppression-EEG on the other hand. The burst-EEG shows a power-peak in the high alpha-band, while the power in the wake- and the suppression-EEG is more spread out and mostly in the lower frequencies. The wake- and the suppression-EEG are much more identical. Nevertheless, the wake-EEG shows a peak around 15 Hz while the suppression-EEG shows a peak at 30 Hz in this subject. The 30 Hz peak is only seen in one of the ten suppression spectra and is therefore presumably an artefact.

T-tests comparing the ten normalised spectra of the three classes in one subject gave a significant result at some frequencies. The results of the t-tests confirm the PCA results; only the 30 Hz peak in the suppression EEG does not seem significant in the t-test.

One disadvantage using PCA is the lack of dynamics in the analysis. The Gabortransform makes it possible to add the dynamical information. Comparison of the Gabortransforms of all three EEG classes showed differences between the classes. In figures 4 to 6 the Gabortransforms of the different classes are shown. The spectra are normalised, which implies that the amplitude differences between burst and suppression are not well recognizable.

The wake-EEG shows a diverse spread of peaks throughout the entire spectrum during the whole time. It shows a dynamical pattern. The burst-EEG shows two separated peaks around 10 Hz between 2 and 6 seconds. During BSP the power is not as spread out as during wake-EEG. The suppression-EEG shows no peaks and a non-dynamical pattern that is a bit masked by the large scale differences. During the wake- and the burst-EEG, the spectrum changes over time, while during the suppression-EEG the spectrum shows a more constant pattern. Based on dynamics, the wake- and the burst-EEG look more identical.
DISCUSSION

The analysis of the BSP with PCA suggests that, although t-tests seem to show that the normalised spectra of the classes look rather identical, it may be possible to classify the different kinds of EEG by their first component. Filtering with this first component to search for burst patterns in earlier stages of anaesthesia, where BSP is not yet visually detected, can be a first step to use this technique in determining the depth of anaesthesia under propofol. PCA can be used to detect the typical burst-EEG. Based on the second component, discrimination between wake- and suppression-EEG may be also possible.

Another kind of detection may be possible by the Gabortransform. In contrast to PCA this technique does not show the spectrum of the burst- or suppression-EEG, but the development of the spectrum. For example two, more or less separated, peaks can be seen at 10 Hz, suggesting that the burst consists of an early and a late 10 Hz component. This development in time is masked by the PCA approach. This dynamical pattern gives an impression of the precise composition of the burst. Gabortransform can thus be used to search for dynamical differences between the classes, but also to search for dynamical changes during deepening of anaesthesia.

The more static pattern of the suppression-EEG and the differences in peak ordering in wake- and burst-EEG may make this technique useful to discriminate between the several classes of the EEG.

In short, the combination of both techniques may give an indication of what kind of EEG is present at a time and may give more insight in the changes in the EEG during deepening of anaesthesia, all based on the characteristics of the BSP.

REFERENCES