DETECTION OF VASOSPASM IN COMATOSE PATIENTS USING EEG SPECTRAL CHARACTERISTICS

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ABSTRACT

Subarachnoid hemorrhage (SAH) is usually caused by the rupture of a brain aneurysm. Vasospasm, the constriction of cerebral vessels reducing blood flow to the brain (leading to ischemia or infarction), is a major cause of morbidity/mortality following SAH. Transcranial Doppler and computed tomography are used to detect vasospasm but cannot be used continuously. However, electroencephalography (EEG) is a sensitive indicator of brain ischemia and also can be monitored continuously.

We therefore developed a new algorithm to calculate and detect changes in quantitative EEG features such as alpha band spectral flatness ratio (SFR; ratio of geometric mean of power to the arithmetic mean of power expressed in dB), as an indicator of vasospasm.

SFR was calculated from auto-regressive model coefficients obtained using Burg's algorithm. Discriminant analysis was used to classify vasospasm and non-vasospasm segments from the EEG. In a pilot study, classification performance was evaluated in 6 patients using the leave-one-out method. The 'True Positive Fraction' and 'True Negative Fraction' were 83% in both cases. We suggest this algorithm may be used clinically to monitor a patient's EEG following SAH, for the early detection of vasospasm. As a result, earlier treatment of vasospasm may result in better patient outcome.

INTRODUCTION

Vasospasm, an arterial constriction with resultant reduction of blood flow causing tissue ischemia, is a major cause of disability and death following aneurysmal subarachnoid hemorrhage (SAH). Vasospasm occurs in over half of SAH patients, and leads to permanent disability or death in over 20% of patients [1]. However, if vasospasm is detected at an early stage, it can be treated [2]. Transcranial Doppler ultrasound (TCD) and cerebral computed tomographic angiography (CTA) are methods used for its detection or diagnosis; however, these methods are not feasible to apply continuously to monitor for vasospasm. Electroencephalography (EEG), on the other hand is increasingly used for continuous monitoring of comatose patients and can detect changes in EEG signals due to tissue ischemia before infarction occurs [3]. For example, persistently reduced relative alpha variability (RAV) seemed to be a predictor of impending neurological symptoms consistent with vasospasm after SAH. Vespa *et al.* [4] demonstrated that RAV is reduced during vasospasm, but is increased as ischemia resolves.

We therefore developed a new software based algorithm to calculate similar quantitative EEG features, such as, the alpha band SFR [5] (AB-SFR) to detect onset of vasospasm.

METHOD

We studied the clinical onset of vasospasm using an 8 electrode longitudinal bipolar montage placed according to the international 10-20 system (F4-T4, T4-P4, P4-Pz, F3-T3, T3-P3, P3-Pz) as suggested by Vespa *et al.* [4]. Continuous (24 hours or more) EEG recordings were simultaneously performed using an 18 channel digital XLTEK (Oakville, Ontario, Canada) EEG

monitor. Standard EEG electrodes were applied to the scalp and standard EKG electrodes were applied for heart monitoring. Impedances were checked twice daily to ensure recording characteristics were satisfactory, with target impedances of less than 5 kilo-ohms. Another separate channel was used for EKG recording.

AB-SFR from 24 segments of EEG data was obtained from 6 patients. We recorded 12 segments during vasospasm and 12 segments were recorded when patients had no vasospasm clinically, as a baseline EEG. Each segment length is 50 minutes divided into 10 minutes of sub segments. From each 10 minute sub-segment, we calculated the mid value of AB-SFR. To calculate the mid value of AB-SFR, each sub segment was further divided into 150 blocks of EEG signals (4 seconds). Using linear interpolation of 150 AB-SFRs from 150 blocks, the mid value of AB-SFR was calculated, simply called AB-SFR. This AB-SFR is recorded in a text file for later use in classification.

In the classification stage, linear discriminant analysis is used. Classification results were obtained using the leave-one-out method because the number of test segments was small. The χ^2 test [6] was used to evaluate the goodness of the fit of the classification accuracy. The Student's t-test was used to evaluate AB-SFR as a classifier. The margin of error was also documented. It is expected that the margin of error [7] will be relatively high as the number of test cases is small.

RESULTS

Classification results in identifying 10/12 vasospasm segments and 10/12 non-vasospasm segments. Therefore, $\chi^2_{calculated}$ with Yates correction is 0.45. The categories in this test are 'vasospasm' and 'non-vasospasm' and the degrees of freedom were, $v = 2 - 1 = 1$. When p= 0.05, $v = 1$, then $\chi^2_{critical}$ is 3.84. Therefore *the algorithm is capable of classifying vasospasm as per the* χ^2 *goodness of fit* (null hypothesis). It was also evident that the classifier was highly correlated within groups. Using the Student's t-test, it can be validated that the baseline AB-SFR and AB-SFR recorded during vasospasm are from separate populations (*alternate hypothesis*). In the t-test, $|t_{calculated}|$= 7.089, when $v = 59$, at p= 0.05 and $t_{critical} = 2.008$ (2-tailed). We can reject the *null hypothesis*, that is, samples from both classes belong to the same population. Therefore AB-SFR may be used for classification to distinguish vasospasm segments and non-vasospasm segments at p= 0.05 (2-tailed t-test). The margin of error in both classification tests is 0.30.

CONCLUSION

We found that AB-SFR can be used as a classifier to detect vasospasm. We are analyzing other quantitative features of the EEG to improve classification of vasospasm segments. If we can detect and therefore treat vasospasm earlier, the important clinical question is whether this will improve patient outcome.

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