Automated Diagnosis of Epilepsy using EEG Power Spectrum

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Abstract

Interictal electroencephalography (EEG) has clinically meaningful limitations in its sensitivity and specificity in the diagnosis of epilepsy because of its dependence on the occurrence of epileptiform discharges. We hypothesize that in addition to epileptiform discharges and seizure activity; there are stable chronic changes in the scalp EEG of patients with epilepsy. We tested this hypothesis by calculating the power spectrum decomposition of non-overlapping 1s, 5s, 60s and 30 min windows of the interictal scalp EEG. The only artifact removed was 60Hz AC line noise. All muscle artifacts and other activity were left intact. Using this information, we developed a computer-aided diagnostic (CAD) tool that has both substantially higher sensitivity and negative predictive value than the identification of interictal epileptiform discharges. The sensitivity was 92% (95% CI: 85-97%) and the negative predictive value was 82% (95% CI: 67%-92%). The specificity, however, was 46% (95% CI: 34-58%). Manual reading of one 20-minute scalp EEG has roughly 98% specificity and 50% sensitivity. Therefore, our CAD tool can be effectively used in combination with manual analysis for their mutual benefit. Our approach used a multilayer perceptron to classify 156 patients admitted for video-EEG monitoring. The patient population was diagnostically diverse with 87 diagnosed with either generalized or focal seizures. The remainder was diagnosed with non-epileptic seizures. These findings suggest that successful implementation of a CAD tool may improve the epilepsy diagnostic process. Further, these findings indicate that there may be diagnostic trends present in the power spectrum decomposition of interictal scalp EEG that have not yet been appreciated.

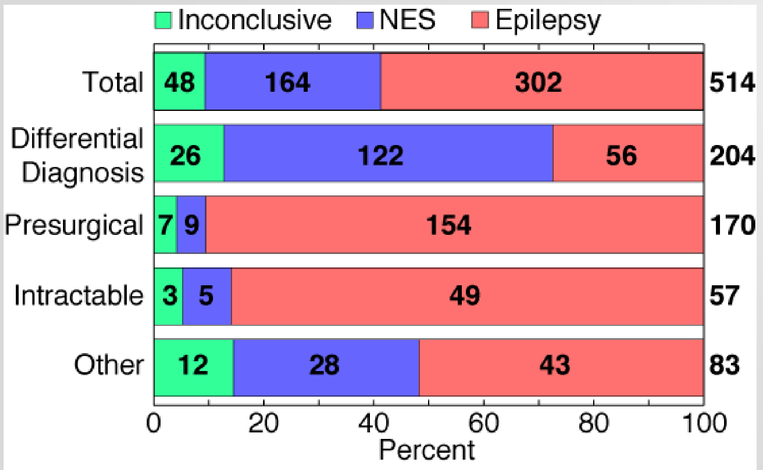

Figure 1: Outcome of Long Term Video-EEG Monitoring
Though varying by the reason for video-EEG admissions, 30% of medication refractory epilepsy is actually non-epileptic seizures.

Introduction

The most specific outpatient diagnostic test for epilepsy, scalp EEG, has only 50% sensitivity. The key limitation is that when no interictal spikes or seizure is observed, the EEG is determined to be inconclusive.

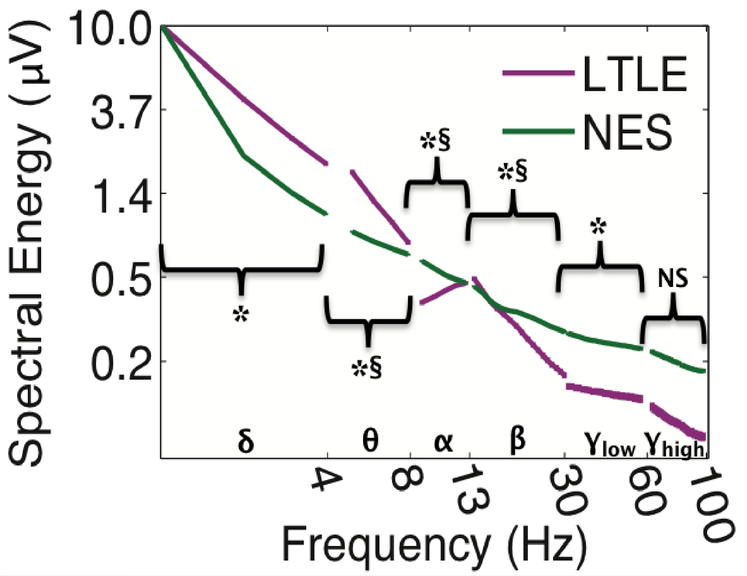

Figure 2: Interictal Scalp EEG Power Spectrum of Epilepsy
Mixed effects robust spline regression of the magnitude of the Power Spectrum of 30 minute windows of the T3-Ref1 electrode. Asterisk and section marker indicate significant differences of intercept and slope, respectively. This shows that there are substantial differences in resting state power in epilepsy vs NES that can be harnessed with machine learning.

Methods

We studied 156 patients admitted for 72+ hour video-EEG monitoring for the diagnostic assessment and characterization of seizure disorder at the UCLA Seizure Disorder Center.

The magnitudes of the FFT of non-overlapping 1s, 5s, 30s and 30min segments were averaged into 1 Hz bins for each of the 25 electrodes in the international 10-20 electrode montage.

The mean, S.D., max and min of each bin, from each channel were input into the maximum relevance, minimum redundancy (mRMR) feature selection toolbox to select 2,400 informative features. A multilayer perceptron diagnosed epilepsy in these 156 patients using cyclical leave-one-out cross validation.

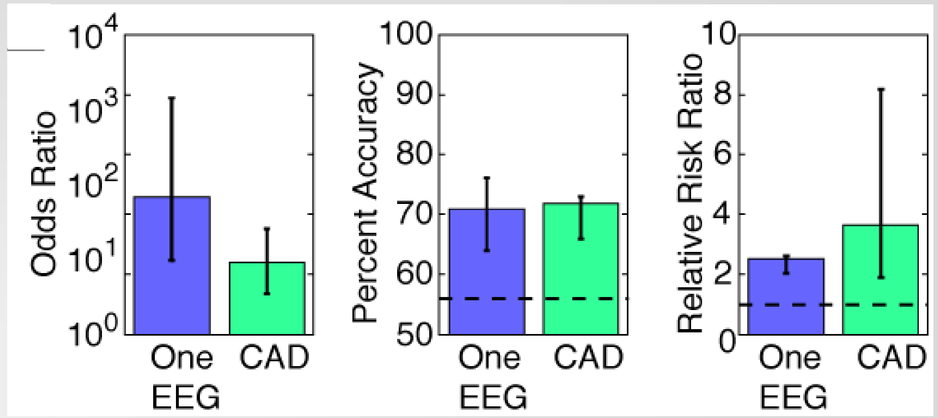

Figure 3: Performance of CAD is comparable to Manual Analysis
Performance of one manually analyzed interictal scalp EEG vs CAD. Dashed line indicates chance. Error bars are SE of the mean. These show how our CAD matches the performance of manual analysis of one outpatient EEG.

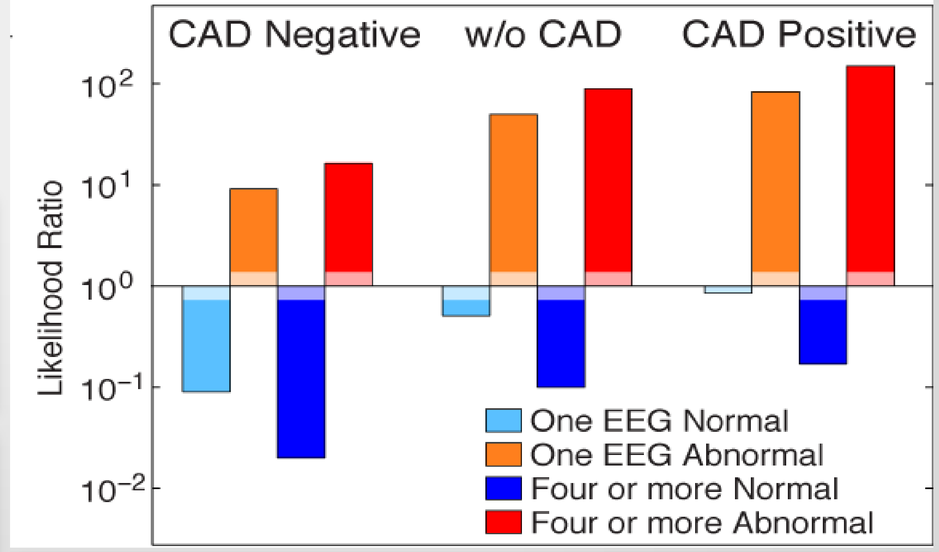

Figure 4: Synergistic Combination of CAD with Manual Analysis
Likelihood ratios of the combination of manual analysis and CAD indicating that CAD increases the value of one interictal scalp EEG to parallel the asymptotic limit of outpatient interictal EEG. Shading indicates 95% CI of chance. The primary benefit of our CAD in combination with manual analysis is the ability to rule out epilepsy and also to justify further assessment when results are inconclusive.

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