Clinical validation study of automated ictal ESI

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Rationale
EEG Source Imaging (ESI) of interictal epileptiform discharges (IEDs) to localize the irritative zone is finding its way into the presurgical evaluation. However, IZ does not indicate where the seizures arise from seizure onset zone (SOZ). Therefore, ESI of ictal EEG signals is considered to be more informative to localize the EZ than the ESI of interictal signals. Nevertheless, due to multiple artefacts that are present in the ictal EEG, the signal-to-noise ratio (SNR) of the recorded EEG signals is generally low. Additionally, rapid propagation of ictal activity in the brain makes it difficult to separate the region where the seizure began from the regions where it spread to. To cope with these difficulties, we developed an automated ictal ESI workflow to localize the SOZ from rhythmic ictal EEG activity.

Aim
In this study, the blinded clinical validation of the automated ictal analysis on 50 consecutive patients in the presurgical evaluation that underwent surgery is presented. The analysis was performed retrospectively and blinded to all data other than the EEG signals.

Methods

EEG - frequency band of interest

- Ictal epoch selection
- Parcellation
- ESI in sublobes
- TF at EEG
- TF at sublobes
- Report

Automated ictal analysis pipeline: a) marking of the onset and indicating the frequency band of interest (performed in the epilepsy center), b) performing the time-frequency (TF) analysis at sensor level, c) acquiring the window of interest (WoI) by a region growing procedure, d) parcellation of gray matter into 3D sublobes, e) applying ESI and constructing electric time-series for each sublobe, f) performing time-frequency (TF) analysis at sublobe level and identifying the SOZ, g) generating the ictal report, h) evaluating the analysis by measuring sensitivity and specificity based on the post-surgical outcome (calculated in the epilepsy center). The automated analysis was performed blinded to patient’s surgical outcome.

Parcellation

Superior

Anterior

Inferior

Posterior

Head model

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Results

TLE-Engel I / Resection: Left Spencer

ETLE-Engel I / Resection: Left Frontal Mesial

Ictal analysis of TLE and ETLE cases with Engel I surgical outcome:
A) ictal EEG epoch from 2s before the marked onset and 3s after. The EEG inside the red rectangle shows the epoch of interest. B) Spectrogram of the channel with the highest energy in the indicated band of interest. The white rectangle determines the Window of Interest (WoI). C) Sublobar time-series from the onset to 3s after. D) Spectrogram of the sublobe with the highest energy in the indicated band of interest. The white rectangle demonstrates the Window of Interest (WoI). E) 3D localization of the source with the highest energy in the sublobe of interest. These points are in concordance with the resection area of each individual patient.

Performance: For the patients with true surgical outcome, the results of all seizures were considered to assign the ESI test as positive case (inside the RA) or negative case (outside the RA). But for the patients with false surgical outcome, result of one seizure could push it to false positive or false negative.

Conclusion

- Automated ictal ESI is feasible and has a similar accuracy to analysis done by human experts.
- Comprehensive source analysis in presurgical evaluation should include both interictal and ictal signals.