Interictal high-frequency oscillations

The rate of interictal high frequency oscillations (HFOs) is a promising biomarker of the seizure onset zone, though little is known about its consistency over hours to days.

An objective criteria for distinguishing pathological from physiological HFOs remain elusive, hindering clinical application. Zhang etal. investigated whether the distinct mechanisms underlying pathological and physiological HFOs are encapsulated in their signal morphology in intracranial EEG (iEEG) recordings and whether this mechanism-driven distinction could be simulated by a deep generative model.

In a retrospective cohort of 185 epilepsy patients who underwent iEEG monitoring, they analyzed 686,410 HFOs across 18,265 brain contacts. To learn morphological characteristics, each event was transformed into a time-frequency plot and input into a variational autoencoder. They characterized latent space clusters containing morphologically defined putative pathological HFOs (mpHFOs) using interpretability analysis, including latent space disentanglement and time-domain perturbation.

mpHFOs showed strong associations with expert-defined spikes and were predominantly located within the seizure onset zone (SOZ). Discovered novel pathological features included high power in the gamma (30-80 Hz) and ripple (>80 Hz) bands centered on the event. These characteristics were consistent across multiple variables, including institution, electrode type, and patient demographics. Predicting 12-month postoperative seizure outcomes using the resection ratio of mpHFOs outperformed unclassified HFOs (F1=0.72 vs. 0.68) and matched current clinical standards using SOZ resection (F1=0.74). Combining mpHFO data with demographic and SOZ resection status further improved prediction accuracy (F1=0.83).

The data-driven approach yielded a novel, explainable definition of pathological HFOs, which has the potential to further enhance the clinical use of HFOs for EZ delineation [1)]

González Otárula et al., retrospectively investigated the intracerebral EEG of patients who became seizure free after subsequent surgery. They marked HFOs during one hour of recordings. They calculated the time delay between pairs of channels as the median delay between their HFOs, and constructed a time line of the delay of each channel with respect to the earliest channel (first source channel). A network was defined when a temporal order could be established among the channels based on the existence of statistically significant delays.

Fifteen patients with good surgical outcome were included. We found ripple networks in all patients, and fast ripple networks in 9. For ripples, first source channels were found in a higher proportion in the seizure onset zone than the rest of the network channels (15/27, 56% vs. 93/262, 35%; p=0.04). For both ripples and fast ripples, first source channels were resected more often that the rest of the network channels (Ripples: 13/27, 48% vs. 65/262, 25%; p=0.01. Fast ripples: 8/9, 89% vs. 17/40, 43%; p=0.002); channels with the highest rates of ripples and fast ripples were resected in a similar proportion.

These results demonstrate that interictal HFOs are organized in networks, and indicate a possible need for the resection of first source channels. However, resecting them is not superior to resecting

channels with highest rates of HFOs [2].

Gliske et al., tested whether the highest HFO-rate channels are consistent across different 10-min segments of EEG during sleep. An automated HFO detector and blind source separation are applied to nearly 3000 total hours of data from 121 subjects, including 12 control subjects without epilepsy. Although interictal HFOs are significantly correlated with the seizure onset zone, the precise localization is consistent in only 22% of patients. The remaining patients either have one intermittent source (16%), different sources varying over time (45%), or insufficient HFOs (17%). Multiple HFO networks are found in patients with both one and multiple seizure foci. These results indicate that robust HFO interpretation requires prolonged analysis in context with other clinical data, rather than isolated review of short data segments [3].

To assess whether high frequency oscillations (HFOs, >150 Hz), known to occur in basal ganglia nuclei, can be observed in the thalamus.

Schnitzler et al., recorded intraoperative local field potentials from the ventral intermediate nucleus (VIM) of the thalamus in patients with Essential Tremor (N = 16), Parkinsonian Tremor (3), Holmes Tremor (2) and Dystonic Tremor (1) during implantation of electrodes for deep brain stimulation. Recordings were performed with up to five micro/macro-electrodes that were simultaneously advanced to the stereotactic target.

Thalamic HFOs occurred in all investigated tremor syndromes. A detailed analysis of the Essential Tremor subgroup revealed that medial channels recorded HFOs more frequently than other channels. The highest peaks were observed 4 mm above target. Macro- but not microelectrode recordings were dominated by peaks in the slow HFO band (150-300 Hz), which were stable across several depths and channels.

HFOs occur in the thalamus and are not specific to any of the tremors investigated. Their spatial distribution is not homogeneous, and their appearance depends on the type of electrode used for recording.

The occurrence of HFOs in the thalamus of tremor patients indicates that HFOs are not part of basal ganglia pathophysiology [4].

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