



WAVEFORM WINDOW #43

“As Focal as Can Be and Buzzes Like a Bee”—High-Frequency Oscillations in Regions of Possible Epileptogenic Discharges

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If the deceased world-famous boxer, Muhammad Ali, was an epileptologist, he would have described the EEG tracing we are presenting in this 43rd edition of the Waveform Window, “As focal as can be and buzzes like a bee!”

Electroencephalography is now a 93-year-old technology, and although it still does a great job at measuring electrical activity of the brain, like most tools in general, it does have its limitations. In reviewing this EEG tracing, we will observe that the epileptogenic morphology we cannot see on an EEG digital page may often be more predictive of a seizure focus than what we actually can see in the 1–30 Hz range.

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Brief history: 75-year-old right-handed woman was at postoperative day 3 after a shunt placement for a moderate-sized intracranial hemorrhage. The patient was having “some confusional bouts lasting many hours.” An extended EEG recording was obtained by the managing team to rule out the possibility of subclinical seizure activity. Throughout the prolonged recording, during which the patient was symptomatic, a couple of brief 10-second page epochs were noted, as in [Figure 1](#). The several hours of confusional bouts were found to be most likely due to “sundowning or possibly toxic metabolic encephalopathy,” as per the neurology team. Although not standard of care, this patient was treated with low-dose Keppra for 6 weeks (500 mg twice daily) and a follow-up EEG was ordered to be performed 6 weeks after discharge, to be sure that the couple of discharges seen had “cooled off,” per managing team report. As a side note, a single clinical seizure can be catastrophic if it occurs while driving, swimming, at a height, or while bathing. In the washroom, where porcelain, tile, or marble is not forgiving, even a fall from a seated position can cause severe injury if a seizure were to occur. Although not standard of care, it was not unreasonable that due to the two brief focal electrographic seizures noted on the EEG recording to treat the patient with a low-dose anticonvulsant for a few weeks and then taper the drug off slowly.

The EEG: This prolonged EEG was recorded in the drowsy state and displayed a 6–6.5 Hz background with a poor anterior-to-posterior gradient. The montage is an anterior-to-posterior montage with left temporal and parasagittal chains on the top, right parasagittal and temporal on the bottom, with midlines in between. A single channel of electrocardiogram (EKG) was recorded at the bottom of the digital page.

At the start of this brief 10-second electrographic seizure with right central focus, one can see mild background voltage suppression in the offending leads (C4 maximal). Abrupt 20 Hz rhythmic beta activity is seen for 1.5 seconds, then zip sharp activity is seen for 3 seconds at 10 Hz maximally with a couple of polyspikes and then slow wave abnormalities at the end of this brief electrographic discharge. Dramatic postictal EEG suppression is seen for the last 2.5 seconds in the right central and frontal leads.

Discussion: What makes this EEG page interesting is the focality and brevity of this electrographic seizure and the high-frequency oscillations (HFOs) noted prior to this 10-second event ([Figure 1](#)). “Over the last decade, the search for a method able to reliably predict and detect seizures hours or minutes in advance of a disabling clinical event to allow for therapeutic treatment or warning devices to be triggered, has been the goal of much modern epilepsy care and research (for the refractory patient) (Jouney et al. 2011).” HFOs as seen during seconds 1 through 4 on this EEG page have been found to be a very good predictor of seizures and seizure focus, and many mathematical models and algorithms are being used today to evaluate EEG recordings for these discharges. “Andrade-Valenca et al. (2011) found that the rates and proportion of channels with gamma and ripple fast oscillations are clearly higher inside the seizure onset zones indicating that they can be used as interictal scalp EEG markers for the seizure onset zones. These fast oscillations are less



FIG. 1. Focal seizure: beta buzz with spiking and phase reversal at C4, with electrical decrement after a brief focal discharge. Sensitivity = 5 $\mu\text{V}/\text{min}$; HFF = 70 Hz; LFF = 0.53 Hz.

sensitive but much more specific and accurate than even spikes to delineate the seizure onset zones.” Many advanced seizure prediction devices today are relying heavily on these oscillations to detect regions of epileptogenicity by detecting changes in the underlying gamma and ripple frequencies.

Additionally, of interest to neurophysiology students, fellows, and technologists, this 10-second EEG page illustrates three less common morphologies of the epileptogenic discharge, “the spike.” The beta biphasic rumbblings seen in first 3–4 seconds on this page are surely epileptogenic spikes as all research has borne out. Biphasic zip sharps are seen during seconds 3 through 7 of the brief electrographic seizure, and triphasic polyspikes are seen as well during the eighth second of this digital page.

The seizure likely started during the first second of this 10-second tracing, but the oscillations were too high in frequency to result in a deflection based on our recording sensitivities. This is one of the many limitations of scalp EEG recording. EEG frequencies beyond 20–30 Hz will often go undetected with nothing but suppression noted to eye of the reader. It is quite interesting that what we cannot see (i.e., the HFOs, such as higher-frequency beta and gamma frequencies) may be more predictive of seizures than even focal sharps and spikes that we can see. The subtle rumbles in the neuronal jungle minutes to hours prior to a clinical event may be the most localizing. Using the discussed data, “EPINETLAB software is an example of a new tool that, using a mathematical analysis, identifies the HFO areas by extracting the statistical properties of the HFO area signal and provides useful information for

a topographic characterization of the relationship between clinically defined seizure onset zones and the HFO area” (Quitadamo et al. 2018).

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