HFO and Infra Low Frequencies in human EEG and wide band EEG

White Paper

In recent years there has been a significant amount of interest in both high frequency oscillations (HFOs) and infra slow EEG activity. While they can be evaluated independently, there is likely benefit from examining both phenomenon, which is usually referred to as wide band EEG analysis. This review is to serve as a brief introduction to HFO and infra slow frequencies and wide EEG band analysis.

Intracranial EEG (iEEG), high frequency oscillations have been found be of interest as a possible correlate with epileptogenic brain regions and the seizure onset zone (Bragin, Engel, Wilson, Fried, & Mathern, 1999) (Worrell, et al., 2008) (Bragin, et al., 2002) (Ikeda A. , 2011). This high frequency, but typically lower amplitude EEG activity is usually subdivided into ripple and fast ripple components. While ripples have been observed in both epileptic and normal brain tissues, fast ripples have been reported to be mainly associated with epileptogenic areas (Wu, et al., 2014). In addition, some literature has identified infra slow activity, sometimes referred to as ictal DC shift (Ikeda A. , DC recordings to localize the ictal onset zone, 2008) (Ikeda A. , Recent advances in the presurgical evaluations in epilepsy surgery, 2004) (Ikeda & Shibasaki, Special EEG recording with ictal pattern, 2004) (Ikeda, Luders, & Shibasaki, Ictal direct current (DC) shifts, 2000) (Ikeda, et al., 1999) (Kanazawa, et al., 2015), slow shifts (Imamura, et al., 2011), and ictal baseline shift (Wu, et al., 2014). This infra slow activity is felt to likely be associated with glial involvement (Imamura, et al., 2011) (Ikeda A. , 2011).

HFOs

Definitions of HFOs have some variance within the literature, though in all cases it is high frequency EEG activity, above the gamma range, which can include both physiologic and pathologic activity.

There are varying definitions of HFO subgroup frequencies;

- HFO 100-500 Hz, Ripple 100-200 Hz and fast ripple 200 or 250-500 Hz (Bragin, Engel, Wilson, Fried, & Buzsaki, High-frequency oscillations in human brain, 1999) (Bragin, Engel, Wilson, Fried, & Mathern, Hippocampal and Entorhinal Cortex High-Frequency Oscillations (100-500 Hz) in Human Epileptic Brain and in Kainic Acid-Treated Rats with Chronic Seizures, 1999).
- HFOs at 100-300 Hz (Imamura, et al., 2011).
- HFO 80-500 or 1000 Hz, ripples as 80-200 or 250Hz and fast ripples as 250-500 or 1000Hz (Worrell, et al., 2008) (Salami, Levesque, Gotman, & Avoli, 2012).

Infra Slow Activity

On the other end of the EEG frequency spectrum is infra slow activity. This is activity from the extremely low frequency range of the EEG spectrum. Literature typically cites a low filter range to 0.016 Hz (Ikeda, et al., 1999) (Imamura, et al., 2011) (Kanazawa, et al., 2015) and typically surface negative in polarity (Ikeda, et al., 1999) (Ikeda A. , DC recordings to localize the ictal onset zone, 2008). They have been found at the onset of seizures (Ikeda A. , DC recordings to localize the ictal onset zone, 2008) and have been reported to even precede more conventional EEG changes (Ikeda, et al., 1999) (Ikeda & Shibasaki, Special EEG recording with ictal pattern, 2004) (Ikeda A. , Recent advances in the presurgical evaluations in epilepsy surgery, 2004) (Imamura, et al., 2011). Evaluation of infra slow activity is felt to help further define the epileptogenic zone (Imamura, et al., 2011) (Kanazawa, et al., 2015).

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Wide Band Analysis

This refers to the analysis of not just the HFO or infra slow EEG frequencies, but the correlation of that activity together. As described by Imamura, et al. (Imamura, et al., 2011) wide band analysis of EEG is available with more recent EEG hardware technological advances, with a cited frequency range for their evaluations at 0.016 Hz-600 Hz. This allowed for the evaluation of time synchronicity between ictal DC shifts, HFOs, and conventional EEG changes associated with seizures. They found that both occurred only in the seizure onset zone, and that the negative slow shift preceded the HFOs and conventional EEG changes by 1.6 and 20.4 s respectively (Imamura, et al., 2011).

Kanazawa, et al (Kanazawa, et al., 2015) found in addition, that "either ictal DC shifts or high frequency oscillations were observed in more restricted areas than conventional ictal changes". They state that infra slow activity and HFOs assisted in identification of epileptic tissue, with the suggestion that the earlier occurrence of DC shift to HFOs could be related to active involvement of glial cells in epilepsy (Kanazawa, et al., 2015).

Of note, Dr Ikeda denotes the relationship of ictal slow activity with the likely involvement of glial cells, and observes the incidence of gliosis within epilepsy populations (Ikeda A. , Recent advances in the presurgical evaluations in epilepsy surgery, 2004) (Ikeda & Shibasaki, Special EEG recording with ictal pattern, 2004) (Ikeda A. , 2011).

Conclusion

The evaluation of human epilepsy has been greatly enhanced by the examination of the high frequency activity, fast ripples of a pathological nature, as well as the ictal DC shifts. Evaluation of both, and their correlative evaluation, likely yields clinically beneficial and complementary information.

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