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Does relative or absolute EEG power have prognostic value in HIE setting?

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About 3–5/1000 births are complicated by Hypoxic Ischemic Encephalopathy (HIE) (Volpe, 2008). Whole-body hypothermia has been shown to mitigate the effects of hypoxic insults (Shankaran et al., 2005) and improve clinical outcomes. EEG monitoring is routinely used to track the ongoing encephalopathy during hypothermia and rewarming. However, the interpretation of prolonged EEG is time consuming and requires expertise, not present in every center. To fill this void, quantitative characterization of the EEG signal has been explored (Bell et al., 1990; Ahmed et al., 2016). In most results, spectral power is either used alone (Bell et al., 1990) or in combination with other features such as higher order statistics (Ahmed et al., 2016), in order to characterize the EEG of infants with HIE. EEG spectral power can be expressed in absolute form (energy in a chosen frequency band) or in relative form (energy in a chosen frequency band divided by the total energy from all of the

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frequency bands). Both forms of spectral power have been used (Bell et al., 1990; Ahmed et al., 2016) in the setting of clinical HIE. In this communication, we compare and contrast these two forms of spectral power to identify the optimal approach.

The study was approved by the Children's National Institutional Review Board, and informed written consent was obtained from a parent of the newborn. For this purpose, we used Nihon Kohden EEG 1100C (Nihon Kohden Corporation, CA, USA) data collected from four term infants with HIE admitted to our tertiary NICU for hypothermia treatment (Shankaran et al., 2005). Infants 1 and 2 survived with no brain injury detected by magnetic resonance imaging; infants 3 and 4 died after withdrawal of care based on severe neurologic injury. In all cases, the therapeutic hypothermia was initiated within 3 h of life as per protocol; however, EEG monitoring began at 10:53 h, 7:31 h, 24:51 h and 10:59 h for infants 1 through infant 4, respectively. The EEG of Infant 1 displayed continuous activity on day of life (DOL) 0; on DOL 1–2 the EEG displayed brief periods of discontinuity, which changed to mainly normally discontinuous transitional and quiet sleep on DOL 3. There was no sign of electrographic seizure. The EEG of infant 2 displayed continuous activity on DOL 0 through DOL 3; also normal sleep-wave cycling was observed on DOL 2 through DOL 3. Infants 3 and 4 displayed either invariant low voltage suppressed background activity or a tracing consistent with electrocerebral inactivity on all days. In this study, we used EEG data from Fp1- C3 channel sampled at 1 kHz. Segments containing artifacts were eliminated and the data were partitioned into 10-min epochs by disregarding epochs with variability less than 5 micro volts or greater than 200 micro volts. For the data in each epoch, power spectrum was estimated using the Welch periodogram approach with a frequency resolution of 0.33 Hz (Halliday et al., 1995). The logarithm transformed power spectra calculated for infants 1 and 3 are shown as contour diagrams in Fig. 1a and b, respectively. For all four infants, the delta power calculated as median of the logarithm transformed power in 0.5 Hz–4 Hz is displayed in Fig. 1c. Similarly, for all four infants, the relative delta power calculated as the ratio of the sum of the powers in 0.5 Hz–4 Hz to the sum of the powers in 0.5 Hz–30 Hz is shown in Fig. 1d. In Infant 1, there was a loss in the EEG signal around 53 h, which is reflected in Fig. 1a as a dark blue contour line and in Fig. 1c as a drop in the spectral power. As can be seen from Fig. 1a and b, infant 1 displays higher power compared with infant 3. This feature is maintained in the absolute delta power for infants 1 and 2 compared to 3 and 4 (Fig. 1c). Infant 4 had respiration and movement artifact that likely account for the higher absolute power compared to infant 3. In contrast, the relative delta power does not capture this difference (Fig. 1d). A similar trend can be observed in the other frequency bands as well.

Spectral power is a frequency-domain representation of variance of the signal. The average value of the spectral power over all the frequency bands yields the variance of the signal. If the natural frequency of a signal is not an integral multiple of the frequency resolution used in the spectral estimation, the power in the natural frequency bin smears into other frequency bins so that the variance is preserved (frequency mismatch). Since the natural frequency of the signal is unknown a priori, the band power is expressed as a relative power, which is not susceptible to any power distortion, caused by the frequency mismatch. However, mainly due to the renormalization factor, the relative power is not able to distinguish between a signal with high variability and a signal with low variability. Based on the data shown in this

communication, we suggest that the absolute power more reliably distinguishes the severity of EEG encephalopathy in infants with HIE than the relative power. Thus, we recommend absolute power should be used to characterize EEG in the setting of neonatal HIE. Nevertheless, caution must be exercised in using the absolute power, as it is highly sensitive to artifacts.

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Fig. 1.

Power spectra of EEG as a function of postnatal age for (a) infant 1 and (b) infant 3 expressed in logarithmic scale. For all four subjects the variation of the logarithm of the absolute delta power as a function of postnatal age is shown in (c) and the variation of the relative delta power (expressed in percentage [%] of total power) as a function of postnatal age is shown in (d).