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Theta activity during the burst suppression following resuscitation from cardiac arrest suggests poor neurological recovery

Ziwei Li; Autumn Williams; Yu Guo; Janaka Senarathna; David L. Sherman; Payam Gharibani; Romergryko G. Geocadin; Nitish V. Thakor.

***Abstract*— Electroencephalographic (EEG) activity during a period known as the "burst suppression phase" following resuscitation from cardiac arrest (CA), has been shown to correlate favorably with neurological outcomes. However, since individual EEG sub-band activities may correspond more specifically to neuronal mechanisms, further analysis of specific EEG sub-bands during this period could facilitate better prognosis. Therefore, using a rodent model of cardiac arrest and resuscitation, we evaluate EEG theta band activity for its capacity to predict post-CA neurological recovery. Here, theta band activity was quantified using its spectral power while neurological outcomes 4 hours post-resuscitation were measured via a scale known as the neurological deficit score (NDS). Our analysis reveals that theta band spectral power is negatively correlated with NDS (-0.75, p<0.05), showcasing the potential for using it as a predictor of neurological outcome.**

***Clinical Relevance*— CA-related neurological recovery is monitored clinically via EEG. Therefore, novel early-predictors of outcomes can enable timely therapeutic interventions.**

I. INTRODUCTION

Cardiac arrest (CA) disrupts the systemic circulation and may cause permanent brain injury even after successful resuscitation. Electroencephalography (EEG) is a standard clinical tool and is used to monitor neurophysiologic recovery following resuscitation from cardiac arrest [1]. Previous studies have shown that the EEG burst-suppression pattern - in which short, high amplitude bursts are interleaved with low amplitude 'suppression' periods - is correlated with measures of neurological outcome [1]. However, these studies only investigate the overall EEG or the gamma sub-band and neglect the rest of the EEG sub-bands. Therefore, here we interrogated the theta sub-band for its capacity to predict neurological recovery.

II. METHODS

Eight male Wistar rats (380-450g) underwent a 7-minute asphyxial CA and resuscitation protocol [2]. EEG was recorded using an RX5 TDT device (Tucker Davis Technologies, FL) for approximately two hours following the resumption of spontaneous circulation (ROSC). Neurological outcomes were accessed at 4 hours post-ROSC via the neurological deficit score (NDS) [1] [3]. A five-level dyadic wavelet decomposition was used to separate the EEG signal into sub-bands. The start and end of the burst-suppression period was calculated using the inflection points of the progression of the sub-band information quantity (SIQ), which has previously been shown to distinguish between the isoelectric, burst-suppression, and continuous EEG phases [4]. $SIQ^k(t)$, SIQ of the k[th] sub-band at timepoint t, is defined as:

$$SIQ^k(t) = -\sum_{m=1}^{M} p_t^k(m) log_2 p_t^k(m) \quad (1)$$

The progression of SIQ is calculated as:

$$\Delta_s(t) = \begin{cases} \frac{SIQ(t)-SIQ_{iso}}{t-t_0}, & SIQ(t) > SIQ_{iso} \\ \Delta_s(t) = 0 \ and \ \Delta_s(t') = 0 \text{ for } 0 \le t' < t \end{cases} \quad (2)$$

where $SIQ(t)$ is the average of $SIQ^k(t)$ over all six subbands (delta, theta, alpha, beta, gamma, super-gamma); SIQ_{iso} represents the average of $SIQ(t)$ during an arbitrarily selected time range, $t_0 - \varepsilon \le t < t_0 + \varepsilon$ in the isoelectric period immediately after CA. Subsequently, theta band activity during this period was quantified by both absolute spectral power and permutation entropy.

III. RESULTS

The mean burst-suppression period start time across the eight subjects was 14.48±0.38 minutes post-ROSC, while the mean end time was 18.84±1.11 minutes post-ROSC. Spearman correlation between absolute spectral power in the theta sub-band in the right hemisphere during this period and NDS was calculated as -0.75 ($p < 0.05$); correlation in the left hemisphere was not found to be significant ($p > 0.1$). Spearman correlation between entropy in the theta sub-band in either hemisphere during this period and NDS was not found to be significant ($p > 0.1$). We also observed burst duration differences between two channels recorded on the same subject, but a non-significant correlation (r=-0.30, p>0.05) was found between difference in two channels burst duration and NDS.

IV. DISCUSSION & CONCLUSION

A negative correlation with NDS indicates that decreased theta band activity is associated with subjects who experienced better neurological outcomes. This study is a preliminary observation and needs further investigation to account for brain regional differences in EEG and subject's variability or tolerance to injury.

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All authors are with the Johns Hopkins University, Baltimore, MD 21287 USA, Author contact: Z. Li: zli187@ jhu.edu).