P54

Beyond the beta rhythm: levodopa-dependent power law exponent changes of subthalamic local field potential recordings in patients with Parkinson's disease

Rosanna Ferrara[1], T. Bocci[1], A. Averna[2], S. Marceglia[3], K. Montemagno[1], R. Ferrucci[1], A. Priori[1]

[1]CRC "Aldo Ravelli" per le Neurotecnologie e le Terapie Neurologiche Sperimentali, Dipartimento di Scienze della Salute, Università degli Studi di Milano, Milano, Italy
[2]Department of Neurology, Bern University Hospital and University of Bern, Bern, Switzerland
[3]Department of Engineering and Architecture, University of Trieste, Trieste, Italy

Introduction: So far, the study of local field potential (LFPs) in Parkinson's disease (PD) has been provided by the linear approach, focused on the brain oscillatory rhythms evaluated as changes in power spectra within specific frequency bands. Measurements of oscillatory activity have been largely used as expression of clinical information, i.e. the exaggerated power in the beta frequency band associated to rigidity and bradykinesia [1]. However, many studies already pointed out how the background activity, expressed as aperiodic and non-oscillatory activity and typically disregarded, actually constitutes a significant part of LFP recordings, since it appears nevertheless modulated in a physiologically-relevant manner. One of the indices that better describes this aperiodic behavior is the power law exponent (PLE) already demonstrated to change with aging and recently supposed to reflect the balance between inhibition and excitation in neuronal populations.

Objective: Assessment of levodopa-dependent PLE changes of subthalamic LFP in PD patients.

Methods: We recorded LFP from the subthalamic nucleus of 22 patients before and after treatment with levodopa, and calculated the PLE (β-exponent). The parameter is defined as the slope of the regression line computed on the spectra in log-log scale. To ensure the non-influence of the periodic oscillatory components, the regression line has been identified following a peak removal operation [3].

Results: The analysis showed significant differences in the β-exponent between pre- and post-levodopa administration ($p_{value}<0.05$ estimated through the nonparametric Mann-Whitney test). Specifically, β-exponents were lower before levodopa in the low frequency bands (<30 Hz).

Discussion: Our findings are consistent with the hypothesis in literature that inversely relates the β-exponent with the excitation/inhibition ratio [4]. Higher β-exponents (steeper PSD-slopes) after levodopa suggest a reduction of the excitation exerted over the neural population generating the LFP, which agrees with the role of dopamine in inhibiting the indirect pathway postulated by the classical pathophysiological model.

Conclusion: In the linear approach, the effects induced by levodopa have usually been linked to the attenuation of the hallmark peak for PD in beta frequency band on PSD [1]. Here, through the nonlinear approach, we went beyond these periodic features. Indeed, the presence/absence of any oscillatory peak has no effect on the computation of the measure. Therefore, we conclude that the β-exponent reflects the intrinsic properties of the complex neurological system, such as the balance inhibition/excitation, and could be proposed as novel non-oscillatory marker to assess clinical status in PD patients at different stages of the disease.

References:

[1] J.-S. Brittain and P. Brown, “Oscillations and the basal ganglia: Motor control and beyond,” NeuroImage, vol. 85, pp. 637–647, Jan. 2014, doi: 10.1016/j.neuroimage.2013.05.084.
[2] B. Voytek et al., “Age-Related Changes in 1/f Neural Electrophysiological Noise,” Journal of Neuroscience, vol. 35, no. 38, pp. 13257–13265, Sep. 2015, doi: 10.1523/JNEUROSCI.2332-14.2015.
[3] M. A. Colombo et al., “The spectral exponent of the resting EEG indexes the presence of consciousness during unresponsiveness induced by propofol, xenon, and ketamine,” NeuroImage, vol. 189, pp. 631–644, Apr. 2019, doi: 10.1016/j.neuroimage.2019.01.024.
[4] R. Gao, E. J. Peterson, and B. Voytek, “Inferring synaptic excitation/inhibition balance from field potentials,” NeuroImage, vol. 158, pp. 70–78, Sep. 2017, doi: 10.1016/j.neuroimage 2017.06.078.