Development of a new algorithm for automatic latency estimation of motor evoked potentials in TMS studies

Maja Rogić Vidaković[1], Joško Šoda[2], Ana Jerković[1], Igor Vujović[2], Josip Lörincz[3], Ivana Zulim[3], Zoran Đogaš[1]

[1] University of Split, School of Medicine, Department of Neuroscience, Laboratory for Human and Experimental Neurophysiology (LAHEN, Split, Croatia
[2] University of Split, Faculty of Maritime Studies, Signal Processing, Analysis and Advanced Diagnostics Research and Education Laboratory (SPAADREL), Split, Croatia
[3] University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Croatia, Department of Electronics and Computing, Split, Croatia

Abstract

Background: An evaluation of motor evoked potentials (MEPs) elicited by TMS over the motor cortex (M1) provides a quantification of cortico-spinal excitability at the time of stimulation with the following MEP estimations: latency, peak-to-peak amplitude (Vpp), duration (iDur), terminal-excluded duration (eDur), number of turns (NT), number of phases (NP), area under the curve (AUC), thickness and size index [1]. Perhaps latency and Vpp are the mostly used measures in the research and clinic. Currently, there are various (free) tools available for estimation of above-mentioned MEP measures in so called on-line and off-line mode. However, the amplitude of MEP response can vary due to fluctuations in neural excitability at the cortical and spinal levels, therefore an estimation of the MEP latency degrades with the lower amplitudes (Fig. 1).

Study objective: The aim of the present study was to present a new algorithm for MEP latency estimation which improves the accuracy of latency estimation and to compare it with: the standard method (available algorithms) [2,3,4,5,6] and manual estimation.

Methods: The proposed algorithm was applied on total of 700 signals (MEPs) recorded in ten healthy subjects. It was found that available algorithms lack precision in MEP latency estimation for the Vpp lower than 100 μV, where signal-to-noise (S/N) ratio is lower than with "strong" MEPs.

Results: The proposed algorithm for MEP latency estimation proved to be successful as the standard methods and accurate enough within a manual assessment, with significantly better achievements of the proposed algorithm compared to the standard method in the percentage of hits for MEPs with amplitudes lower than 100 microvolts (78,02 % versus 47,83 %). Significant differences have been found in the percentage deviation index (PDI) for MEP latency estimation (referring to MEP signals with amplitudes lower than 100 μV) between the proposed algorithm and the standard method using manual assessment as reference.

Conclusions: The study present a new algorithm for MEP latency estimation and validation results to prove its efficacy. We believe that a new algorithm for MEP latency estimation will be an additional armamentarium in MEP latency estimation, especially when analysing signals with low MEP amplitudes values.

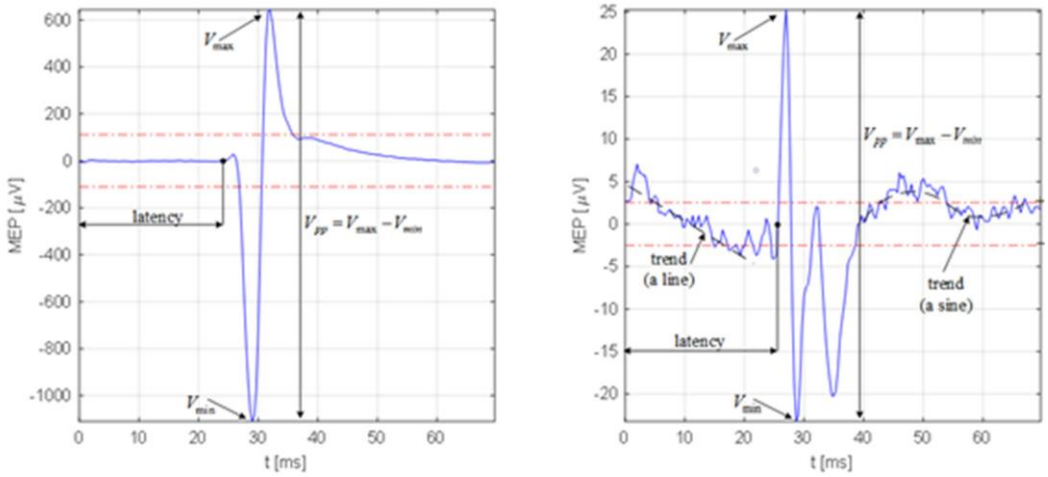

Fig. 1. An example of two MEP response evoked after single magnetic pulse to the M1

References

[1] Nguyen D. T. A., Rissanen S. M., Julkunen P., Kallioniemi E., and Karjalainen P. A. Principal Component Regression on Motor Evoked Potential in Single-pulse Transcranial Magnetic Stimulation (2019), IEEE Transactions on Neural Systems and Rehabilitation Engineering, https://doi.org/10.1109/TNSRE.2019.2923724.

[2] Shivakeshavan, R. G., Disha, G., Ajay, P., Mishra, Asht M., M., Hill N., J., Carmel, J. B. G. D., Motometrics: A Toolbox for Annotation and Efficient Analysis of Motor Evoked Potentials, (2019), Frontiers in Neuroinformatics, Vol. 13, https://doi.org/10.3389/fninf.2019.00008

[3] MEPHunter, a Free Software for Signal Visualization and Analysis (2014)., Innovation and Dissemination Center for Neuromathematics (NeuroMat), https://neuromat.numec.prp.usp.br/content/mephunter-a-free-software-for-signal-visualization-and-analysis/

[4] Jackson N., Greenhouse, I., VETA: An Open-Source Matlab-Based Toolbox for the Collection and Analysis of Electromyography Combined With Transcranial Magnetic Stimulation (2019), Frontiers in Neuroscience, Vol. 13, Art. 975, https://doi.org/10.3389/fnins.2019.00975

[5] Harquel, S., Beynel, L., Guyader, N., Marendaz, C., David, O., and Chauvin, A. (2016). CortExTool: a toolbox for processing motor cortical excitability measurements by transcranial magnetic stimulation. Available at: https://hal. archives-ouvertes.fr/hal-01390016
[6] Mullins, C. R., Hanlon, C. MAVIN: An Open-Source Tool for Interactive Analysis and Visualization of EMG Data, (2016), Brain Stimulation, Vol. 09, Issue 02, pp. 305-306., https://doi.org/10.1016/j.brs.2015.11.009