Publication

A novel assistive method for rigidity evaluation during deep brain stimulation surgery using acceleration sensors

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Title A novel assistive method for rigidity evaluation during deep brain stimulation surgery using acceleration sensors
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Keywords AmpQ = quantitatively identified rigidity-suppressing amplitude; AmpS = subjectively assessed amplitude; DBS = deep brain stimulation; FF = fields of Forel; MER = microelectrode recording; OR = operating room; PD = Parkinson's disease; Parkinson's disease; QC = quantitatively assessed change; S-EMG = surface electromyography; STN = subthalamic nucleus; USB = Universal Serial Bus; ZI = zona incerta; acceleration sensor; deep brain stimulation; fields of Forel; functional neurosurgery; intraoperative; quantification; rigidity; subthalamic nucleus

Despite the widespread use of deep brain stimulation (DBS) for movement disorders such as Parkinson's disease (PD), the exact anatomical target responsible for the therapeutic effect is still a subject of research. Intraoperative stimulation tests by experts consist of performing passive movements of the patient's arm or wrist while the amplitude of the stimulation current is increased. At each position, the amplitude that best alleviates rigidity is identified. Intrarater and interrater variations due to the subjective and semiquantitative nature of such evaluations have been reported. The aim of the present study was to evaluate the use of an acceleration sensor attached to the evaluator's wrist to assess the change in rigidity, hypothesizing that such a change will alter the speed of the passive movements. Furthermore, the combined analysis of such quantitative results with anatomy would generate a more reproducible description of the most effective stimulation sites. To test the reliability of the method, it was applied during postoperative follow-up examinations of 3 patients. To study the feasibility of intraoperative use, it was used during 9 bilateral DBS operations in patients suffering from PD. Changes in rigidity were calculated by extracting relevant outcome measures from the accelerometer data. These values were used to identify rigidity-suppressing stimulation current amplitudes, which were statistically compared with the amplitudes identified by the neurologist. Positions for the chronic DBS lead implantation that would have been chosen based on the acceleration data were compared with clinical choices. The data were also analyzed with respect to the anatomical location of the stimulating electrode. Outcome measures extracted from the accelerometer data were reproducible for the same evaluator, thus providing a reliable assessment of rigidity changes during intraoperative stimulation tests. Of the 188 stimulation sites analyzed, the number of sites where rigidity-suppressing amplitudes were found increased from 144 to 170 when the accelerometer evaluations were considered. In general, rigidity release could be observed at significantly lower amplitudes with accelerometer evaluation (mean 0.9 +/- 0.6 mA) than with subjective evaluation (mean 1.4 +/- 0.6 mA) ($p > 0.001$). Of 14 choices for the implant location of the DBS lead, only 2 were the same for acceleration-based and subjective evaluations. The comparison across anatomical locations showed that stimulation in the fields of Forel ameliorates rigidity at similar

amplitudes as stimulation in the subthalamic nucleus, but with fewer side effects. This article describes and validates a new assistive method for assessing rigidity with acceleration sensors during intraoperative stimulation tests in DBS procedures. The initial results indicate that the proposed method may be a clinically useful aid for optimal DBS lead placement as well as a new tool in the ongoing scientific search for the optimal DBS target for PD.
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