

Using acceleration sensors to quantify symptoms during deep brain stimulation surgery.

Shah A.¹, Coste J.², Schkommodau E.¹, Lemaire J.J.², Hemm-Ode S.¹

¹Institute for Medical and Analytical Technologies, University of Applied Sciences and Arts Northwestern Switzerland, Switzerland

²Centre Hospitalier Universitaire de Clermont-Ferrand, Image-Guided Clinical Neurosciences and Connectomics (EA 7292, IGCNC), Université d'Auvergne, France

ashesh.shah@fhnw.ch

Abstract: The use of Deep Brain Stimulation (DBS) surgery is increasing as a treatment for movement related disorders. One of the important areas of improvement is the target selection procedure. To do so, we measured the acceleration of tremor by sensors in 6 patients during their DBS surgeries to evaluate the changes quantitatively. The post-operative data analysis revealed that acceleration measurements are very sensitive to the changes in tremor and that they can be used to identify clinically effective stimulation amplitudes. With the aim to increase objectivity in symptom evaluation, we intend to introduce real-time analysis so as to provide more information to the neurosurgeon to aid him in his target selection during the surgery.

Keywords: movement related disorders, acceleration measurements, tremor quantification, deep brain stimulation

Introduction

The usage of Deep brain stimulation (DBS) of basal ganglia to treat neurological movement related disorders like Parkinson's disease (PD) and Essential Tremor (ET) has increased considerably in the recent years. However, due to incomplete understanding of the mechanism of action of DBS, optimal target definition is difficult. To overcome this, intraoperative stimulation tests are performed along the predetermined trajectories to semi-quantitatively evaluate the clinical effects on tremor while gradually increasing the stimulation parameters (voltage/current), determining the thresholds for clinical effects (subjective threshold) and side effects at each anatomical measurement position.

Various methods have been proposed to quantitatively evaluate tremor using accelerometer ([1], [2]) as well as other sensing techniques ([3], [4]), but not specifically during DBS surgery. Methods to quantitatively evaluate tremor intra-operatively ([5], [6]) using accelerometers have been proposed, but they were not made a part of the routine surgical protocol. Our aim is to measure the acceleration of the patient's wrist before, during and after the DBS surgery, to extract multiple parameters to quantify the changes in the tremor and use these parameters to aid the neurosurgeons in optimizing the final target for implanting the electrodes.

Methods

We have recorded acceleration data from 6 bilateral DBS implantations for PD (n=2) and ET (n=4), under an ongoing clinical study at the University Hospital Clermont-Ferrand, France. A 3-axis accelerometer is placed inside an in-house developed plastic case and tied to the patient's wrist (Fig. 1) to measure its acceleration during test stimulations. Acceleration data is recorded at all the test stimulation positions on all the planned trajectories. The acceleration recording is performed by connecting the accelerometer via a USB cable to a laptop using in-house developed application. The acceleration recording is started earlier than the test stimulation and continues while the stimulation amplitude is varied (Fig 2). No specific instructions are given to the neurosurgeon or the patient for the posture of the arm or movements. The data is recorded while the neurosurgeon performs his routine evaluation. The data recorded without any test stimulation is used as a baseline for comparison with data recorded during the test stimulation. The amplitudes of stimulation at which an effect is visually observed on the symptoms (subjective threshold) and at which side-effects occur (side-effect threshold) are noted in the software.

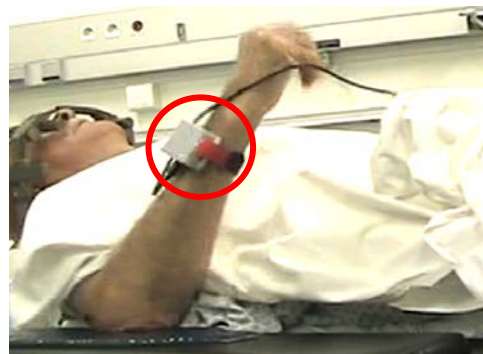


Figure 1: The plastic case containing the accelerometer tied to the patient's wrist.

The accelerometer data recorded is then post-operatively analysed to extract statistical features to quantitatively identify the changes in the symptoms. As a first step, movements other than tremor are removed (detrending) using the smoothness Priors method [7]. Then the data is low pass filtered at 10 Hz to remove the noise. From this data, statistical features (viz. standard deviation, energy, entropy, main frequency component and main frequency

amplitude) are extracted by moving a window of 2 seconds over it.

The extracted features are then normalized to the baseline value and the normalized feature set is used to find effective stimulation amplitude (acceleration threshold). Based on the normalized data, 3 different acceleration thresholds are extracted: 1) more than 75% change compared to baseline 2) more than 50% and less than 75% change compared to baseline 3) more than 25% and less than 50% change compared to baseline.

The accelerometer thresholds and the side effect thresholds are examined visually and a final implant location is decided based on them to compare with the actual final implant location.

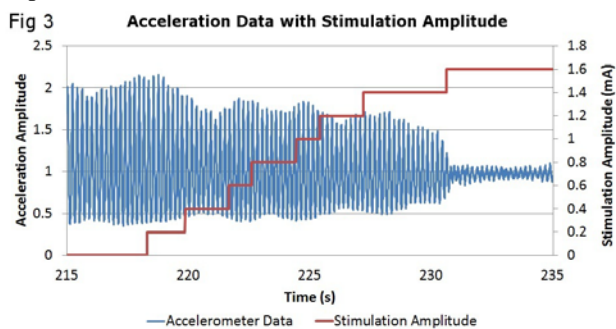


Figure 2: Graph showing acceleration data (blue) along with stimulation amplitude (red) with time.

In order to have a statistically significant comparison, we used Wilcoxon two-sided signed rank test to compare the features 1) before the subjective threshold and at the subjective threshold 2) before the acceleration threshold and at the acceleration threshold.

Results

The Wilcoxon two-sided signed rank test has identified a statistical significant change in tremor ($p < 0.01$) for signal energy, standard deviation and peak frequency amplitude. The signal energy and peak frequency amplitude seem to be the most sensitive statistical features showing a higher percentage change compared to baseline. The results also say that, in most cases (>80%), the accelerometer threshold was found at a lower stimulation amplitude than the subjective threshold (Fig. 3). The final implant site decided based on the acceleration measurements were not always consistent with the ones decided subjectively during the surgery. In some cases, the choices were on different trajectories. This suggests that the use of acceleration measurements during the surgery may improve the target selection for DBS surgery.

Discussion

The present study describes a method to quantitatively evaluate tremor using statistical parameters extracted from the acceleration signal of the wrist and the significance of the results from 6 patients. Based on the results of this study we can say that the use of such quantitative methods may improve the target selection procedure for the DBS surgeries. Such quantitative methods make the surgical treatment more

objective for individual patients. We also found that the addition of acceleration measurement equipment in the OR did not increase the duration of the surgery or interfere with any other procedure.

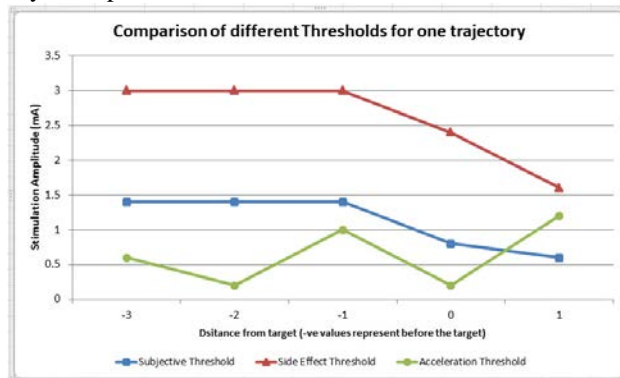


Figure 3: Comparison of different thresholds for one trajectory of a DBS patient.

The results of the study clearly suggest that acceleration measurements in the OR are feasible. One of the main factors that affect the acceleration measurements is the recording of the baseline data. It is important that during the baseline recording, the patient shows high tremor symptoms. Our next steps are to perform the data analysis in real-time during the surgery so that the quantitative information is made available to the neurosurgeon to aid in his decision. Further analysis and research is also planned with the recorded data. We intend to use the acceleration sensor to evaluate rigidity during DBS surgery as well. We intend to correlate the data with the anatomical brain structures stimulated during the surgery and other electro-physiological information. This might bring new information related to the mechanism of action of DBS.

Bibliography

- [1] Keijsers, N. L. (2006). "Ambulatory motor assessment in Parkinson's disease." *Mov Disord* 21(1): 34-44
- [2] Dunnewold, R. J. (1997). "Quantitative assessment of bradykinesia in patients with Parkinson's disease." *J Neurosci Methods* 74(1): 107-12
- [3] Papapetropoulos, S. (2008). "Objective monitoring of tremor and bradykinesia during DBS surgery for Parkinson disease." *Neurology* 70(15): 1244-9
- [4] Koop, M. M. (2006). "Improvement in a quantitative measure of bradykinesia after microelectrode recording in patients with Parkinson's disease during deep brain stimulation surgery." *Mov Disord* 21(5): 673-8
- [5] Journee, H. L. (2007). "Intraoperative neurophysiological assessment of disabling symptoms in DBS surgery." *Neurophysiol Clin* 37(6): 467-75.
- [6] Birdno, M. J. (2008). "Tremor varies as a function of the temporal regularity of deep brain stimulation." *Neuroreport* 19(5): 599-602
- [7] Tarvainen, M.P; Ranta-aho, P.O; Karjalainen, P.A. An advanced detrending method with application to HRV analysis.