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University of Applied Sciences and Arts Northwestern Switzerland
School of Life Sciences

Acceleration measurements to quantify changes in rigidity during deep brain stimulation surgery

A.Shah[1], J. Coste[2,3], JJ. Lemaire[2,3], M. Ulla[2], E. Schkommodau[1], S. Hemm-Ode[1]

[1]Institute for Medical and Analytical Technologies, School of Life Sciences, University of Applied Sciences and Arts Northwestern Switzerland, Muttenz, Switzerland

[2]CHU de Clermont-Ferrand, France

[3]Image-Guided Clinical Neuroscience and Connectomics - ISIT, Université d'Auvergne, Clermont-Ferrand, France

Background

Deep brain stimulation (DBS) has few uncertainties associated with suboptimal target selection. The feasibility of using acceleration measurements to evaluate tremor quantitatively during DBS surgery has been shown earlier (1). However, to be able to quantitatively evaluate the clinical effects of intraoperative stimulation on Parkinson's disease patients, it is important to take rigidity as a symptom into consideration. The aim of our study was to evaluate the feasibility to objectively assess the clinical effect during intraoperative stimulation tests performed along the trajectory using acceleration measurements of the evaluating neurologist's wrist. We hypothesize that acceleration of the neurologist's movement and rigidity are inversely proportional.

Method and Patients

The **equipment** used for our measurements included a 3 axis acceleration sensor, placed inside a plastic case and recording at 400 Hz (Fig 1). It was tied to the neurologist's wrist using a Velcro strap (Fig 2). This sensor was connected to a laptop via a USB cable and data was recorded using an in-house developed software. Along with this setup, the acceleration recording software was connected to the electrical stimulation system to synchronize the two data sets to millisecond accuracy (Fig 3).

Acceleration data **recording** is performed for every test stimulation position, and is started before stimulating in order to record data corresponding to the baseline evaluation of patient's rigidity. The data recording continues till all amplitudes of stimulation current are tested for a position.

The **analysis** of acceleration data is done post-operatively using Matlab (Mathworks Inc., Massachusetts, USA):

- Filtering to eliminate noise and non-rigidity data.
- Division into smaller sets of time-length of 2 seconds.
- Extraction of statistical features (standard deviation, signal energy, entropy, peak frequency and peak frequency amplitude.) from each dataset.
- Identification of a baseline statistical feature set
- Calculation of relative changes of features for each data set (Fig 4).
- Identification of stimulation amplitude corresponding to maximum change in statistical features (Acceleration Threshold).

Additionally, Wilcoxon signed rank test was used to identify the significance of changes in the statistical features before and at effective stimulation amplitudes identified subjectively.

Under a **clinical study** in University Hospital, Clermont-Ferrand, France, using the above setup, data was recorded from 3 PD patients undergoing DBS surgery for treatment of rigidity. A total of 76 test stimulation positions were recorded and analyzed using this method.

Results

- Standard Deviation, Signal Energy and Peak Frequency Amplitude increased significantly with reduction in rigidity ($p<0.001$, $\alpha=0.01$).
- Out of 76 stimulations, subjective thresholds were found for 50, while acceleration analysis found 71 thresholds.
- For the 50 positions where both thresholds were found, the acceleration threshold was Lower | Equal | Higher in 27 | 18 | 5 cases.

Discussion

- The additional acceleration measurements during the surgery did not increase operation time or the patient's discomfort.
- Sufficient baseline data is necessary for proper identification of acceleration thresholds.
- The additional 21 threshold identified based on acceleration data could better the judgment of the final implant site.
- There is an inherent subjective component in the acceleration analysis because the evaluation is done by the neurologist.
- Further analysis in relation to anatomy could result in better target structures and could raise additional knowledge of the mechanisms of action of DBS

Conclusion

- The acceleration of the neurologist's movement is inversely proportional to change in patient's rigidity.
- Acceleration measurements confirm the subjective evaluation, but they seem to be more sensitive (Fig 5).
- Quantitative rigidity evaluation is feasible during DBS surgery.

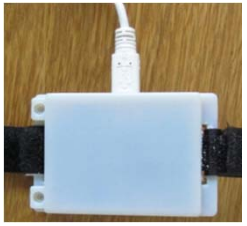


Fig 1: *Acceleration Sensor housed in plastic case*



Fig 2: *Neurologist wearing the sensor during rigidity evaluation.*

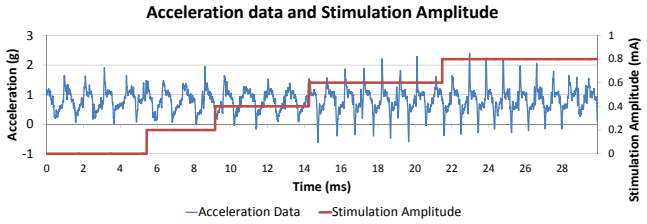


Fig 3: *Acceleration data and stimulation amplitude for one position.*

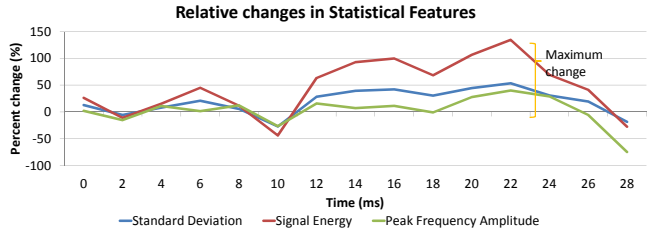


Fig 4: *Relative change in statistical features compared to baseline.*

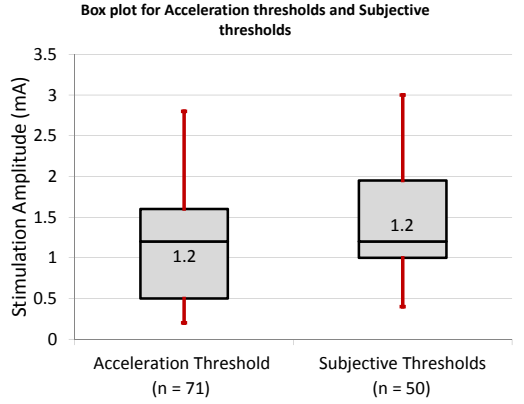


Fig 5: *Box plot of the two thresholds. Acceleration thresholds are lower than the subjective ones.*

References : 1) Shah A, Coste J, Lemaire J et al. A method to quantitatively evaluate changes in tremor during deep brain stimulation surgery. In: 2013 6th International IEEE/EMBS Conference on Neural Engineering (NER), pp 1202–1205

Ashesh Shah
Email : ashesh.shah@fhnw.ch
Phone : +41-61-461-4413

Fachhochschule Nordwestschweiz
Gruendenstrasse 40
4132 Muttenz, Switzerland.