Using acceleration sensors to identify rigidity release threshold during Deep Brain Stimulation surgery

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USING ACCELERATION SENSORS TO IDENTIFY RIGIDITY RELEASE THRESHOLD DURING DEEP BRAIN STIMULATION SURGERY

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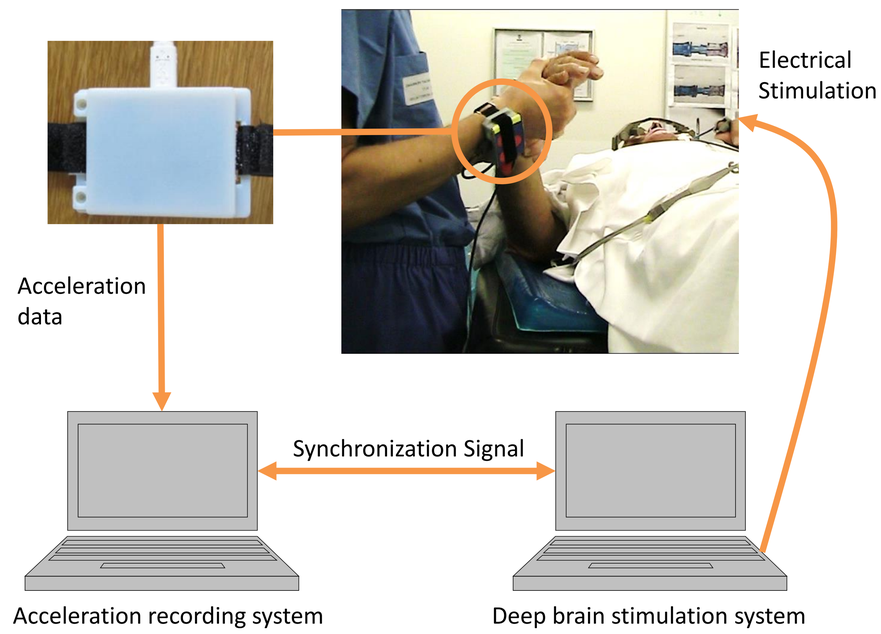
Background

Deep brain stimulation (DBS) is now a widely accepted surgical treatment for Parkinson's disease (PD). Electrodes are implanted in the patient's brain after intraoperative test stimulation. Changes in parkinsonian rigidity during test stimulation are detected by an evaluator, usually a neurologist, by identifying changes in the resistance of the patient's arm to a passive movement. When a stimulation-induced reduction in rigidity is observed, the stimulation amplitude is noted; this is the clinical rigidity release threshold. The aim of the present study was to test the hypothesis that, at the moment of reduction in rigidity, the speed with which the evaluator moves the patient's arms increases, and that this change and its amplitude can be detected with an acceleration sensor.

Methods

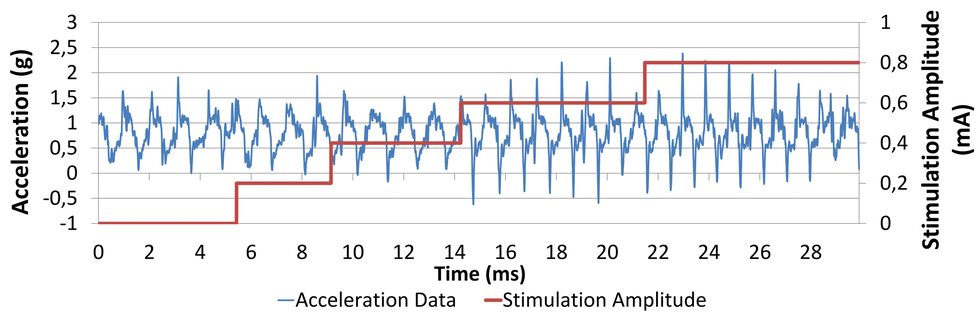
Data Recording setup



Step 1: Data recording setup. A 3 axis accelerometer evaluation board (STEVAL-MKI022V1, ST) housed in a non-conductive printed plastic case (FullCure 830 Vero White, Objet Geometries Ltd) is mounted on the evaluators wrist using a Velcro strap. This sensor is connected to a laptop with in-house developed recording software. This software is also connected to the deep brain stimulation system which provides current during the test stimulations.

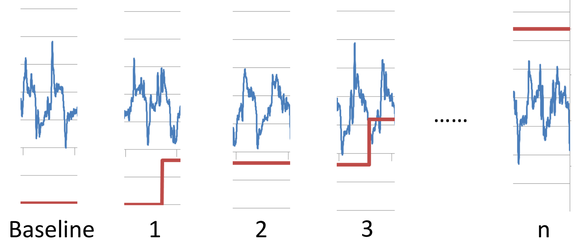
Output

Acceleration data synchronized with test stimulation current



Step 2: Synchronization of two data sets. Accelerometer data is recorded during all test stimulations in synchronization with the electrophysiology system.

Data Processing



Step 3: Statistical features are extracted from the recorded acceleration data in a windowed manner. Features extracted from data during test stimulation are normalized to those extracted from baseline data when there was no test stimulation.
Wilcoxon signed rank test was used to identify which features changed with change in rigidity

Feature Extraction

Window	Baseline	1	2	3	.....	n
Std. Dev	0.289998	0.326865	0.273751	0.312869		0.346294
Sig. Energy	0.08483	0.10719	0.075328	0.09781		0.119767
Entropy	3.812613	3.732637	3.668649	4.124105		3.796258
Freq.	0.761719	0.761719	1.142578	0.761719		1.142578
PFA	121.0322	123.6341	102.3569	134.2219		114.1474

Threshold Identification

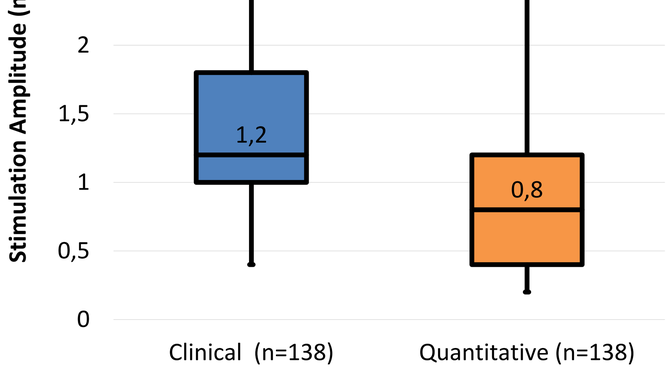
Rigidity Release Threshold Identification

Step 4: The data set with the highest change compared to baseline is identified and the stimulation amplitude corresponding to this data set is defined as the "Quantitatively identified rigidity release threshold"

Results

Results

- Three statistical features were identified to well describe rigidity release (Standard Deviation, Signal Energy and Spectral Amplitude of the Peak Frequency)
- Out of the 190 test stimulations, rigidity release thresholds were found using the clinical method for 144 evaluations, while using quantitative method, 160 thresholds were found. For 138 test stimulations, thresholds were found using both the methods.
- The rigidity release thresholds found using accelerometer evaluation are significantly lower than those found clinically (Fig 5).



Results of Clinical Application

Fig 5: Box plot showing comparison between clinical threshold and quantitative threshold

Clinical Application

- Clinical study carried out in University Hospital Clermont-Ferrand, France.
- Data was recorded from 9 PD patients who underwent DBS surgery
- A total of 190 test stimulations were performed and data analysed following steps 1 to 4.

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.
- 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.

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