A method to quantitatively evaluate tremor during deep brain stimulation surgery

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Purpose

Deep brain stimulation (DBS) of basal ganglia using surgically implanted electrodes is now an effective and widely-used method to treat neurological movement related disorders such as Parkinson's Disease (PD) and Essential Tremor (ET). The mechanism of action of DBS is not fully understood; optimal target definition is difficult and thus most groups use complementary intraoperative methods. Intraoperative stimulation tests are performed along the predetermined trajectories to 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. Currently, these evaluations are performed semi quantitatively by the neurosurgeon or the neurologist. Our method intends to improve the targeting procedure and make it more objective by measuring the acceleration of the patient's wrist.

Methods

Under the on-going clinical study at the University Hospital Clermont-Ferrand, France, accelerometer data recordings have been performed during 6 bilateral DBS implantations for PD (n = 2) and ET (n = 4). A 3-axis accelerometer (±2/±4/±8 g digital output evaluation board based on LIS331DLH accelerometer, ST Micro), placed inside a non-conductive printed plastic case (FullCure 830 VeroWhite, Objet Geometries Ltd - Belgium) slightly bigger than a wrist watch, is tied to the patient's wrist during intraoperative test stimulation. At each test stimulation position, while the intensity of electric current used for stimulation is slowly increased, data from the accelerometer is recorded using in-house developed software Lemur. In addition, the moment and the kind of side effect occurrence are noted. The electrophysiology system responsible for the stimulation is synchronized with the accelerometer system. The final surgical target in which the chronic stimulation electrode is implanted afterwards is chosen by the neurosurgeon by mentally integrating the multitude of anatomical, electrical and clinical data, including clinical efficacy, therapeutic stimulation thresholds and side effects. The above procedure is performed for DBS implantation on both sides of the brain.

Currently, the recorded accelerometer data is analysed postoperatively with plans to do it online during the surgery. As a first step of analysis, the accelerometer data is detrended using smoothness priors method. This data is then low pass filtered and statistical features like standard deviation, signal energy, entropy, main frequency component and amplitude are calculated from it in a windowed manner.

These statistical features are then divided into two groups a) the time period before reaching the subjective threshold and b) at the subjective threshold, and they are compared statistically (Wilcoxon twosided signed rank test) to confirm changes in relation to the subjectively defined threshold. In addition to recording data during stimulation, data was also recorded without any stimulation to set a baseline for comparison. The data recorded at all the stimulation amplitudes is normalized to the baseline value and then used to find the therapeutic thresholds (Fig. 1b).

Based on the percentage change from the baseline, 3 different accelerometer thresholds are calculated (25, 50 and 75 %) and are compared to subjective thresholds. We also used the accelerometer threshold and the side effect threshold to decide a final implant site.

Results

The Wilcoxon two-sided signed rank test has identified a statistical significant change in tremor (p\0.01) for signal entropy, energy and 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 (Fig. 1b). Out of the 3 different accelerometer thresholds, the 75 % threshold matched closely to the ones found subjectively during the surgery. In most cases ([90 %), the accelerometer threshold was found at a lower stimulation amplitude than the subjective threshold (Fig. 2).

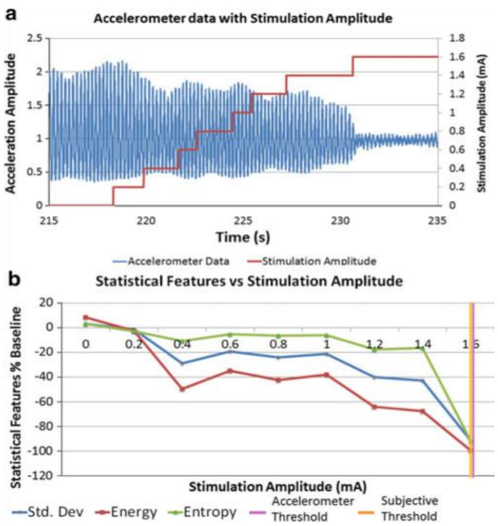

Fig. 1 Stimulation amplitudes (a) and statistical features (b)

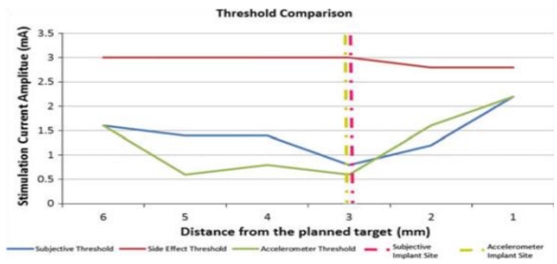

Fig. 2 Subjectively defined stimulation threshold

Conclusion

The present study describes a method to perform tremor assessments using mathematical parameters extracted from the acceleration signal of the wrist. The accelerometer recording in the OR does not increase the duration of the surgery or interfere with any other procedure. The subjectively defined stimulation threshold was confirmed by the acceleration measurements, and it seems that the measurements were more sensitive than the neurologist's evaluation (Fig. 2). Further research is planned with the recorded data. The data will be correlated with the anatomical brain structures stimulated during the surgery. This might bring new information related to the mechanism of action of DBS.