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Quantitative rigidity evaluation during deep brain stimulation surgery - a preliminary study

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Background

Deep brain stimulation (DBS) is a common neurosurgical procedure for relieving movement related disorders such as those observed in Parkinson's disease [Lemaire, 2007]. Besides risks such as bleeding and infection, DBS extends uncertainties associated with suboptimal target selection [Hemm, 2010]. In addition to the fact that the mechanism of action of DBS is still incompletely known, we hypothesize that suboptimal exploitation of intraoperative data could be responsible as well. In fact, intraoperative stimulation tests are performed along the trajectory to semi quantitatively evaluate the induced clinical results. Our aim was to evaluate the feasibility to objectively assess the clinical effect based on acceleration measurements of the neurologist's wrist.

Patients and Methods

One patient referred for bilateral DBS-implantation in the subthalamic nucleus (STN) for the treatment of Parkinson's disease was included in the study. A 3-axis accelerometer evaluation board integrated in a homemade plastic case (FullCure 830 VeroWhite, Objet Geometries Ltd - Belgium) was fixed on the neurologist's wrist during intraoperative test stimulation (Fig. 1) on both sides. Without stimulation ("initial baseline") and while the intensity of electric current used for stimulation was slowly increased, the neurologist continuously moved the patient's wrist in order to determine the moment of and the amplitude at rigidity release ("stimulation threshold"). In addition, the moment and the kind of side effect occurrence were noted. In the end, the DBS electrodes were implanted at the anatomical positions where the lowest stimulation threshold and a large range until side effect were noticed.

At each position for each amplitude of electric current (3 to 14 tested amplitudes per anatomical position; mean: 5,78), up to the maximum stimulation threshold (3mA), standard deviation, signal energy, entropy and the maximum amplitude contained in the frequency spectrum were calculated. First, for each test stimulation position, mathematical parameters were determined a) for the time period before reaching the stimulation threshold identified by the neurologist and b) after reaching the threshold, and they were compared statistically (Wilcoxon two-sided signed rank test). In order to be able to better compare the changes in the different features with amplitude increase, values were normalized to the initial baseline values obtained without stimulation. We identified the acceleration based stimulation threshold (at least one mathematical feature had to increase of at least 25 % compared to the initial baseline) and compared the result to the threshold identified by the neurologist.

No significant difference was found for the maximum amplitude in the frequency spectrum ($p=0.077$). In 13 out of 18 cases signal energy showed the highest percentage change compared to the initial baseline values at the threshold identified by the neurologist. The stimulation threshold identified based on accelerometry was in most cases lower than the subjectively determined one (Fig. 2 and 3). If the accelerometer data had been used for the choice of the final implantation site, there would probably have been no difference on the left side. On the right side, the -7-mm spot would probably have been chosen due to the better clinical result (Fig. 3).

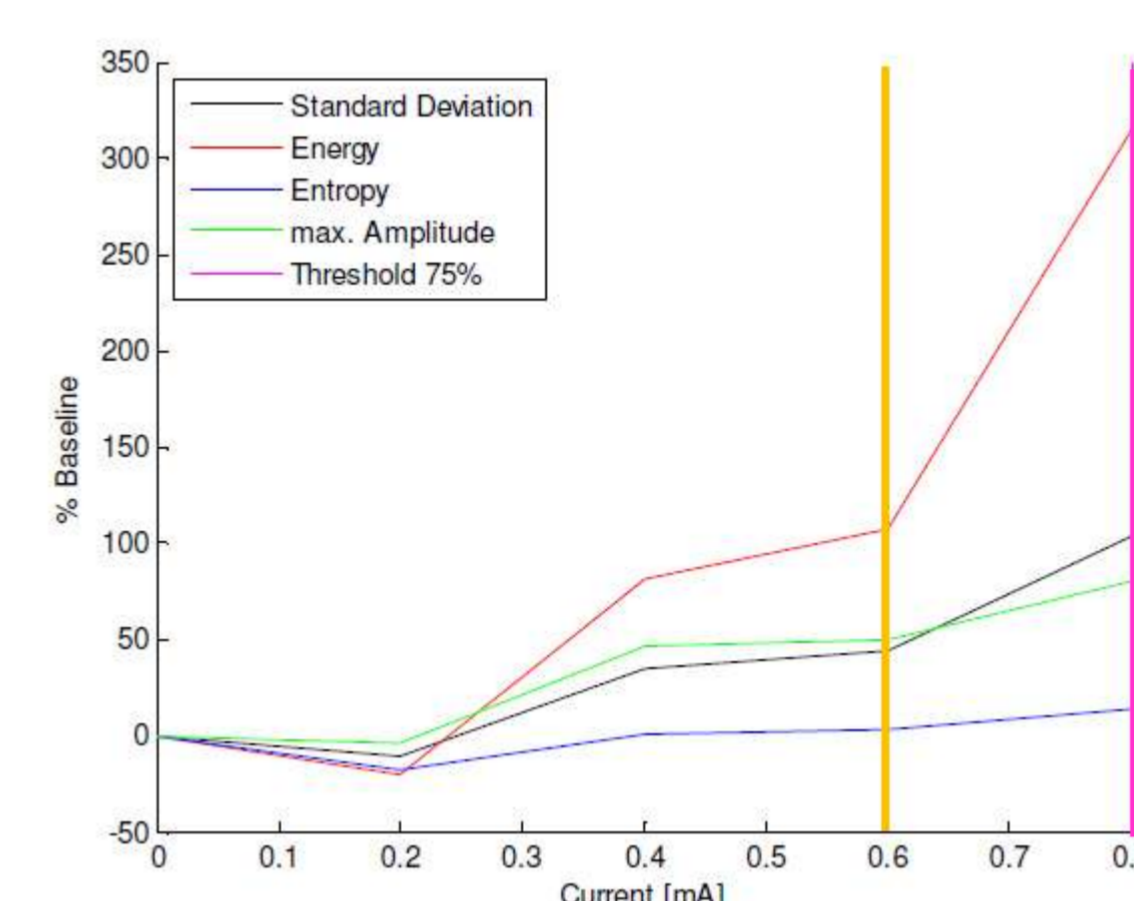


Figure 2
Presentation of different mathematical parameters in function of the amplitude of the stimulation current. Orange vertical bold line: threshold detected with the accelerometer; vertical purple line: stimulation threshold identified by neurologist.

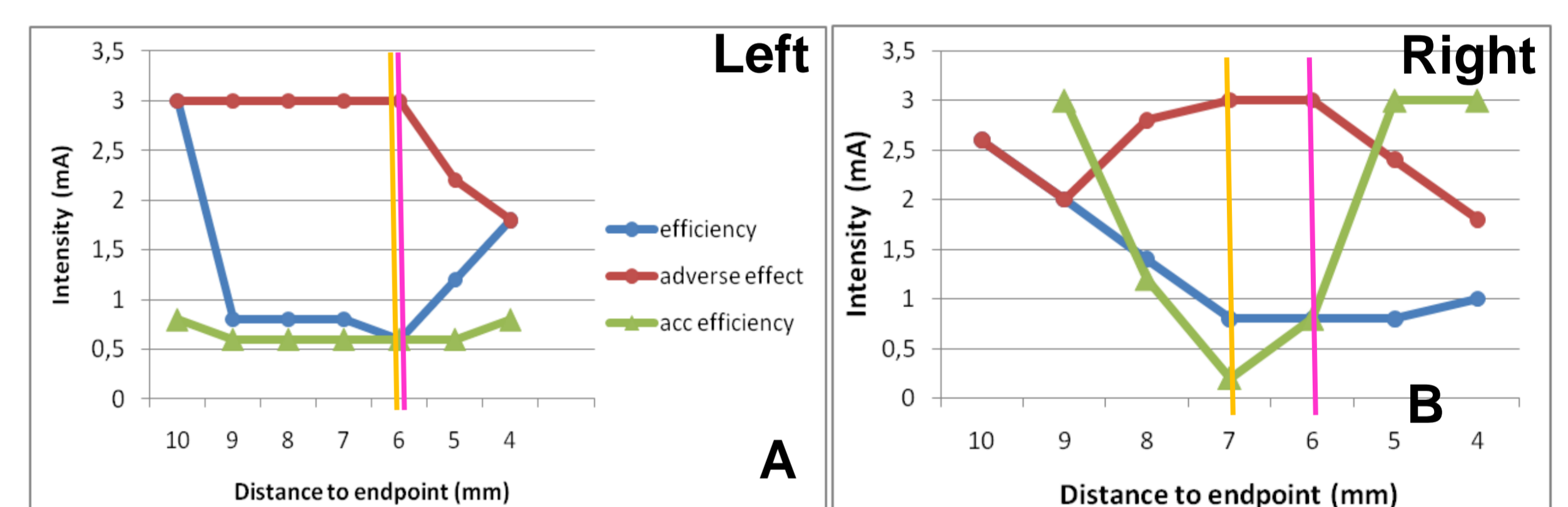


Figure 3
Stimulation and side effect thresholds according to the distance to the endpoint of the trajectory. Red curve: side effect threshold; Blue and green curve: stimulation thresholds (neurologist and accelerometer respectively); Purple line: finally chosen implantation site; orange line, implantation site that would have been chosen based on the acceleration measurements. A) Left trajectory. B) Right trajectory.

Discussion

The present study has demonstrated the feasibility to perform rigidity assessments using mathematical features (signal energy, entropy and standard deviation) extracted from the acceleration signal of the wrist. Signal energy seemed to be the most sensible parameter as the percentage change is higher compared to the initial clinical state than for the other parameters. The stimulation threshold determined by the neurologist was confirmed by the acceleration measurements and it seems that the measurements were in many cases more sensitive to changes than the neurologist's evaluation. The choice of the final implantation site might be slightly different when based on acceleration data alone, but before further interpretation, a detailed statistic analysis is necessary to define the most adapted criteria for accelerometric threshold identification. Furthermore, sites in which major differences appear between the two evaluation methods (Fig. 3A, Position - 10), a deeper analysis will be performed. In general, the results have to be confirmed by a larger clinical study. The correlation with the anatomical position of each measurement site might bring new information about the mechanism of action of DBS.

References

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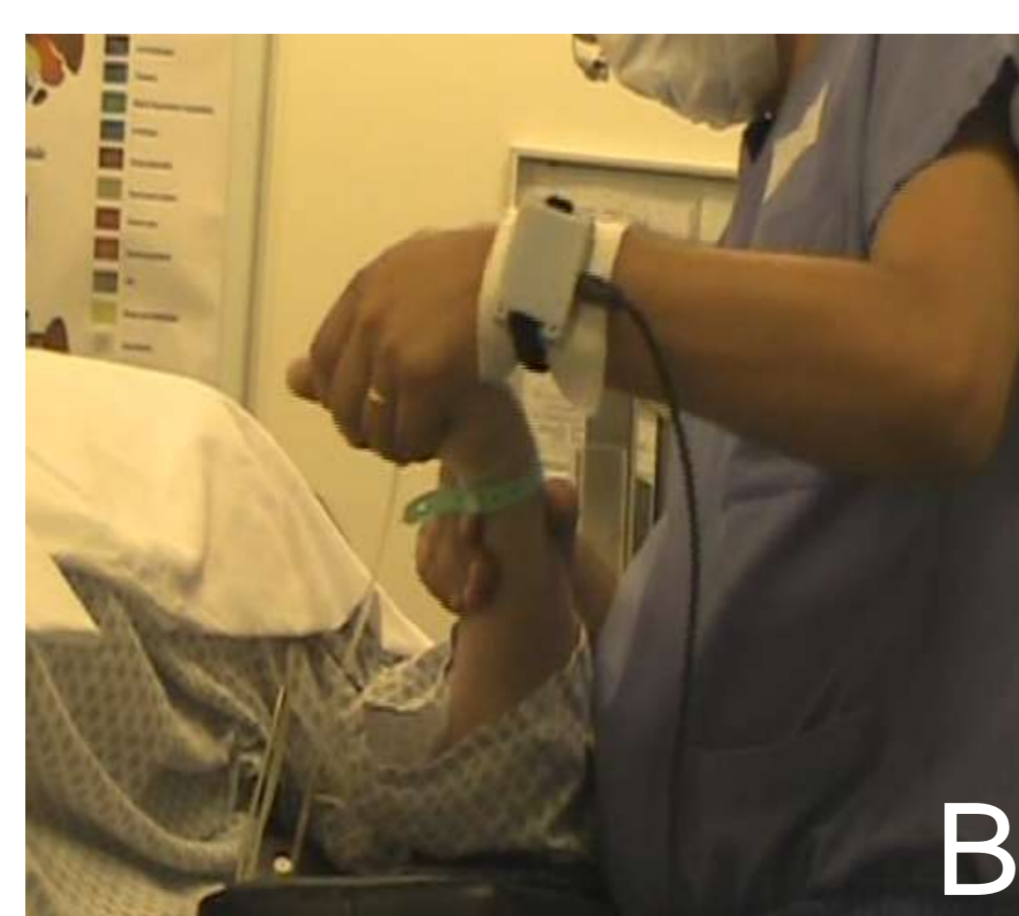
Acknowledgements

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Figure 1 :

The accelerometer integrated in the plastic case (A) and fixed to the neurologist's wrist during rigidity assessment (B).



Results

Accelerometer measurements were performed on both sides. In total the neurologist identified a threshold in 20 positions. A statistical significant change in rigidity ($p<0.01$) has been identified for signal entropy, energy and standard deviation when comparing the signal before and at the identified threshold.

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