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# Optical measurements for guidance during deep brain stimulation surgery

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**Abstract**— Deep brain stimulation (DBS) is an established treatment for Parkinson’s disease and related movement disorders. The success of DBS is highly dependent on electrode location, electrical parameter settings and the surgical procedure. In this paper an overview of the current status of optical measurements for intracerebral guidance performed during DBS implantation is presented. Laser Doppler perfusion monitoring and/or reflection spectroscopy measurements have been done in relation to more than 70 DBS lead implantations towards targets in the deep brain structures. The techniques have also been compared with impedance monitoring, and simulation of the measurement depth has been done with Monte Carlo technique. These studies show that grey-white matter boundaries can be determined with a resolution higher than for both impedance measurements and magnetic resonance imaging.

**Keywords**— Deep brain stimulation, stereotactic neurosurgery, intracerebral guidance, laser Doppler perfusion monitoring, reflection spectroscopy

## I. INTRODUCTION

One of the most common and effective procedures for relieving movement related disorders such as Parkinson’s disease is deep brain stimulation (DBS) [1]. During the intervention, an electrode is inserted towards a target area along a pre-calculated trajectory determined from magnetic resonance imaging (MRI) or computed tomography (CT). Optimal clinical outcome requires not only safe and accurate navigation towards the target but also a well defined target area specified depending on symptom. Common target areas are the subthalamic nucleus (STN), zona incerta (Zi), globus pallidus internus (GPi) or various parts of the thalamus. Other structures are also currently under investigation and some are found useful for relief of symptoms like pain and psychiatric illness.

Inter- and inpatient variations and displacement of the brain occurring in conjunction with the surgical procedure can result in a deviation of the target during implantation from the pre-planned coordinates determined from a MR or CT batch of images. This can result in a suboptimal effect of the stimulation as well as in stimulation induced side-effects. The introduction of the electrode does further carry

a potential risk of damaging blood vessels with subsequent hemorrhages. Recent studies show a bleeding rate for DBS-implantation between 1-6 % depending on target areas used for the DBS procedure [1, 2].

It is not possible to fully compensate for deviations during probe insertion by the available neuronavigation systems, which are based on pre-operative images. Intracerebral recordings, such as physiological mapping using e.g. micro-electrode recording (MER) [3] or impedance measurements [4] are possible ways to overcome this problem. MER has a very high resolution but may introduce an increased risk of bleeding [5, 6]. Impedance has a limited resolution but can distinguish between cerebral spinal fluid and white fibre tracts. A possible way to increase the precision, accuracy and safety during stereotactic procedures is to use intracerebral recording of optical signals. Giller and colleagues [7] have used diffuse reflectance spectroscopy during stereotactic neurosurgery in patients undergoing DBS implantation and the described technique shows promising results in detecting grey-white matter boundaries. These findings have been confirmed by us and we have also shown that a fixed wavelength e.g. 780 nm, the same wavelength applicable as in laser Doppler systems, can be used for detection of brain tissue boundaries [8]. In this paper an overview of the current status of optical measurements performed by us during DBS implantation is presented.

## II. MATERIALS AND METHODS

Recordings have so far been done with laser Doppler perfusion monitoring (LDPM) and/or reflection spectroscopy in more than 70 DBS implantation procedures at the University Hospitals in Linköping and Umeå. The study was approved by the respective local ethics committees (D No. M182-04) and all patients gave their informed consent.

Stereotactic imaging was performed after placement of the Leksell<sup>®</sup> stereotactic frame model G (Elekta Instrument AB, Sweden). Direct anatomical targeting [9] for the STN, GPi and Zi was performed on stereotactic MRI studies using a 1.5 T scanner. During surgery an electrode (l = 190 mm, Ø = 1.5 mm) with optical fibres was used to create

tracts for the DBS-electrodes along the pre-calculated trajectory. Measurements of optical signals (LDPM and reflection spectroscopy) were performed along the trajectory from the cortex towards the target area. This was done either continuously while the surgeon manually inserted the electrode with an as even speed as possible (lasting for 1-2 minutes), or in steps ranging from 2-10 mm along the trajectory. A final measurement was always done with both techniques in the target area.

### III. RESULTS

These measurements demonstrate that it is possible to distinguish between grey and white matter as well as between different target areas [8, 10, 11]. This has been achieved with both the LDPM and spectroscopy system. Furthermore the LDPM system makes it possible to monitor the microcirculation along the trajectory as well as in the deep brain structures. An example of simultaneous measurements of the total light intensity (representing the grayness of the tissue) and the microvascular blood flow towards the STN is presented in Fig. 1.

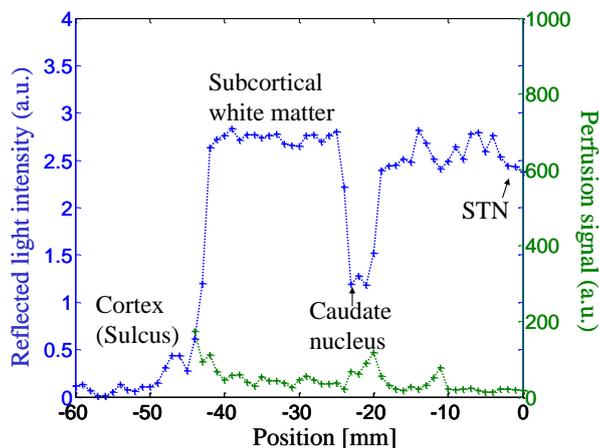


Fig. 1 Recording of microvascular perfusion (green curve) and total light intensity (blue curve) during probe insertion towards STN. Measurements were done in 1 mm steps.

### IV. DISCUSSION AND CONCLUSIONS

The techniques have recently also been compared with impedance monitoring [11], and simulation of the measurement depth has been done with Monte Carlo technique [12]. These studies show that the resolution of the optical measurements is higher than for both impedance and magnetic resonance imaging. The next step in the project is to investigate the relation between microvascular blood flow and blood vessels, and to compare the optical technique

with other intracerebral methods such as microelectrode recording. Furthermore, a multi-center study for investigation of the applicability of “bar-codes” to targets commonly used for DBS implantation will be undertaken.

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