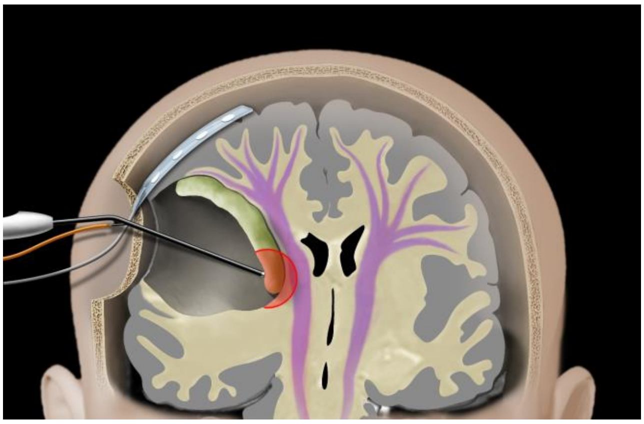
Towards a Computational Model for Impedance-Based Brain Tumor Resection

Background In neurosurgery, tissue discrimination is vital for a successful outcome. Surgeons aim at maximizing the resection of brain tumor to improve patient survival, while preserving important functional areas to maintain the quality of life of the patients. The challenge is therefore to achieve optimal tumor resection, which is especially difficult in case of infiltrating brain tumors. Image-guidance systems are of limited use in this context due to the high precision requirements and to the intraoperative motion of soft tissues.



Electrical subcortical mapping has been proposed as a technique to detect the proximity between the surgical tools and the motor pathways/corticospinal tract (CST). This mapping has been instrumental in achieving a high rate of complete resection, while reducing the risks of motor deficits. However, the relationship between the electrical stimulation threshold that elicits a motor evoked potential (MEP) and the distance between the surgical tool and the CST remains unclear. The clinical rule of thumb relationship assumes a linear correlation between the stimulation intensity and the distance to the CST. This subcortical mapping assumes that a 10 mA stimulation is able to provoke a response at a distance of 10 mm from the CST, which has been interpreted as 1 mA equals roughly 1 mm. However, electric current decreases with the square of the distance, and depends on the properties of the tissues in the stimulation field. The figure above illustrates brain tumor resection with electrical subcortical mapping (copyright Andreas Raabe). The tumor is represented in green, the CST in purple, the electrical field in red.

Although successful clinically, some patients still show post-surgical motor deficits. Therefore, a better understanding of the subcortical mapping process may more precisely determine the distance between the surgical tools and the CST, which could limit patient risk, while ensuring an optimal resection of the tumor close to the CST.

Aim This project aims at developing a first version of a computational model of the electrical subcortical mapping. The ability of the model to provide an understanding of subcortical mapping will be evaluated on clinical data.

Materials and Methods The project is divided into two parts. In the first part, the student will analyse about ten patients that underwent implantation for deep brain stimulation for Parkinson's disease. These patients did not undergo tumor resection, but they were stimulated intraoperatively at known positions and the distance to the CST can be calculated. This will facilitate the setup of the model. In the second part, the student will incorporate MEP threshold measurements from more than 500 patients that underwent surgery of different brain tumors. In these patients, the stimulation was performed at the end of tumor resection and the position is known approximately. The student will implement the computational model in COMSOL. For starters, the student will also use the Lead-DBS toolbox with Matlab to gain a first understanding of the topic.

Nature of the Thesis:
Literature review 10%
Data analysis and modelling 70%
Writing 20%

Requirements:
Knowledge of finite element analysis (e.g., COMSOL, SCIRun)

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References:

[1] Raabe, A., Beck, J., Schucht, P., & Seidel, K. (2014). Continuous dynamic mapping of the corticospinal tract during surgery of motor eloquent brain tumors: evaluation of a new method. Journal of neurosurgery, 120(5), 1015-1024.

[2] Seidel, K., & Raabe, A. (2020). Cortical and subcortical brain mapping. In Neurophysiology in Neurosurgery (pp. 121-135). Academic Press.