Tissue classification during surgical drilling using impedance spectroscopy

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Abstract: Many types of surgery involve drilling through bone, and it is important to avoid inadvertently cutting sensitive tissues such as nerves. This study investigates whether it is possible to distinguish tissue types from their impedance characteristics over 100 Hz – 1 MHz using electrodes mounted on a probe.

1 Introduction

Drilling through cortical tissue is a key step in many surgeries and many technologies, such as surgical robots [1], focus on improving the accuracy and repeatability of this task. We are motivated by the constraints of Robotic Cochlear Implantation where it is important to avoid damage to the facial nerve. Since nerves have different impedance characteristics to other tissues (and specifically to cortical and cancellous bone), we explore whether electrodes mounted on a probe (or eventually a drill) can be used to measure and distinguish tissue types.

2 Methods and Results

Experiments were performed on three anesthetized and ventilated sheep. Titanium reference screws were implanted into the mastoid for registration. Using a surgical robot system designed for cochlear implantation [2] drill trajectories (eight per animal) were implemented. For each trajectory, up to five measurement points were planned starting at 1.2 mm before the facial nerve. At each point, the drill was removed, the trajectory irrigated (NaCl 0.9%) and an impedance spectroscopy probe inserted to measure Z at 100 Hz – 1 MHz between the probe tip and a body-surface electrode. After the experiment, the mastoid was removed and μCT images acquired to assess drill-to-facial nerve distances.

Example results are shown in Fig 1, corresponding to the μCT image in Fig 2. There is a decrease in $|Z|$ and change of $\angle Z$ as the probe moves from the cancellous bone into the nerve (p4).

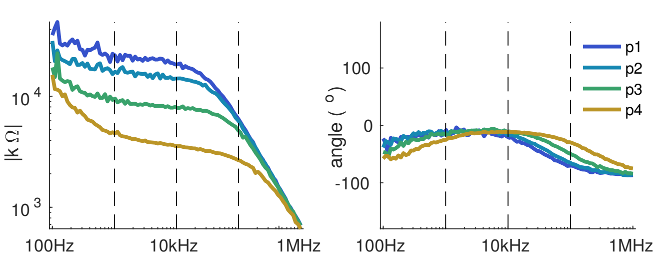

Figure 1: Impedance magnitude (left) and phase (right) for a representative trajectory. Points indicate the approach of the probe to the nerve, entering it at p4.

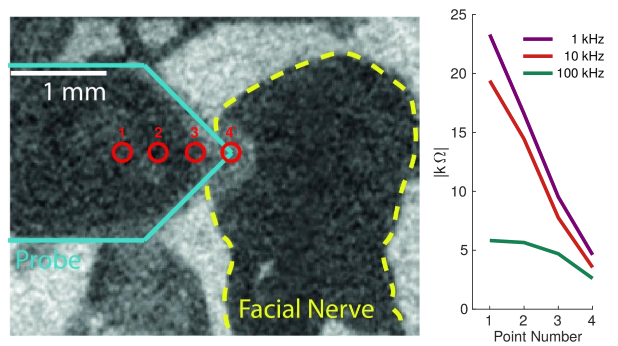

Figure 2: Post-operative μCT slice (left) of the drill trajectory where red dots indicate the probe tip at points p1 . . . p4. $|Z|$ (right) at three frequencies as a function of point number.

3 Discussion

Preliminary results show a promising ability to distinguish tissue types using impedance measurements. The most sensitive range appears to be 1 – 10 kHz with useful contributions at other frequencies. Using the in-vivo data and a ground-truth classification of tissue types from the μCT data, we will assess the accuracy with which it is possible to distinguish tissues with impedance data.

Analysis is continuing to optimizing the probe for increased sensitivity. Using a finite element model (Fig 3) we are exploring probe designs and conducting in-vitro tests.

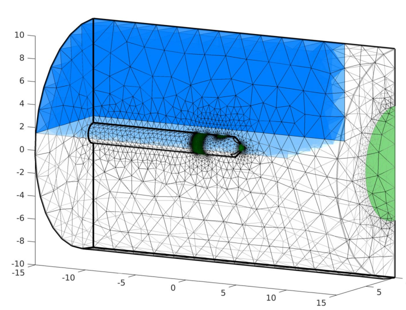

Figure 3: FEM of a probe in a uniform cylindrical tissue near to a lateral transition between tissue types. A large external electrode is shown at right. Different electrode designs are shown on the probe.

References

[1] J Anso et al, *IEEE T Biomed Eng*, 66:237–245, 2019.
[2] Weber et al *Sci Robot*, 2:eaal4916, 2017.