**Border Detection and Image Analysis of Implanted Deep Brain Stimulation Leads in Close Proximity: A High-Resolution Postoperative Computed Tomography Case Study**

**Introduction**

Deep brain stimulation (DBS) is a neurosurgical treatment that involves the implantation of electrodes in deep target regions of the brain for treatment of Parkinson’s Disease1, essential tremor2, dystonia3 and some neuropsychiatric disorders.4,5 Precise placement of the DBS electrode has been shown to be critical for DBS success and patient outcomes.6-8 DBS surgeries are commonly performed as bilateral cases in which the first DBS electrode is implanted in a deep target region of the brain and the second DBS electrode is implanted in the contralateral hemisphere shortly thereafter. However, there are clinical indications for DBS cases involving unilateral implantation of two electrodes within a similar target region. Such surgeries may result in inherent difficulties in the interpretation of DBS lead location from postoperative computed tomography (CT) data, especially in cases where the signal produced at the active contacts at the distal lead overlap due to close proximity of DBS leads. The objective of this study was to provide a solution for analyzing postoperative CT data for such DBS cases.

**Methods**

In this study we use MATLAB to analyze an image string of postoperative CT DICOM (.dcm) files acquired at high resolution (≤1.0 mm resolution in all directions). Using a for loop we specify the range of images within the image string to iterate upon, identifying the region within the brain containing signal from the implanted DBS leads. Both of the implanted DBS electrodes in this case study were Abbott/St. Jude Medical Infinity™ leads (Figure 1). For each iteration within the loop we perform a cropping function to crop only the region of CT including signal from the DBS leads. Each cropped image is normalized to set intensities between zero and one before creating a binary image by replacing all values above a globally determined threshold with ones and setting all other values to zeros. From the binarized images edge detection was performed to identify the borders of each DBS lead which were numerically labeled. Because each image in the image string had different signal intensities at the region of the DBS lead, various sensitivity factors used to binarize images were specified such that two objects corresponding to each DBS lead were identified in each iteration of the loop (Table 1). Following this process, the centroids of each DBS lead were identified and stored in an array. The distance between the centroids of detected signal from the DBS lead were computed in each iteration of the loop. The separation of DBS leads along the entire length of the distal electrode contacts and proximal leads are represented in Figure 2. Distances were computed at 5 millimeter intervals in the Z-direction from the distal lead tip spanning the entire length of implanted DBS leads.

**Discussion/Results**

The maximum separation of DBS leads was observed to be approximately 9 millimeters occurring 5 centimeters from the distal lead tip measured in the Z-direction (Figure 2). Thus, maximum separation of the DBS leads occurred along the proximal lead. The sharp drop in lead separation between 5.5 centimeters and 6 centimeters observed in Figure 2 represents the point at which the proximal leads begin to converge before being capped and bolted within the skull. If we were able to devise a method for measuring lead separation at the point in which the leads are capped within the skull we would expect to see a continued drop in the measured distance between leads as they would eventually converge to zero at the point in which they are capped and bolted within the skull.

A common phenomenon in DBS surgery involves the accumulation of Intracranial air (ICA) between the cranium and the brain during surgery, causing movement of brain tissue relative to its natural anatomical position that resolves in the weeks following surgery. Previous research in this field has shown the proximal lead to bend in association with subdural air volume accumulated during surgery.9 The observed increase in separation between DBS leads along the proximal lead at 5 centimeters from the distal tip (Figure 2) may be a result of ICA volume influencing the proximal lead to bend and causing further separation between leads.

**Conclusion**

The separation between DBS leads implanted unilaterally in similar target regions appears to remain relatively constant throughout the entire length of the DBS lead. A slight increase in the measured separation between DBS leads was observed at the proximal lead before a sharp decrease in separation at the point at which the proximal leads begin to converge before being capped and bolted within the skull. The observed increase in separation between DBS leads along the proximal lead may be explained by an association of ICA volume accumulated during surgery and bending of the proximal lead.

**References**

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**Figure Captions**

Figure 1: DBS Abbott/St. Jude Medical Infinity™ lead model. Four contact regions along the distal lead are represented as 1 (most distal electrode contact), segmented contacts 2-4, segmented contacts 5-7, and 8 (most proximal electrode contact). Contact regions are 1.5 mm in length and are separated by 0.5 mm spacing. Approximately 0.5 mm proximal to contact 8 is an electrode marker which is used to determine the orientation of the contact region.

*Figure 2:* Distance between DBS leads as measured in the XY-Plane in millimeters is plotted as a function of the distance from DBS lead distal tip in the Z-Direction in centimeters. The greatest separation between DBS leads was observed along the proximal lead at 5 centimeters from the distal tip. This corresponded to approximately a 9 millimeter separation between DBS leads.

*Table 1:* Parameter table of sensitivity factors used at different regions of the DBS lead for image binarization.

**Figures**

*Figure 1:*



*Figure 2:*



Table 1:

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| --- | --- | --- | --- |
| Sensitivity Factor | DBS Lead Region | Signal Intensity | Estimated Span of DBS Lead |
| 0.9999 | Distal Electrode Contacts | Very High | ~ 1 cm |
| 0.999 | Distal Electrode Tip & Electrode Marker | High | ~ 0.5 cm |
| 0.99 | Proximal Lead | Medium | ~ 0.5 cm |
| 0.9 | Proximal Lead | Low | ~ 3 cm |