Assessment of implant accuracy using high-resolution postmortem MRI

Lucy Liang[1], Elvira Pirondini[1], Jonathan C Ho[1]

[1]University of Pittsburgh

ASAP Collaborative Research Network

Lucy Liang
University of Pittsburgh

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ABSTRACT

Deep brain implant accuracy is important for successful experiments in non-human primates. In this protocol, we describe the steps to use postmortem imaging to assess the accuracy of an implant by visualizing implant location with a small thermal ablation and comparing its coordinates to image based pre-surgical planning.

This protocol is supplementary to the manuscript:
Liang, L., Zimmermann Rollin, I., Alikaya, A., Ho, J.C., Santini, T., Bostan, A.C., Schwerdt, H.N., Stauffer, W.R., Ibrahim, T.S., Pirondini, E., Schaeffer, D.J., 2024. An open-source MRI compatible frame for multimodal presurgical mapping in macaque and capuchin monkeys. *BioRxiv* https://doi.org/10.1101/2024.02.17.580767

PROTOCOL REFERENCES

Liang, L., Zimmermann Rollin, I., Alikaya, A., Ho, J.C., Santini, T., Bostan, A.C., Schwerdt, H.N., Stauffer, W.R., Ibrahim, T.S., Pirondini, E., Schaeffer, D.J., 2024. An open-source MRI compatible frame for multimodal presurgical mapping in macaque and capuchin monkeys. *BioRxiv* https://doi.org/10.1101/2024.02.17.580767

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We use this protocol and it's working

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MATERIALS

Thermal Ablation

- Radiofrequency cannula (S-100 5 mm ActiveTip Straight cannula 22G, Abbott)
- Radiofrequency electrode (RF-SE-10 Reusable Stainless Steel Electrode, Abbott)
- Grounding pad (Abbott)
- Radiofrequency generator (NeuroTherm NT 1100, Abbott)

Imaging Equipment

- 9.4T/31 cm horizontal-bore Bruker AV3 HD animal scanner

Tissue Preparation

- Euthanasia drug (Fetal Plus or equivalent)
- Perfusion machine
- 1x phosphate buffered saline (PBS)
- 4% paraformaldehyde (PFA)
- Brain dissection tools

Image Processing Software

- FSL (Smith et al. 2004)

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BEFORE START INSTRUCTIONS

Follow this protocol after all terminal experiments have been completed, but before euthanizing the animal.

Note: Perfusion with 4% PFA may cause some degree of tissue shrinkage. We observed an average of 3.3% shrinkage with our brain tissue.

Thermal ablation & tissue preparation

1 Before euthanizing the animal according to protocol, perform a thermal lesion through the deep brain electrode.

We use a radiofrequency cannula (S-100 5 mm ActiveTip Straight cannula 22G, Abbott) and a radiofrequency electrode (RF-SE-10 Reusable Stainless Steel Electrode, Abbott), with a radiofrequency generator (NeuroTherm NT 1100).

Parameters: ~80°C, 1min

2 Remove electrode (not MR compatible) from the brain and euthanize the animal.

3 Perfuse transcardially with 1x phosphate buffered saline (PBS), followed by 4% paraformaldehyde (PFA).

4 Dissect out the brain with care. Carefully remove the dura and any blood clots from the surface of the brain.

5 Place the brain in 4% PFA for an additional 24 hours, then, move to 1x PBS.

Imaging and implant error calculation

6 Collect T2 or T2* weighted images of the brain in a 9.4 T/31 cm horizontal-bore Bruker AV3 HD animal scanner with the following parameters:
T2: 125 µm isotropic,TR/TE = 1500/60ms, FOV = 52×80×56 mm
T2*: 80 µm isotropic, TR/TE = 100/16 ms, FOV = 55×70×45 mm

7 Visualize the images in FSL, and align the anterior commissure to posterior commissure (ACPC) line with the x-axis of the mid sagittal plane with the FLIRT function.

8 Identify the tip of the electrode (at the center of the thermal lesion) within the internal capsule (or your target of interest), and record the coordinates.

9 Calculate the X_i, Y_i, and Z_i distance (in pixels) from the posterior commissure (PC) point. Convert to metric distance using pixel resolution.

(coordinate subscript "i" indicates implant coordinates, "t" indicates target coordinates)

10 Calculate target implant error in each axis by subtracting implant coordinates and target coordinates (e.g. $X_e = X_i - X_t$)

11 Finally, calculate the overall target implant error (IE) using Euclidean distance $IE = sqrt(X_e^2+Y_e^2+Z_e^2)$