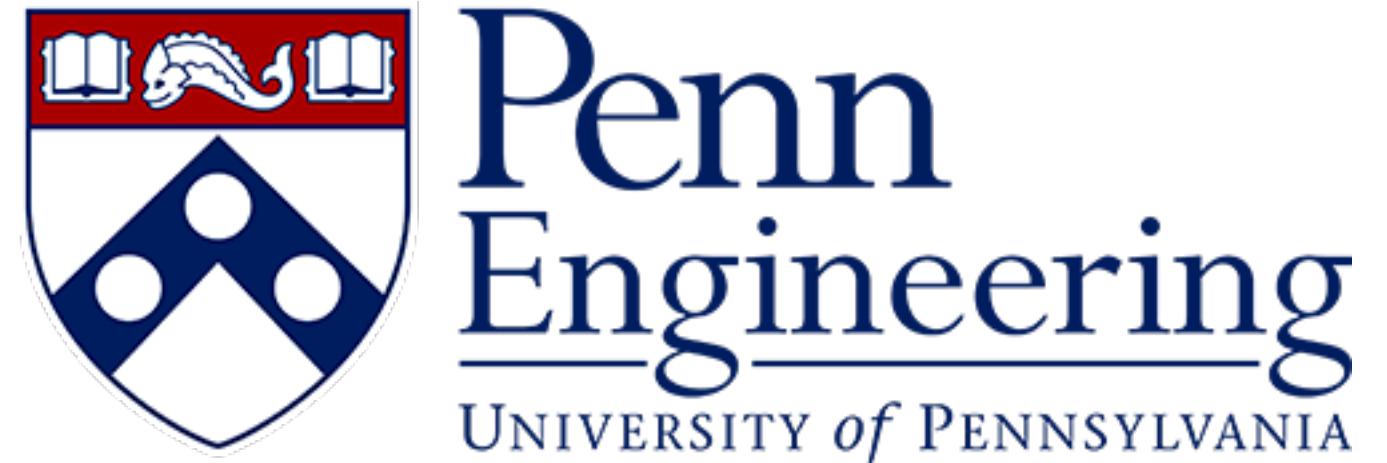


iEEG-RECON

Alfredo Lucas

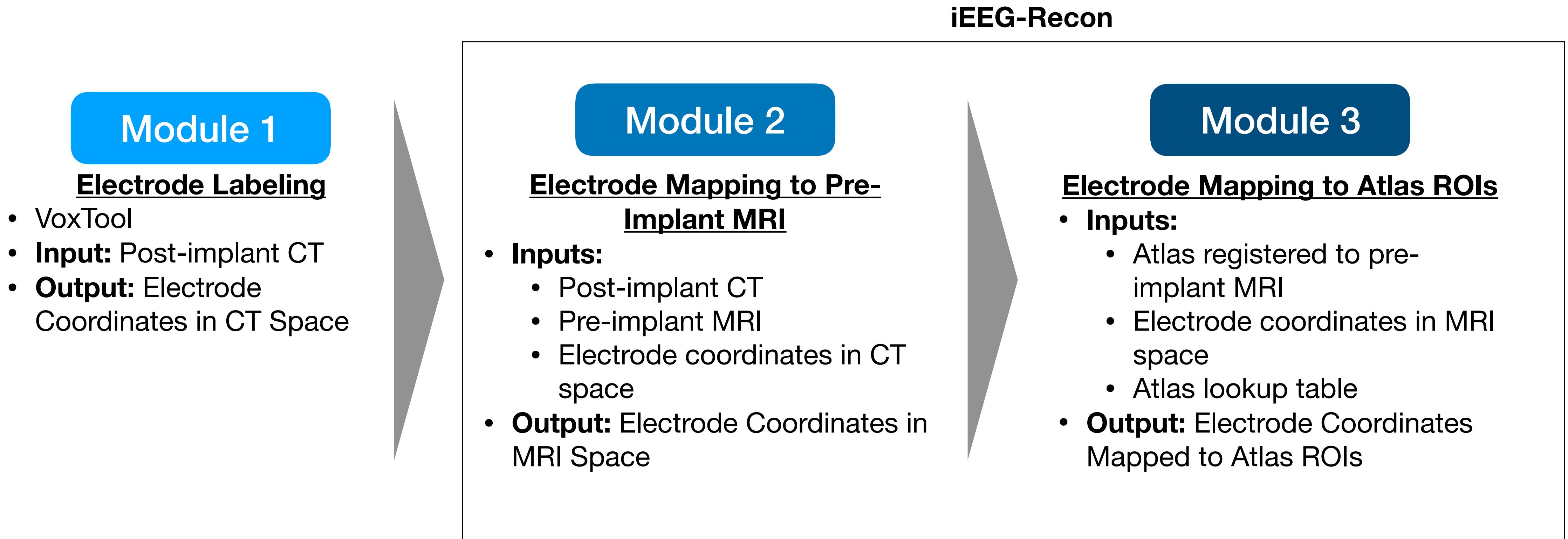


iEEG-Recon Overview



- Nipype based electrode coregistration pipeline
- Available as a Docker container (recommended) and stand-alone Python installation. Analogous Matlab version will also be available
- Because it is built in Nipype, we can easily incorporate different features from multiple Neuroimaging software into the pipeline
- Containerized Docker image allows for ease of dissemination across collaborators (Docker image includes required Neuroimaging software, no need to struggle installing FSL, ANTS, etc.)
- Standalone Python version allows for complete access to those who want to see the inner workings of the pipeline

Pipeline Overview



Proposed (pseudo)BIDS Structure

- Post-implant CT:

sub-RIDXXX_ses-clinical01_acq-3D_space-T01ct_ct.nii.gz

- Pre-implant MRI - Clinical:

sub-RIDXXX_ses-clinical01_acq-3D_space-T00mri_T1w.nii.gz

- Pre-implant MRI - Research:

sub-RIDXXX_ses-research3T_acq-3D_space-T00mri_T1w.nii.gz

- Electrode Coordinates (output of *Module 1 - previously VOX_coords_mother.txt*):

sub-RIDXXX_ses-clinical01_space-T01ct_desc-vox_electrodes.txt

Proposed (pseudo)BIDS Structure

BIDS

sub-RIDXXX

ses-clinical01

anat

sub-RIDXXX_ses-clinical01_acq-3D_space-T00mri_T1w.nii.gz

ct

sub-RIDXXX_ses-clinical01_acq-3D_space-T01ct_ct.nii.gz

ieeg

sub-RIDXXX_ses-clinical01_space-T01ct_desc-vox_electrodes.txt

ses-research3T

anat

sub-RIDXXX_ses-research3T_acq-3D_space-T00mri_T1w.nii.gz

Optional

Module 2 - Overview

Command:

```
ieeg_recon -s sub-RID0031 -m 2 -cs ses-clinical01 -rs ses-research3T  
-d /BIDS
```

Arguments:

- s: subject ID
- m: Module number
- cs: Name of clinical session
- rs: Name of session with reference MRI
- d: Path to BIDS directory containing all subjects

Expected Runtime: 7-10min

Module 2 - Registering to the Research MRI

Command:

```
ieeg_recon -s sub-RID0031 -m 2 -cs ses-clinical01 -rs ses-research3T  
-d /BIDS
```

The above command will use the following files:

BIDS

sub-RID0031

ses-clinical01

anat

sub-RID0031_ses-clinical01_acq-3D_space-T00mri_T1w.nii.gz

ct

sub-RID0031_ses-clinical01_acq-3D_space-T01ct_ct.nii.gz

ieeg

sub-RID0031_ses-clinical01_space-T01ct_desc-vox_electrodes.txt

ses-research3T

anat

sub-RID0031_ses-research3T_acq-3D_space-T00mri_T1w.nii.gz

sub-RID0051

sub-RID0117

Module 2 - Registering to the Clinical MRI

Command:

```
ieeg_recon -s sub-RID0031 -m 2 -cs ses-clinical01 -rs ses-clinical01  
-d /BIDS
```

The above command will use the following files:

BIDS

sub-RID0031

ses-clinical01

anat

sub-RID0031_ses-clinical01_acq-3D_space-T00mri_T1w.nii.gz

ct

sub-RID0031_ses-clinical01_acq-3D_space-T01ct_ct.nii.gz

ieeg

sub-RID0031_ses-clinical01_space-T01ct_desc-vox_electrodes.txt

ses-research3T

anat

sub-RID0031_ses-research3T_acq-3D_space-T00mri_T1w.nii.gz

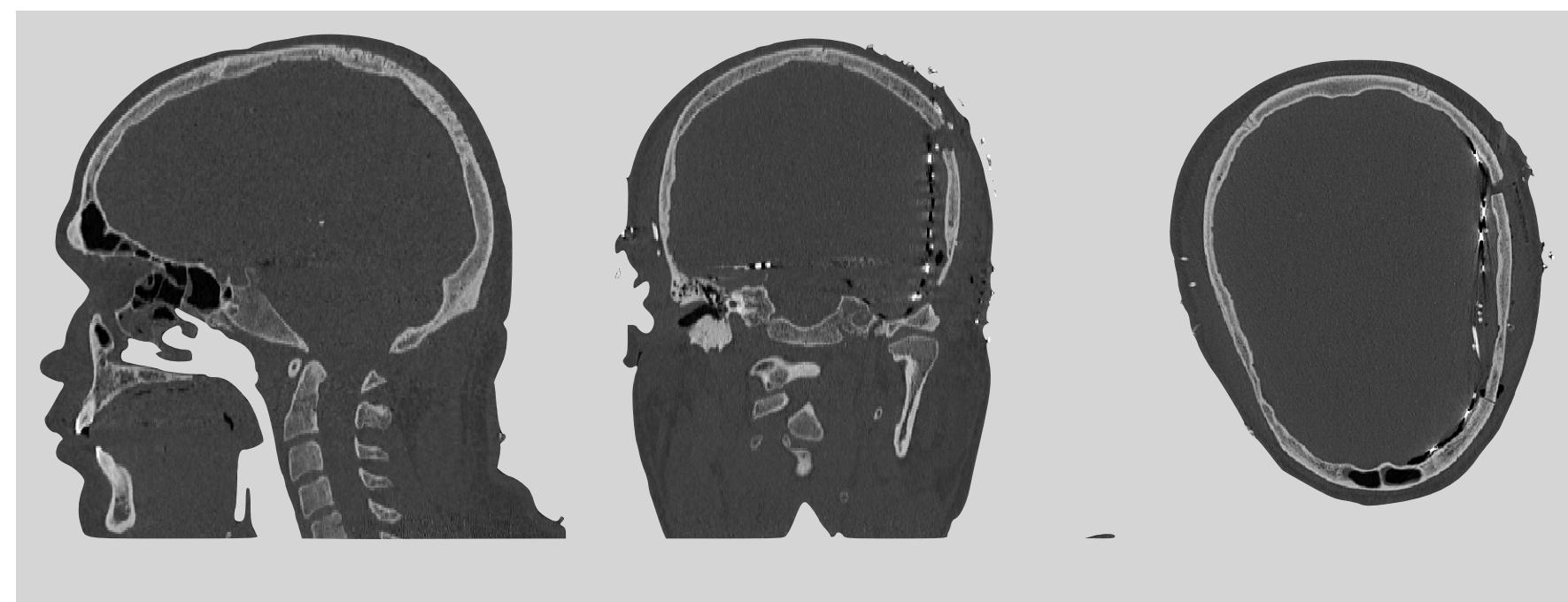
sub-RID0051

sub-RID0117

Module 2 - Step 1: Conversion to RAS

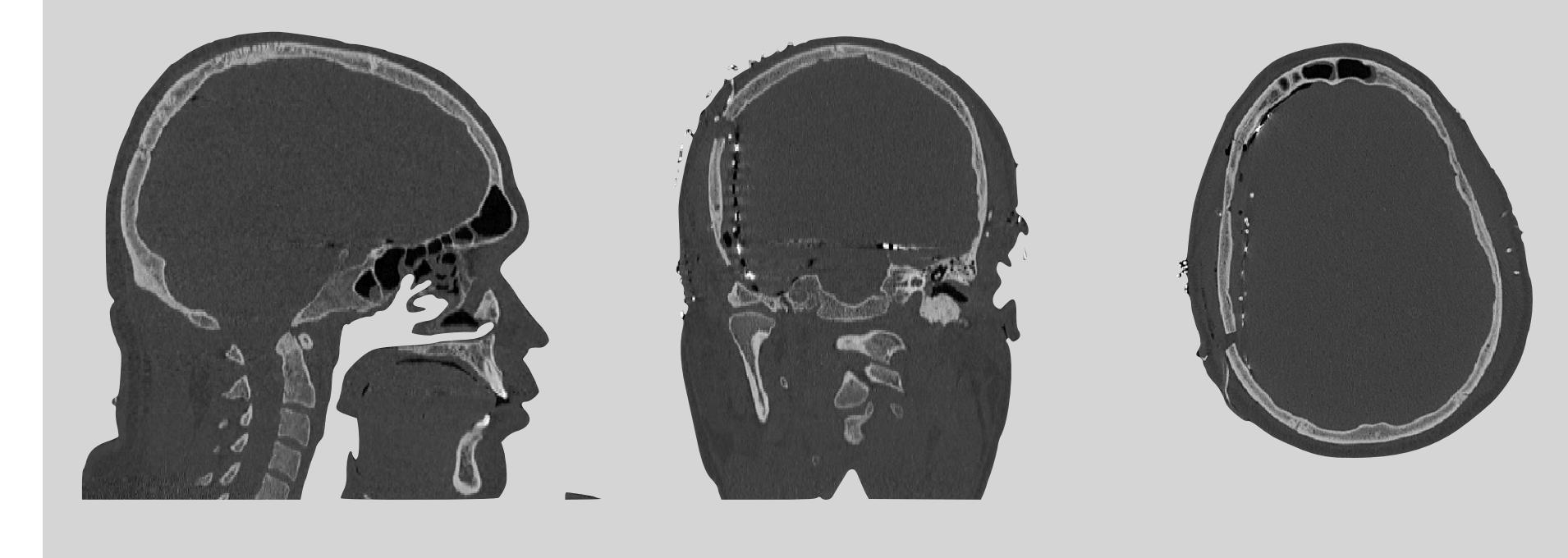
Post-ictal CT

sub-RID0117_ses-clinical01_acq-3D_space-T01ct_ct.nii.gz



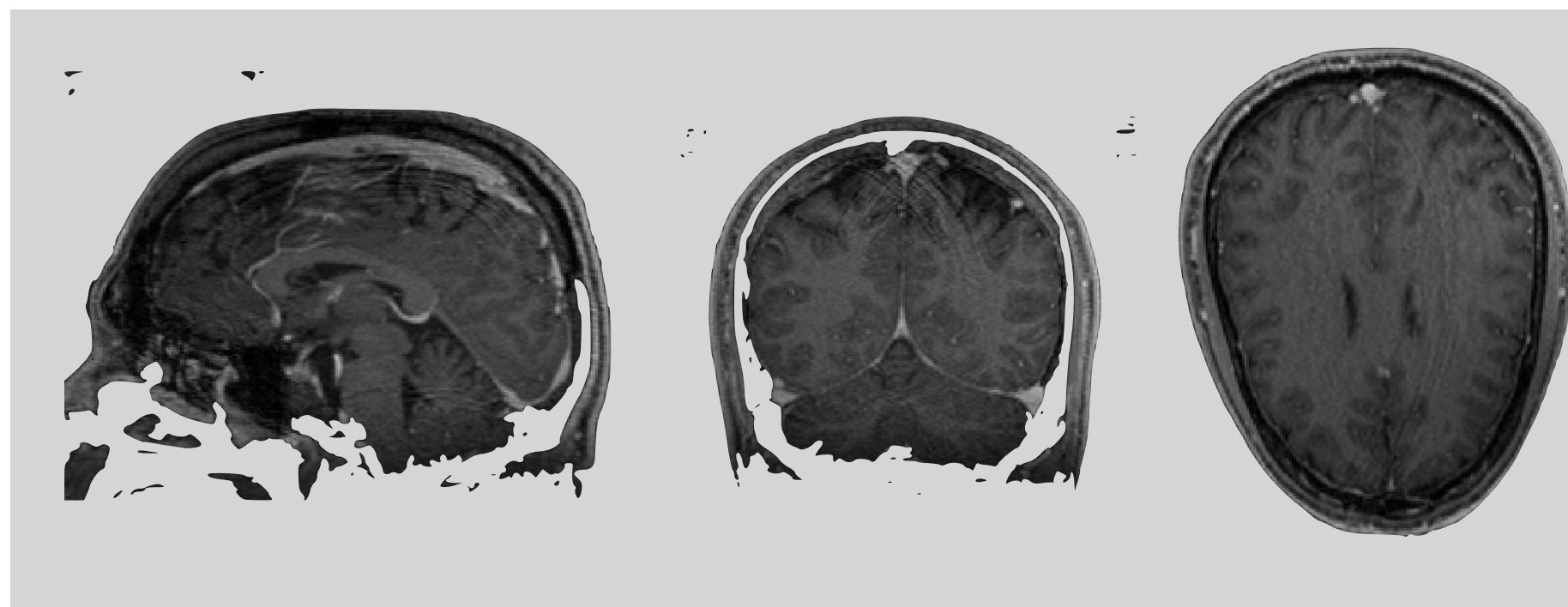
Post-ictal CT in RAS Space

sub-RID0117_ses-clinical01_acq-3D_space-T01ct_ct_ras.nii.gz



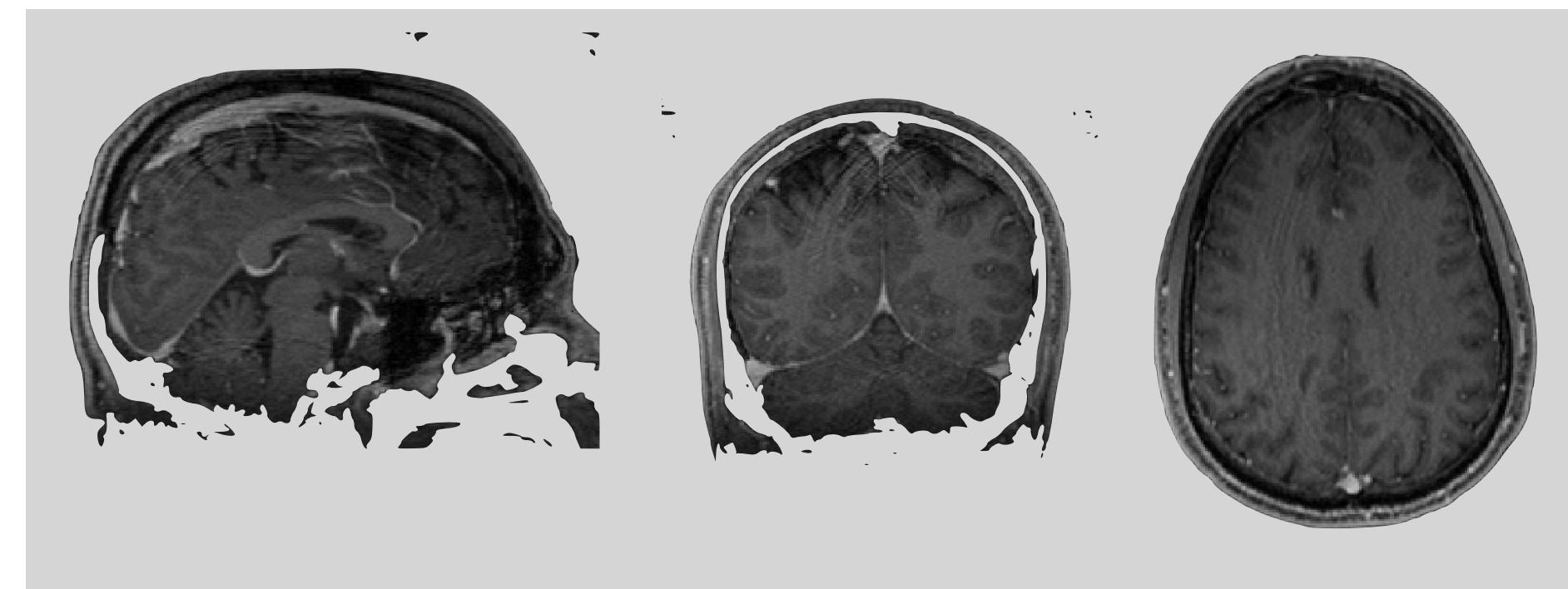
Reference MRI

sub-RID0117_ses-clinical01_acq-3D_space-T00mri_T1w.nii.gz



Reference MRI in RAS Space

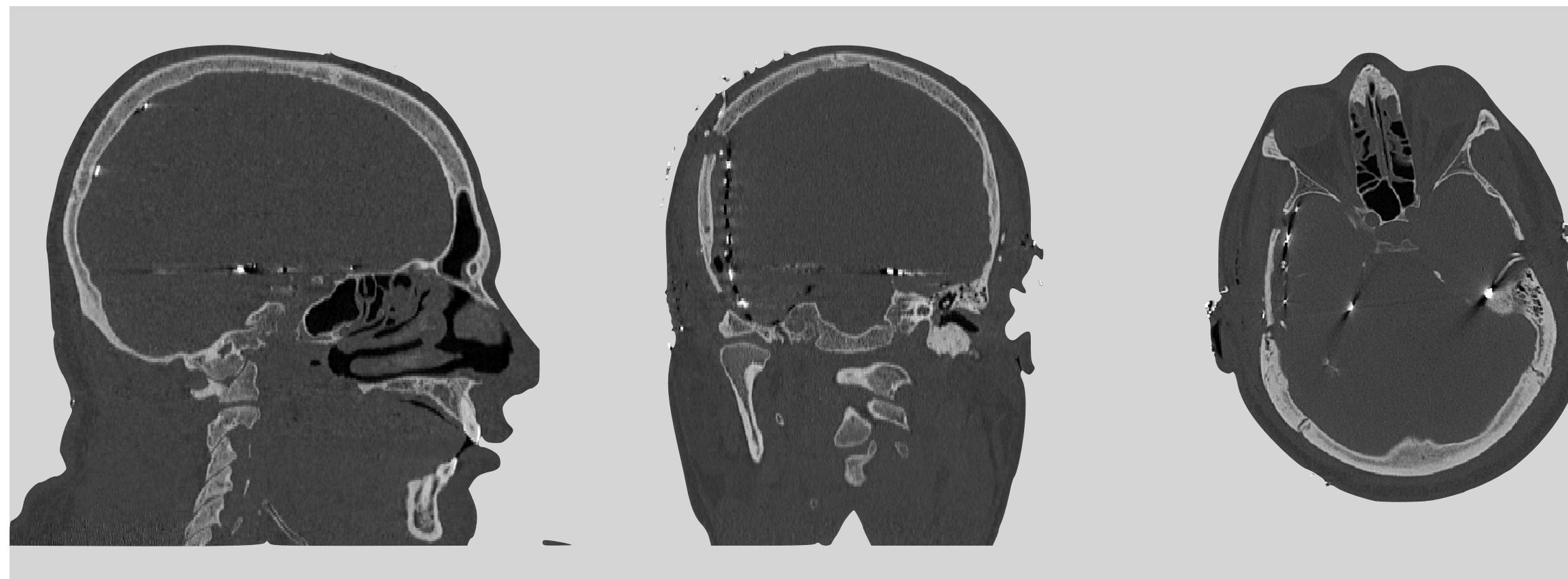
sub-RID0117_ses-clinical01_acq-3D_space-T00mri_T1w_ras.nii.gz



Module 2 - Step 2: Intensity Thresholding the CT

Post-ictal CT in RAS Space

sub-RID0117_ses-clinical01_acq-3D_space-T01ct_ct_ras.nii.gz



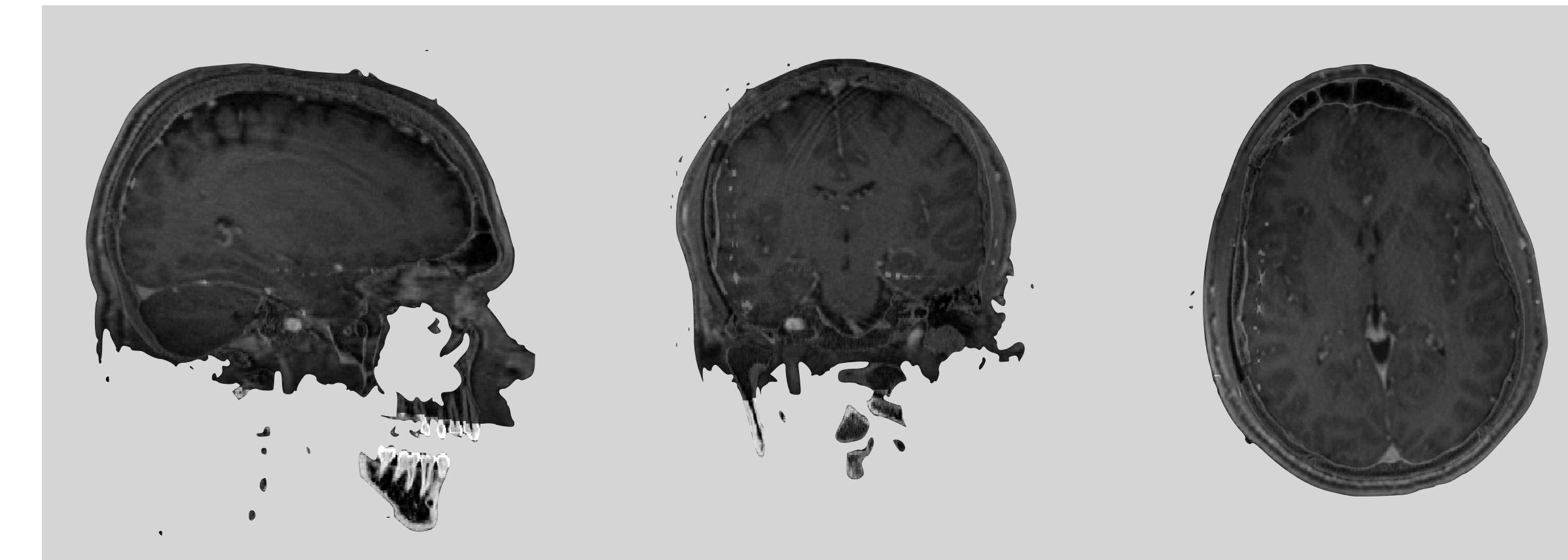
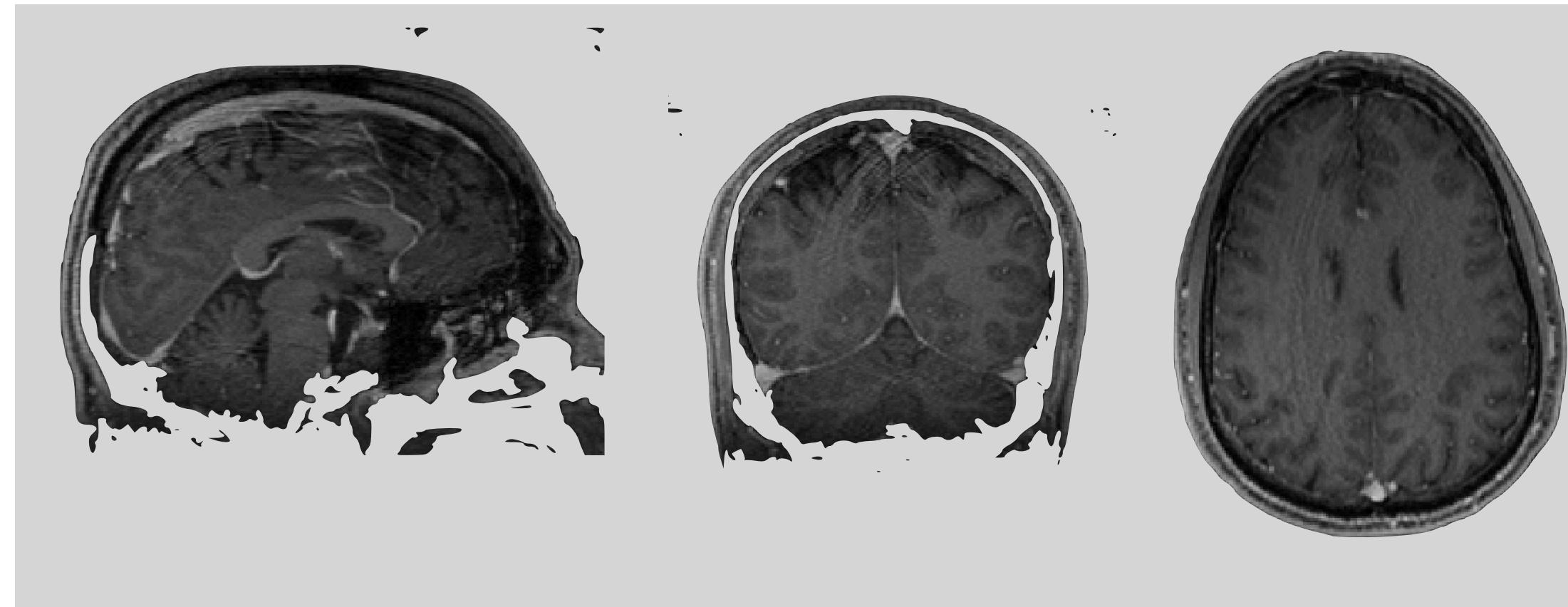
Thresholded post-ictal CT in RAS Space

sub-RID0117_ses-clinical01_acq-3D_space-T01ct_ct_ras_thresholded.nii.gz



Module 2 - Step 3: Registering CT and MRI

sub-RID0117_ses-clinical01_acq-3D_space-T00mri_T1w_ras.nii.gz



sub-RID0117_ses-clinical01_acq-3D_space-T01ct_ct_ras_thresholded.nii.gz



MRI in CT Space:

sub-RID0117_ses-clinical01_acq-3D_space-T01ct_T1w.nii.gz

CT in MRI Space:

sub-RID0117_ses-clinical01_acq-3D_space-T00mri_ct_thresholded.nii.gz

Transforms:

sub-RID0117_ses-clinical01_T01ct_to_T00mri.mat

sub-RID0117_ses-clinical01_T00mri_to_T01ct.mat

Module 2 - Step 4: Applying Transform to Coordinates

Electrode Coordinates in CT Space - Voxel Space (output of VoxTool - Module 1)

sub-RID0117_ses-clinical01_space-T01ct_desc-vox_electrodes.txt

1	LAT1	315	200	112	S	4	1
2	LAT2	324	215	108	S	4	1
3	LAT3	341	226	106	S	4	1
4	LAT4	360	230	109	S	4	1
5	LDA1	306	233	127	D	4	1
6	LDA2	315	232	125	D	4	1
7	LDA3	325	232	124	D	4	1
8	LDA4	335	231	123	D	4	1
9	LDH1	324	257	125	D	4	1
10	LDH2	333	254	124	D	4	1
11	LDH3	343	252	124	D	4	1
12	LDH4	353	251	124	D	4	1
13	LPT1	335	311	131	S	4	1
14	LPT2	346	296	125	S	4	1
15	LPT3	356	282	121	S	4	1



Electrode Coordinates in MRI Space - Voxel Space

sub-RID0117_ses-clinical01_space-T00mri_desc-vox_electrodes.txt

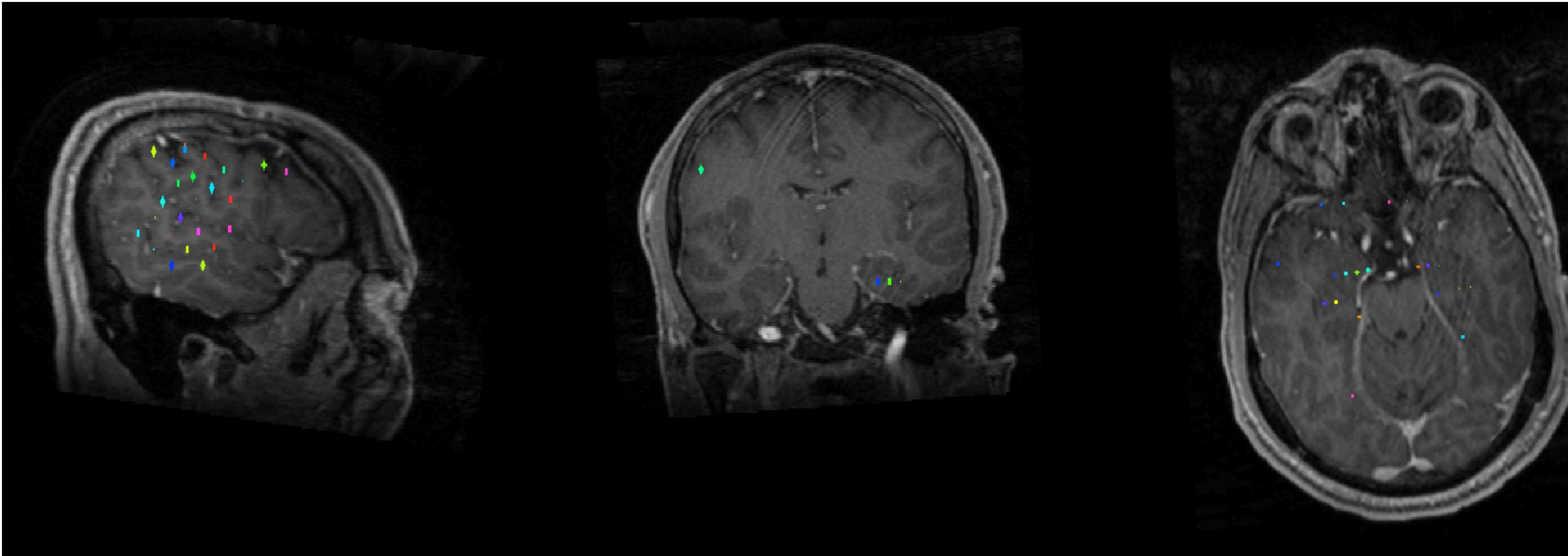
Electrode Coordinates in MRI Space - mm Space

sub-RID0117_ses-clinical01_space-T00mri_desc-mm_electrodes.txt

Module 2: Visualization Tools

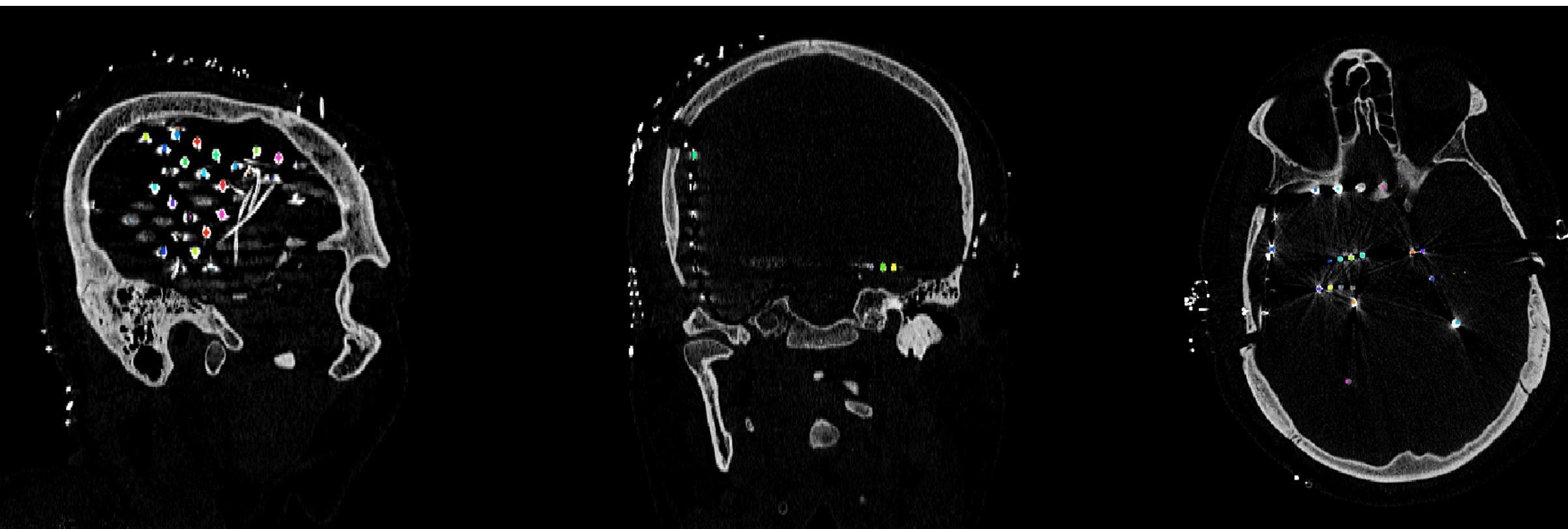
Electrode Spheres in MRI Space

sub-RID0117_ses-clinical01_acq-3D_space-T00mri_T1w_ras_electrode_spheres.nii.gz



Electrode Spheres in CT Space

sub-RID0117_ses-clinical01_acq-3D_space-T01ct_ct_ras_electrode_spheres.nii.gz



ITK-SNAP Labels File

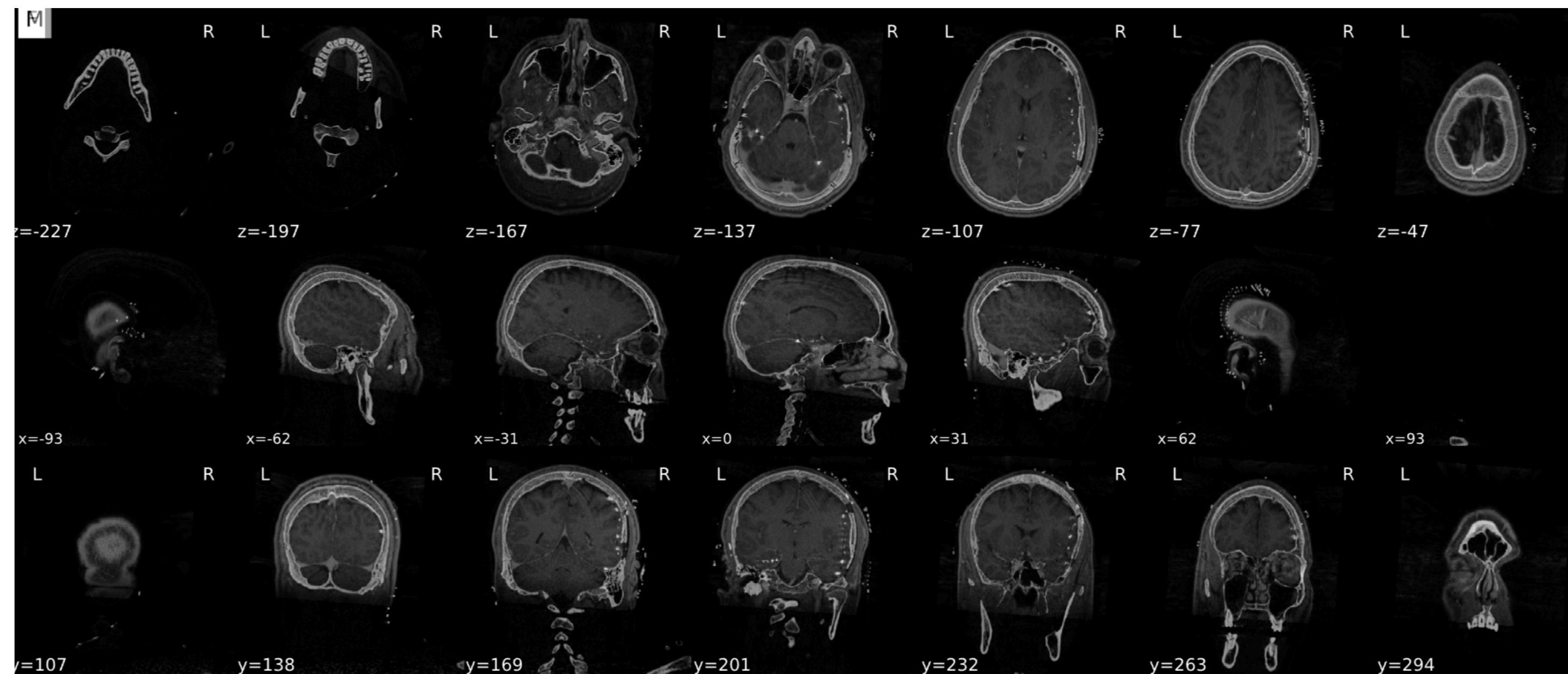
sub-RID0117_ses-clinical01_space-T01ct_desc-vox_electrodes_itk_snap_labels.txt

```
1 #####
2 # ITK-SnAP Label Description File
3 # File format:
4 # IDX -R- -G- -B- -A-- VIS MSH LABEL
5 # Fields:
6 #   IDX: Zero-based index
7 #   -R-: Red color component (0..255)
8 #   -G-: Green color component (0..255)
9 #   -B-: Blue color component (0..255)
10 #  -A-: Label transparency (0.00 .. 1.00)
11 #   VIS: Label visibility (0 or 1)
12 #   IDX: Label mesh visibility (0 or 1)
13 #   LABEL: Label description
14 #####
15 #####
16 0 0 0 0 0 0 0 "Clear Label"
17 1 94 199 104 1 1 1 "LAT1"
18 2 57 46 112 1 1 1 "LAT2"
19 3 198 51 1 1 1 1 "LAT3"
20 4 51 235 144 1 1 1 "LAT4"
21 5 63 233 234 1 1 1 "LDA1"
22 6 47 39 106 1 1 1 "LDA2"
23 7 99 48 184 1 1 1 "LDA3"
24 8 94 3 102 1 1 1 "LDA4"
```

Module 2: Visualization Tools

Registration SVG Report

sub-RID0117_ses-clinical01_T00mri_T01ct_registration.svg

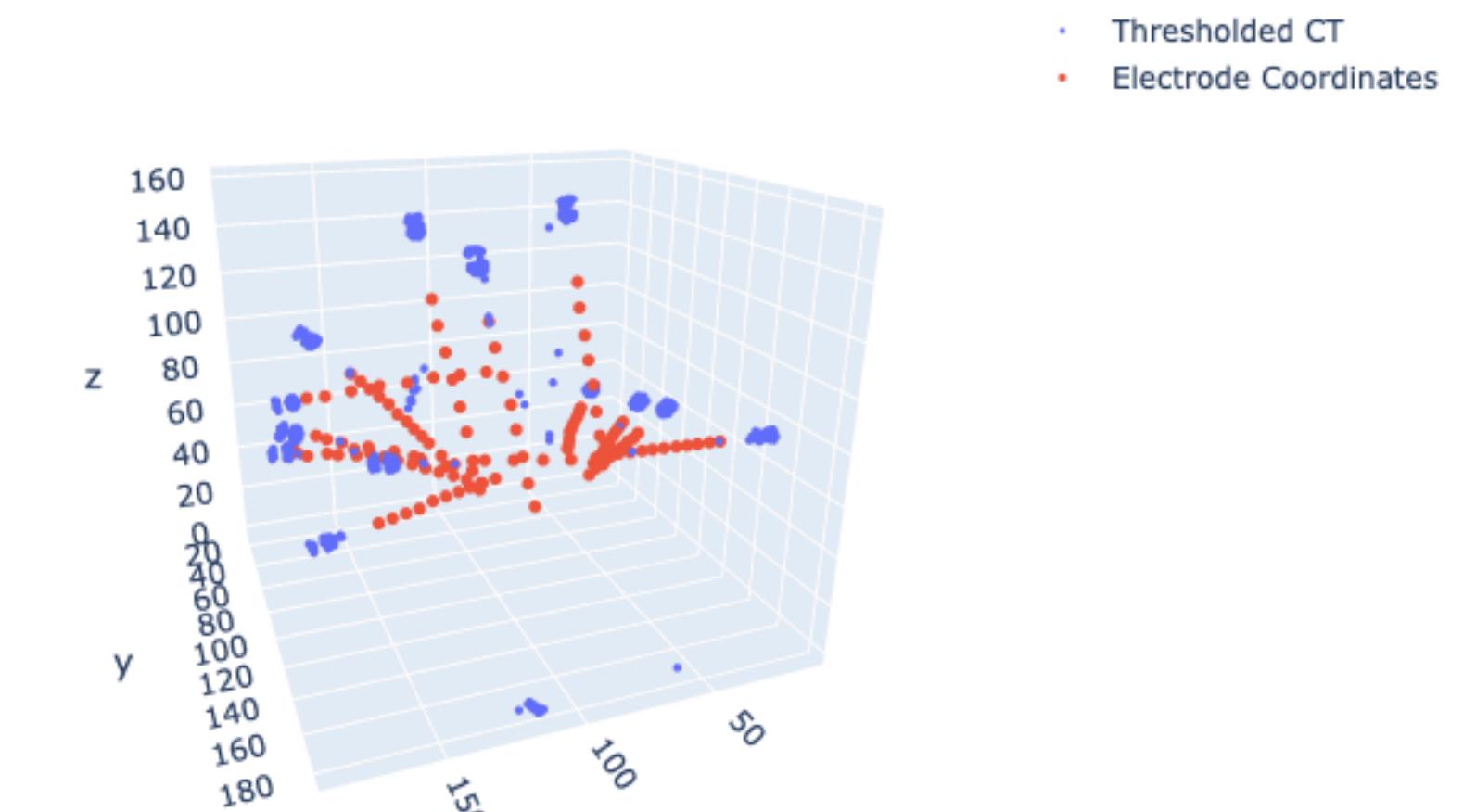


file:///Users/allucas/Documents/research/CNT/P33_ieeg_recon/source_data/sample_bids/sub-RID0117/derivatives/ieeg_recon/clinical_module/sub-RID0117_ses-clinical01_T00mri_T01ct_registration.svg

Electrode and Thresholded CT Scatterplot

sub-RID0117_ses-clinical01_space-T00mri_desc-mm_electrodes_plot.html

sub-RID0031 - Electrode Scatterplot (vox)



Note:

This scatterplot is in MRI mm space, therefore if everything aligns here, all the other steps in the pipeline worked successfully

Module 3 - Overview

Command:

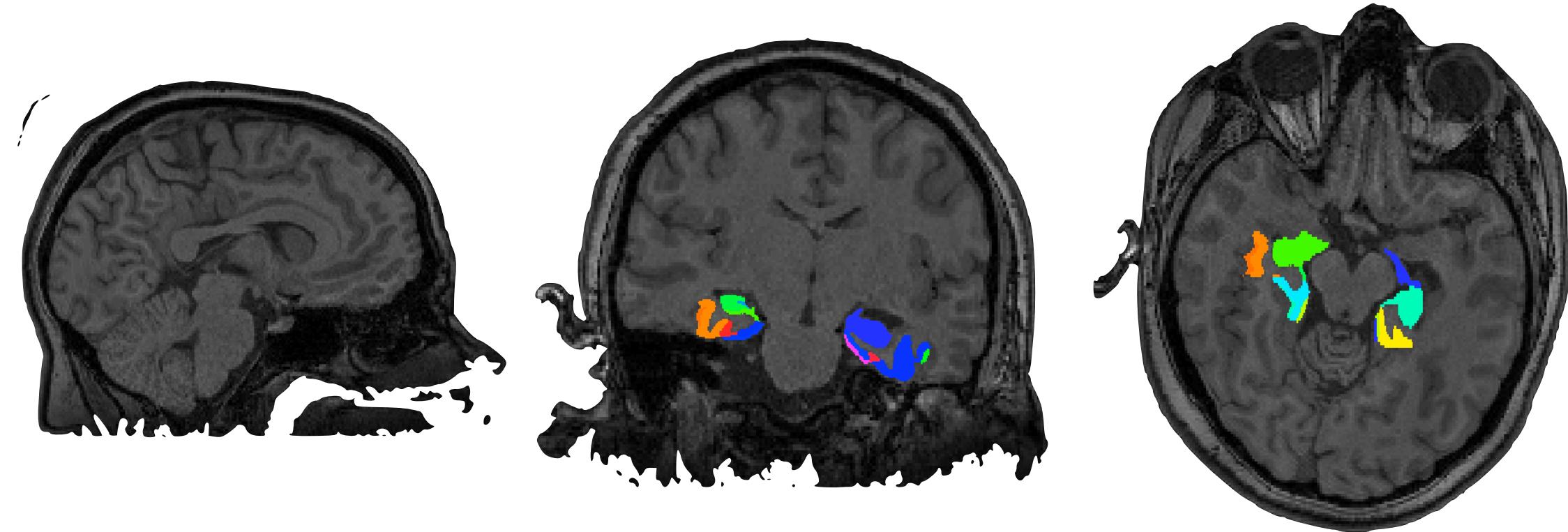
```
ieeg_recon -s sub-RID0031 -m 3 -d /BIDS -a aparc+aseg.vep.nii.gz -an  
VEP -ri DKTatlas+aseg+VEP_indices.txt -rl  
DKTatlas+aseg+VEP_labels.txt -r 2 -rs ses-research3T
```

Arguments:

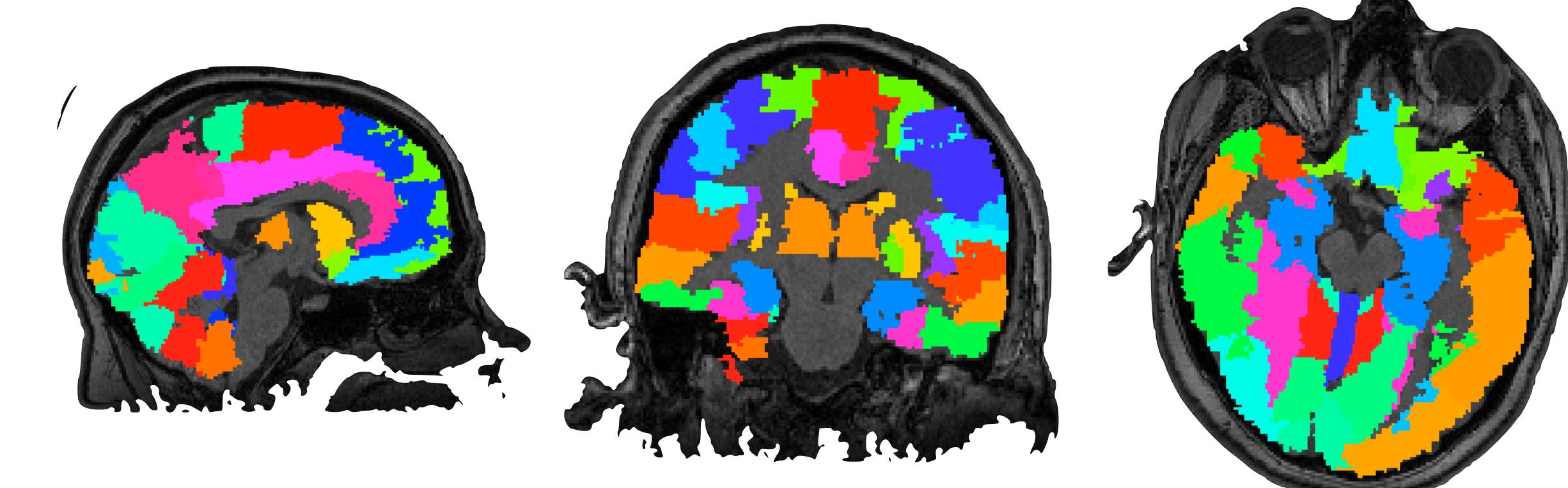
- s: subject ID
- m: Module number
- d: Path to BIDS directory containing all subjects
- a: Path to NIFTI file with subject specific segmentation
- an: Name of atlas/subject specific segmentation (used to name output)
- ri: Path to textfile with ROI indices
- rl: Path to textfile with ROI labels
- r: Radius (in mm) of sphere used to localize electrode
- rs: Name of session with reference MRI

Module 3 - Inputs Explained: Any atlas registered to the reference MRI works - Just provide the path

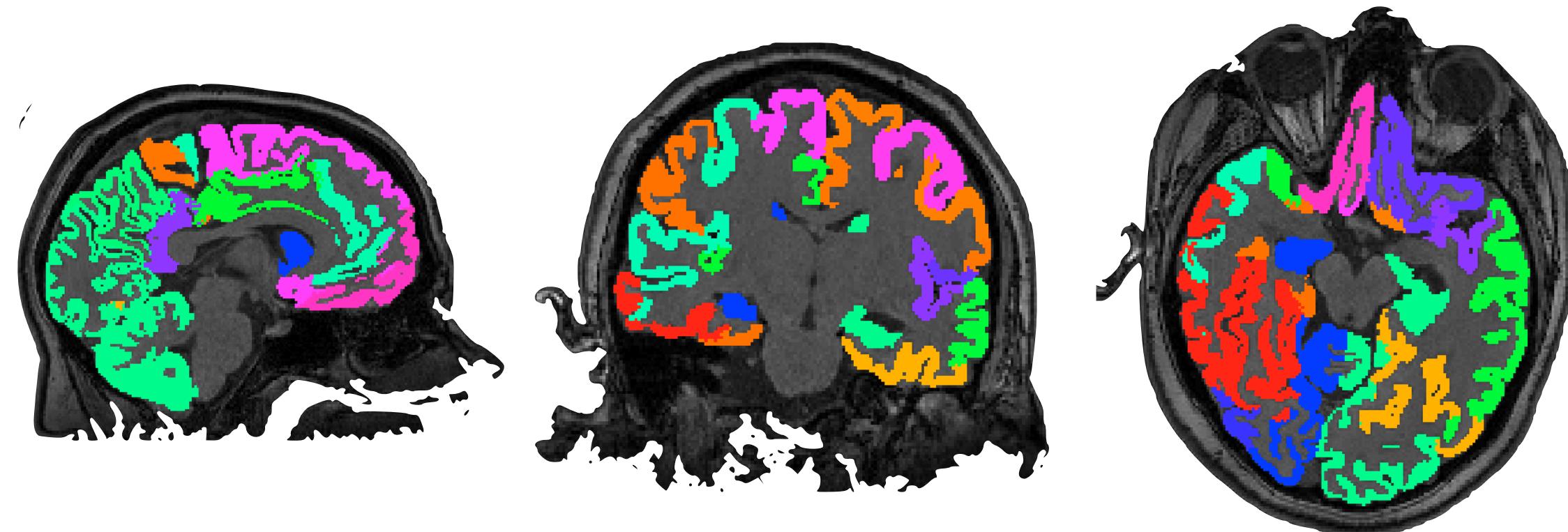
Hippocampal Segmentation from ASHS



AAL atlas registered to input MRI



Cortical and Subcortical VEP Parcellation from FreeSurfer



Module 3 - Inputs Explained

Atlas Lookup Table

ROI Indices

-ri: DKTatlas+aseg+VEP_indices.txt

```
0  
71001  
71002  
71003  
71004  
71005  
71006  
71007  
71008  
71009  
71010  
...
```

ROI Labels

-rl: DKTatlas+aseg+VEP_labels.txt

```
Empty-Label  
Left-Frontal-pole  
Left-Orbito-frontal-cortex  
Left-Gyrus-rectus  
Left-F3-Pars-Orbitalis  
Left-F3-Pars-triangularis  
Left-F3-pars-opercularis  
Left-Inferior-frontal-sulcus  
Left-F2-rostral  
Left-F2-caudal  
Left-Middle-frontal-sulcus  
...
```

Module 3 - Alternative: .csv file has the lookup table - Use the -lut flag

Command:

```
ieeg_recon -s sub-RID0031 -m 3 -d /BIDS -a aparc+aseg.vep.nii.gz -an  
VEP -lut DKTatlas+aseg+VEP_lut.csv -r 2 -rs ses-research3T
```

Arguments:

- s: subject ID
- m: Module number
- d: Path to BIDS directory containing all subjects
- a: Path to NIFTI file with subject specific segmentation
- an: Name of atlas/subject specific segmentation (used to name output)
- lut: Path to .csv file with atlas ROI values and labels
- r: Radius (in mm) of sphere used to localize electrode
- rs: Name of session with reference MRI

Module 3 - Inputs Explained

Atlas Lookup Table

ROI Indices and Labels (there should be no headers)

-lut: DKTatlas+aseg+VEP_lut.csv

```
0,Empty-Label
71001,Left-Frontal-pole
71002,Left-Orbito-frontal-cortex
71003,Left-Gyrus-rectus
71004,Left-F3-Pars-Orbitalis
71005,Left-F3-Pars-triangularis
71006,Left-F3-pars-opercularis
71007,Left-Inferior-frontal-sulcus
71008,Left-F2-rostral
71009,Left-F2-caudal
71010,Left-Middle-frontal-sulcus
71011,Left-SFS-rostral
```

Module 3 - Outputs

sub-RID0031_space-T00mri_atlas-VEP_radius-2_desc-
vox_coordinates.txt

```
LB10 36.3397 83.9124 58.2533 71046.0 Left-T2-posterior  
LC1 72.5176 106.447 60.0058 71074.0 Left-Hippocampus-posterior  
LC2 69.8773 101.535 59.8237 71074.0 Left-Hippocampus-posterior  
LC3 67.6056 97.1863 59.922 5.0 Left-Inf-Lat-Vent  
LC4 65.3035 92.3532 60.9107 2.0 Left-Cerebral-White-Matter  
LC5 62.6935 87.9258 59.8381 2.0 Left-Cerebral-White-Matter  
LC6 59.9188 83.4639 59.8672 2.0 Left-Cerebral-White-Matter
```

sub-RID0031_space-T00mri_atlas-ASHS_radius-2_desc-
vox_coordinates.txt

```
LB10 36.3397 83.9124 58.2533 0.0 "Clear-Label"  
LC1 72.5176 106.447 60.0058 2.0 "Left-Posterior-hippocampus"  
LC2 69.8773 101.535 59.8237 2.0 "Left-Posterior-hippocampus"  
LC3 67.6056 97.1863 59.922 0.0 "Clear-Label"  
LC4 65.3035 92.3532 60.9107 0.0 "Clear-Label"  
LC5 62.6935 87.9258 59.8381 0.0 "Clear-Label"  
LC6 59.9188 83.4639 59.8672 0.0 "Clear-Label"
```

sub-RID0031_space-T00mri_atlas-AAL116_radius-2_desc-
vox_coordinates.txt

```
LB10 36.3397 83.9124 58.2533 8201.0 Temporal_Mid_L  
LC1 72.5176 106.447 60.0058 4101.0 Hippocampus_L  
LC2 69.8773 101.535 59.8237 4101.0 Hippocampus_L  
LC3 67.6056 97.1863 59.922 0.0 Empty-Label  
LC4 65.3035 92.3532 60.9107 0.0 Empty-Label  
LC5 62.6935 87.9258 59.8381 0.0 Empty-Label  
LC6 59.9188 83.4639 59.8672 8201.0 Temporal_Mid_L
```

Running Module 2 and 3

Command:

Change module to -1

```
ieeg_recon -s sub-RID0031 -m -1 -cs ses-clinical01 -rs ses-
research3T -d /BIDS -a aparc+aseg.vep.nii.gz -an VEP -ri
DKTatlas+aseg+VEP_indices.txt -rl DKTatlas+aseg+VEP_labels.txt -r 2
```

Installing the Docker Module

Command:

```
docker pull lucasalf11/ieeg_recon
```

Running the Docker Command - Module 2

Original Command:

```
ieeg_recon -s sub-RID0031 -m  
2 -cs ses-clinical01 -rs  
ses-research3T -d /BIDS
```

Docker Command:

```
docker run \  
-v /BIDS:/source_data \  
lucasalf11/ieeg_recon \  
-s sub-RID0031 \  
-m 2 \  
-cs ses-clinical01 \  
-rs ses-research3T \  
-d /source_data
```

Note that the only difference between the original command and the docker command is that the local BIDS directory is mounted into a folder within the container called /source_data, and this then becomes the input to -d

Things that the user would have to change are underlined

Running the Docker Command - Module 3

Original Command:

```
ieeg_recon -s sub-RID0031 -m 3 -d /BIDS  
-a aparc+aseg.vep.nii.gz -an VEP -ri  
DKTatlas+aseg+VEP_indices.txt -rl  
DKTatlas+aseg+VEP_labels.txt -r 2 -rs  
ses-research3T
```

Docker Command:

```
docker run \  
-v DKTatlas+aseg+VEP_labels.txt:/atlas_files/labels.txt \  
-v DKTatlas+aseg+VEP_indices.txt:/atlas_files/indices.txt \  
-v aparc+aseg.vep.nii.gz:/atlas_files/atlas.nii.gz \  
-v /BIDS:/source_data \  
lucasalf11/ieeg_recon \  
-s sub-RID0031 \  
-m 3 \  
-an AAL116 \  
-r 2 \  
-rs ses-research3T \  
-d /source_data \  
-a /atlas_files/atlas.nii.gz \  
-ri /atlas_files/indices.txt \  
-rl /atlas_files/labels.txt
```

Things that the user would have to change are underlined

Docker to Singularity Command Look-Up Table

Note: all singularity commands must be run from the folder where you initially call “singularity pull”

<code>docker pull lucasalf11/ieeg_recon</code>	→ <code>singularity pull docker://lucasalf11/ieeg_recon</code>
replace: <code>docker run</code>	→ with: <code>singularity run</code>
replace: <code>-v</code>	→ with: <code>-B</code>
replace: <code>lucasalf11/ieeg_recon</code>	→ with: <code>ieeg_recon_latest.sif</code>

Example:

```
docker run \
-v /BIDS:/source_data \
lucasalf11/ieeg_recon \
-s sub-RID0031 \
-m 2 \
-cs ses-clinical01 \
-rs ses-research3T \
-d /source_data
```

→

```
singularity run \
-B /BIDS:/source_data \
ieeg_recon_latest.sif \
-s sub-RID0031 \
-m 2 \
-cs ses-clinical01 \
-rs ses-research3T \
-d /source_data
```

Differences between commands are in **bold**