Stereoelectroencephalography

in Presurgical Evaluation of Focal Epilepsy

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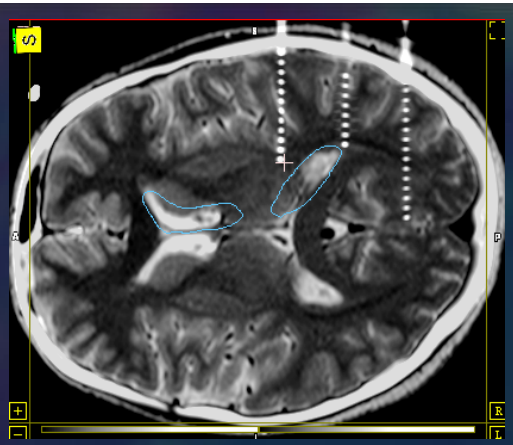
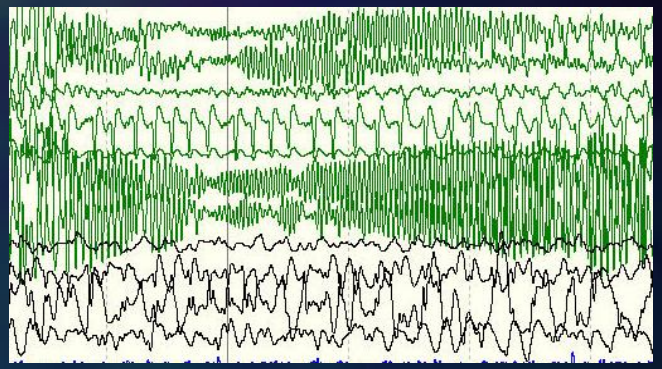
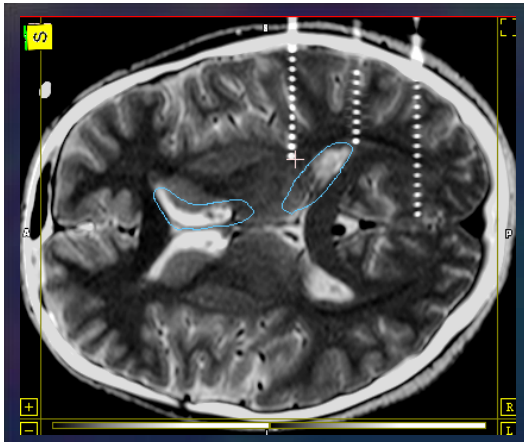




Why Stereoencephalography?

- The only technique that provides direct access to electrophysiological recordings in the seizure onset zone, when located in deep brain structures
- Allows determination of the depth of epileptogenic areas
- Requires insertion of depth electrodes (7-14)
- Electrode placement is achieved through stereotactic techniques



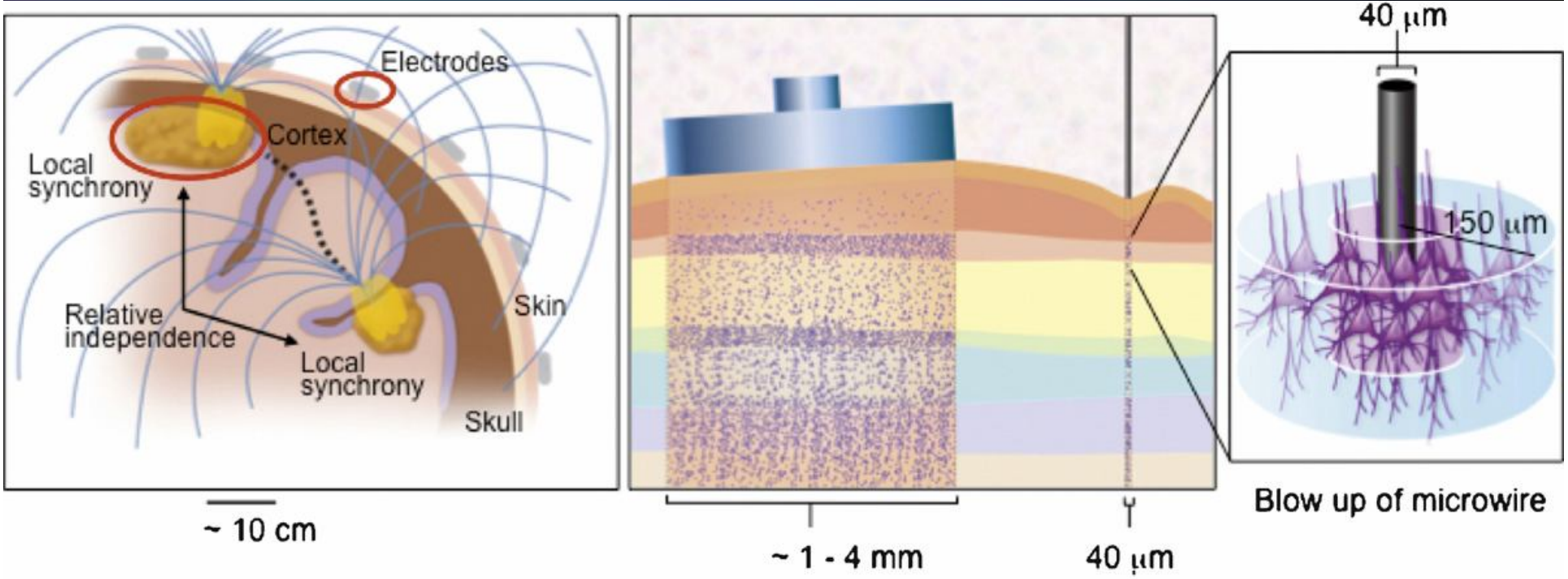
Stereotaxy

- Uses a 3D coordinate system to locate brain structures
- Requires a stereotactic positioning device
- Multi-modal imaging (CT, MRI, Angiography etc) that allows visualization of patient anatomy and co-registration with the stereotactic frame

Electroencephalographic depth recordings

- High specificity / spatial resolution
- High frequencies well evidenced
- Stable, no EMG artifacts

Spatial scale of scalp, cortical and depth recordings



- Scalp EEG requires a ~7cm^2 patch having synchronous activity
- ECoG and SEEG require ~10mm^2 of cortex
- Microwires, a sphere having R~150μm

After Worrell et al, Progress in Neurobiology, 2012

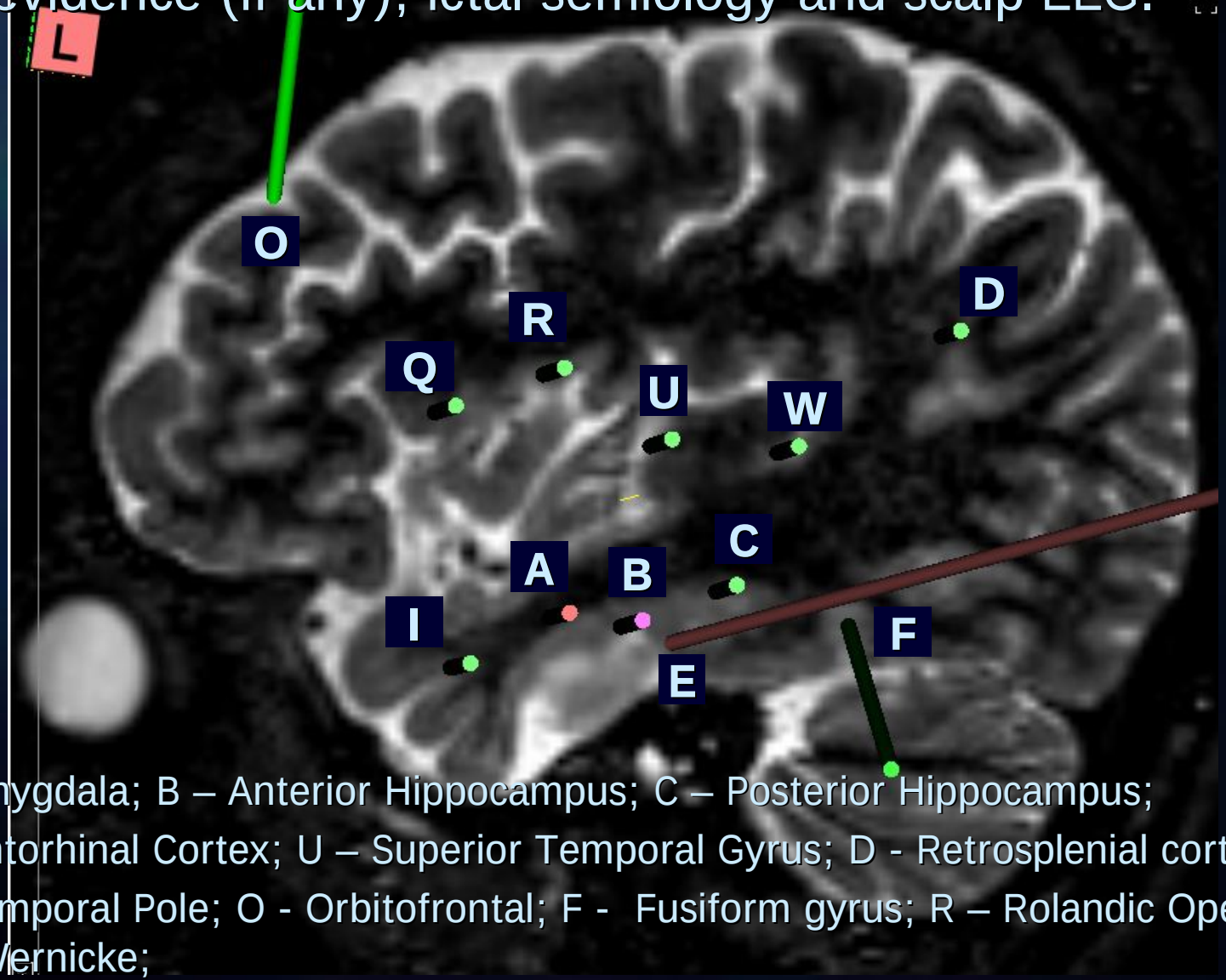
Goals of SEEG investigation

- Confirming that brain regions suspected of being involved in seizure onset and propagation show the expected ictal pattern.
- Delineating the border of the epileptogenic zone as precisely as possible, to perform the minimum cortical resection.
- Assessing whether the complete removal of the epileptogenic zone will be possible or not by performing stimulation mapping of the eloquent areas.
- Evaluating the precise relationships between an anatomical lesion (when present) and the epileptogenic zone.

After Kahane et al, 2004

Implantation patterns

- Follow a certain hypothesis, based on the anatomical evidence (if any), ictal semiology and scalp EEG.

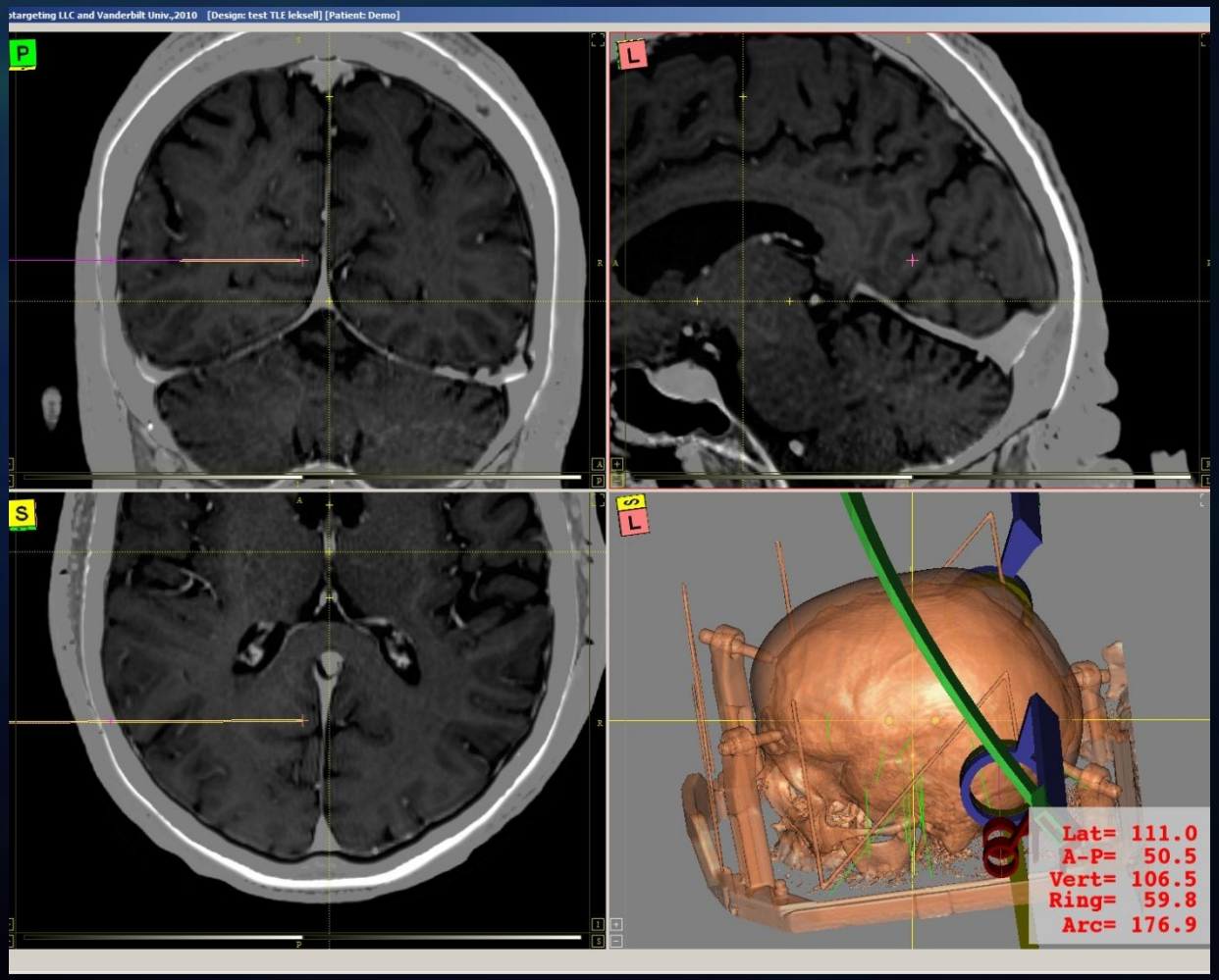


A - Amygdala; B – Anterior Hippocampus; C – Posterior Hippocampus;
E – Entorhinal Cortex; U – Superior Temporal Gyrus; D - Retrosplenial cortex;
I – Temporal Pole; O - Orbitofrontal; F - Fusiform gyrus; R – Rolandic Operculum;
W – Wernicke;

Stereotactic planning

Preoperative MRI with contrast

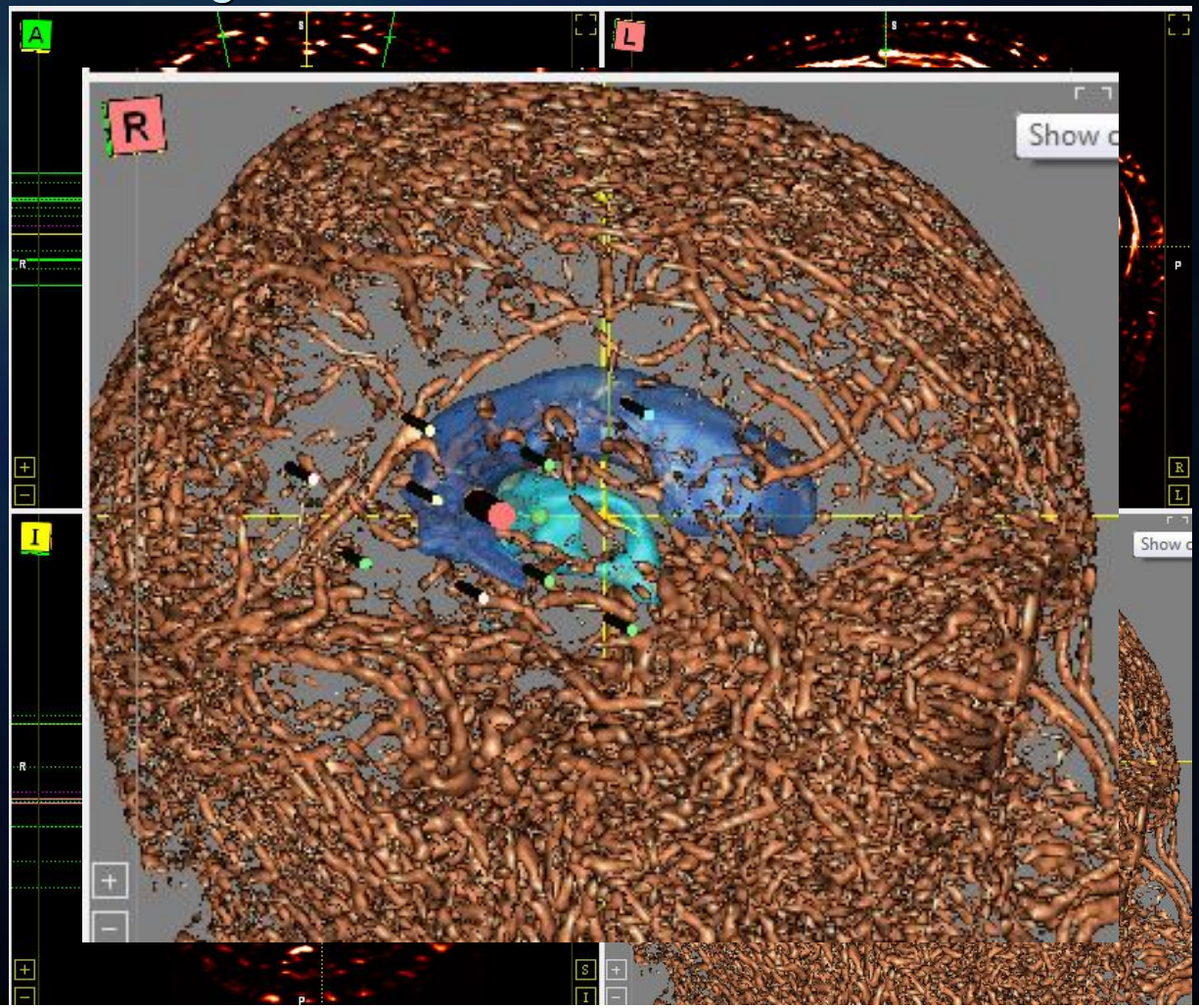
- Patient anatomy, vasculature



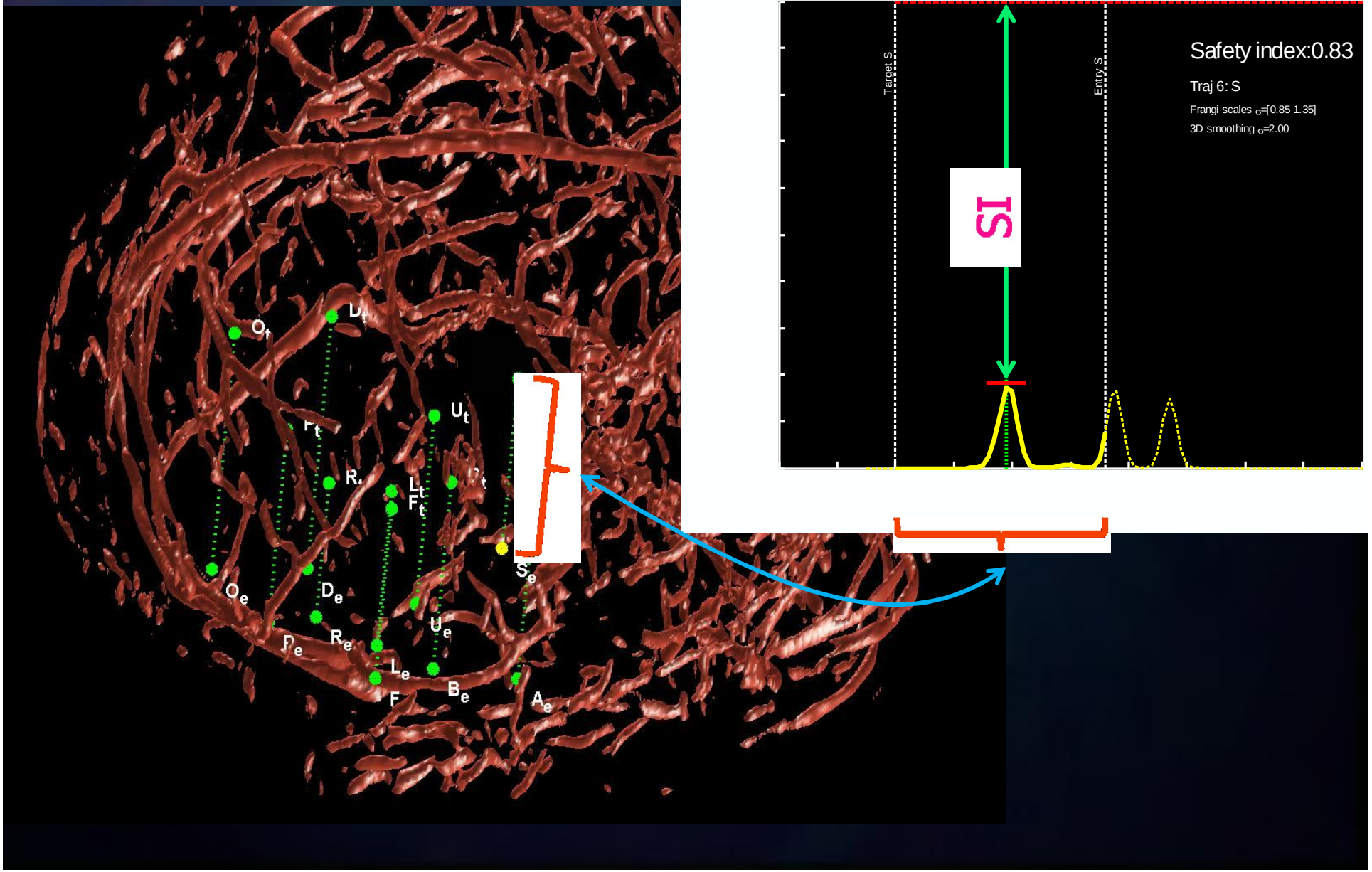
Stereotactic planning

Angiography

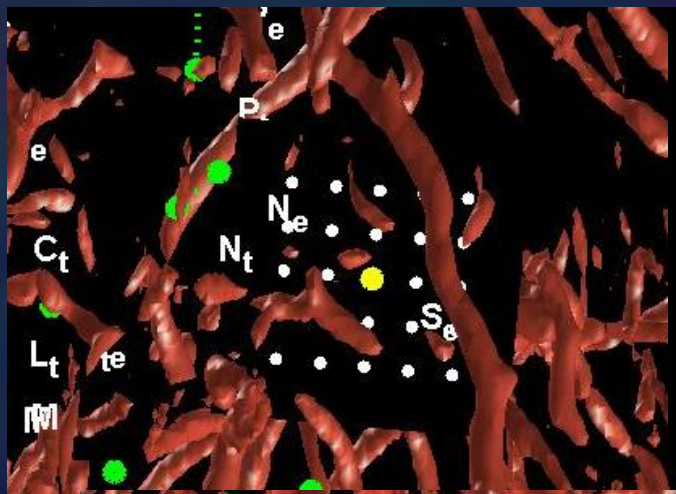
- Virtual angiography from contrast-enhanced MRI through3D Frangi vesselness filtering

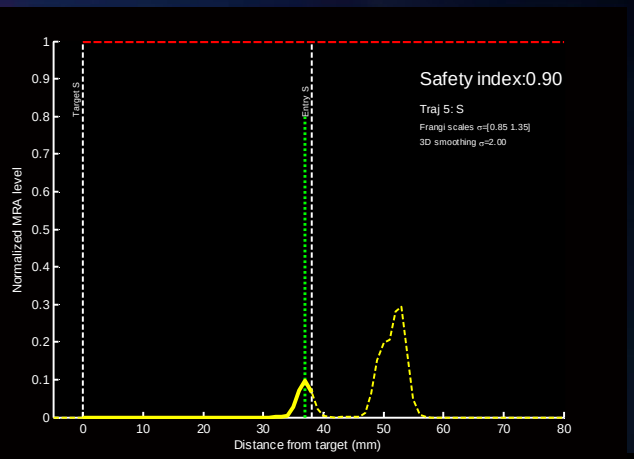


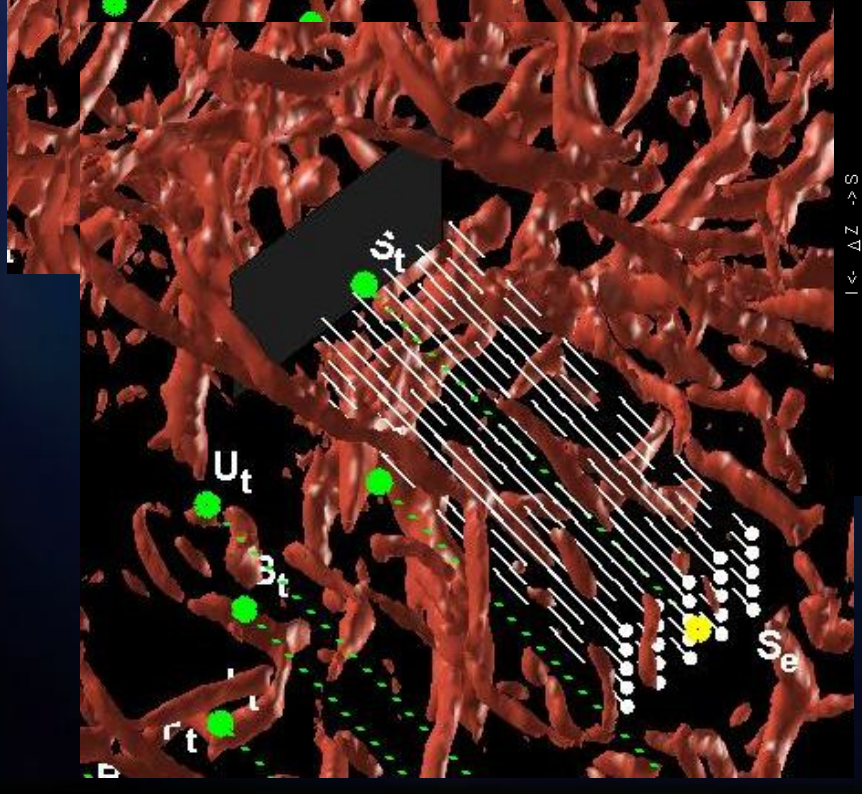
Safe electrode placement

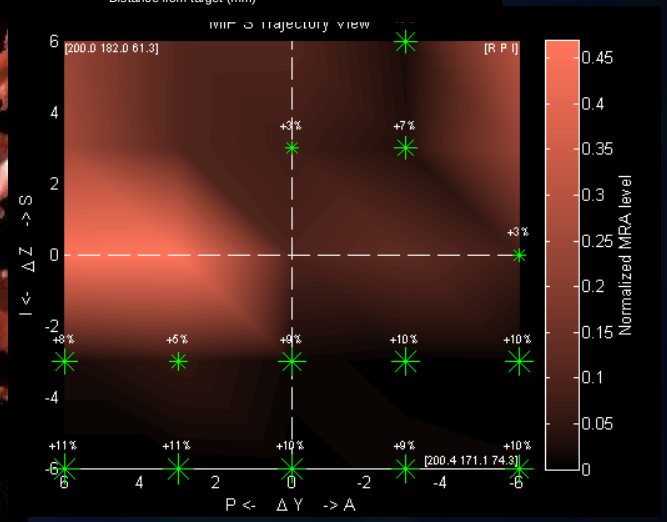


Safe electrode placement

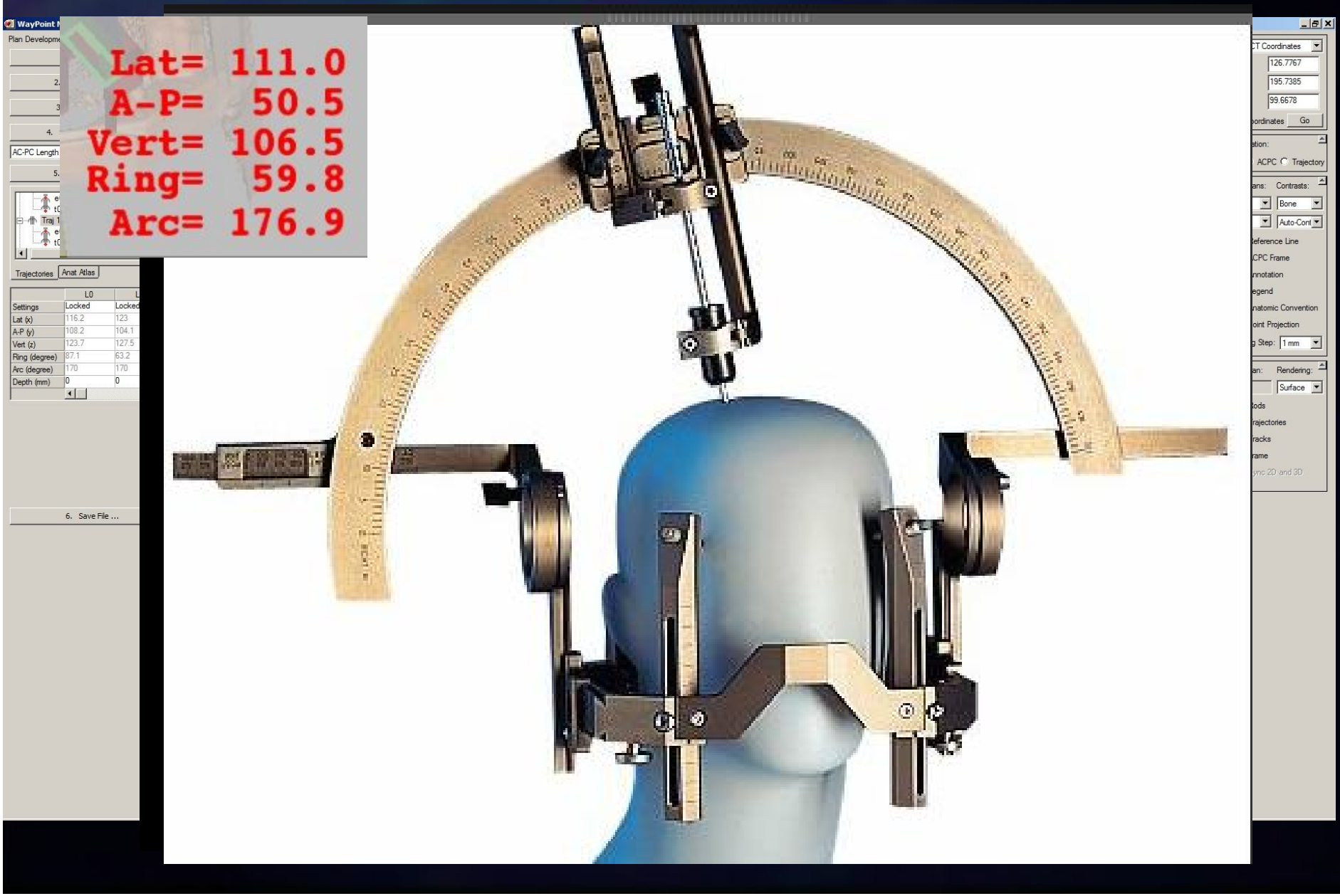






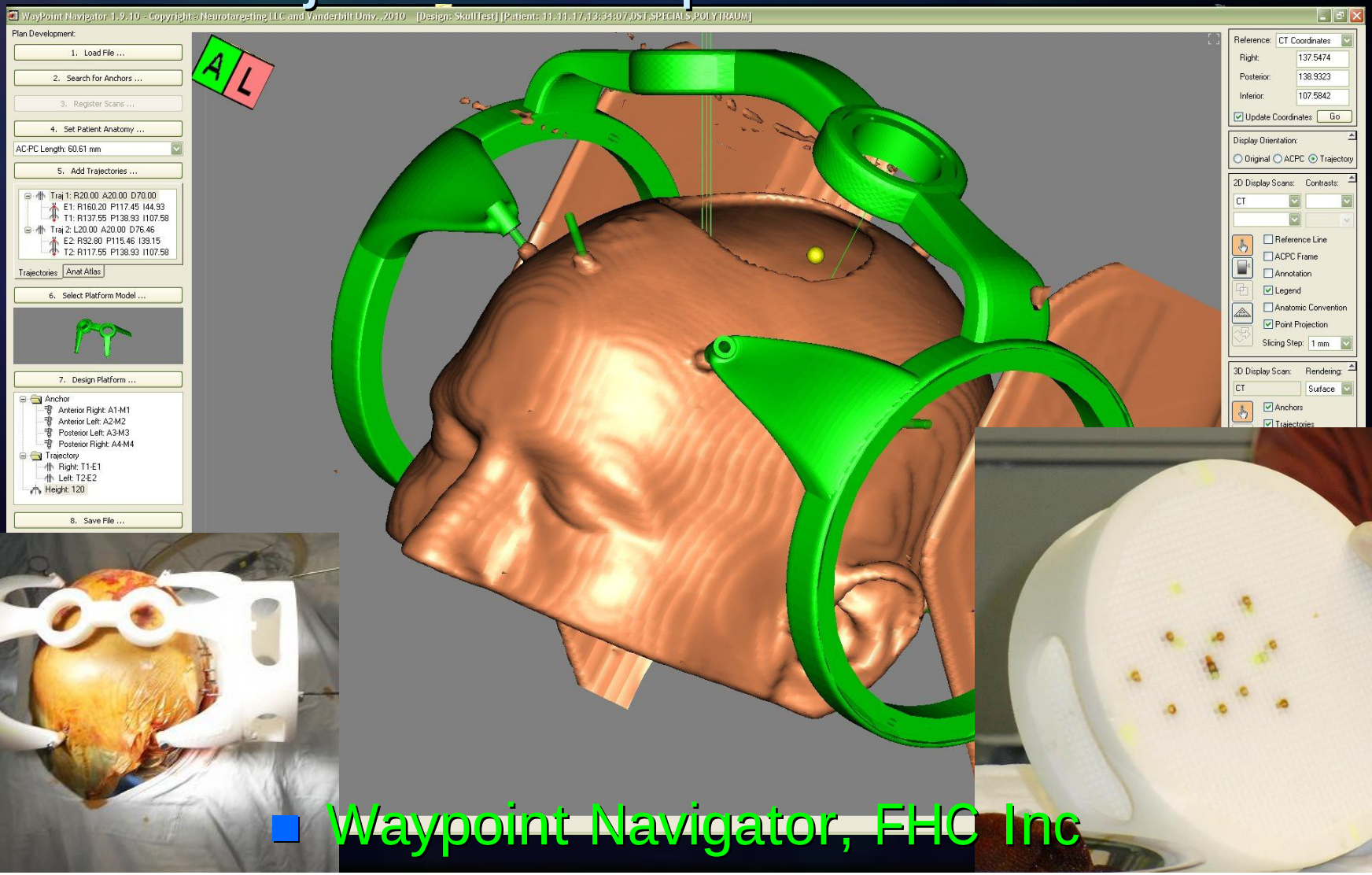


Stereotactic frame – Leksell



Stereotactic devices

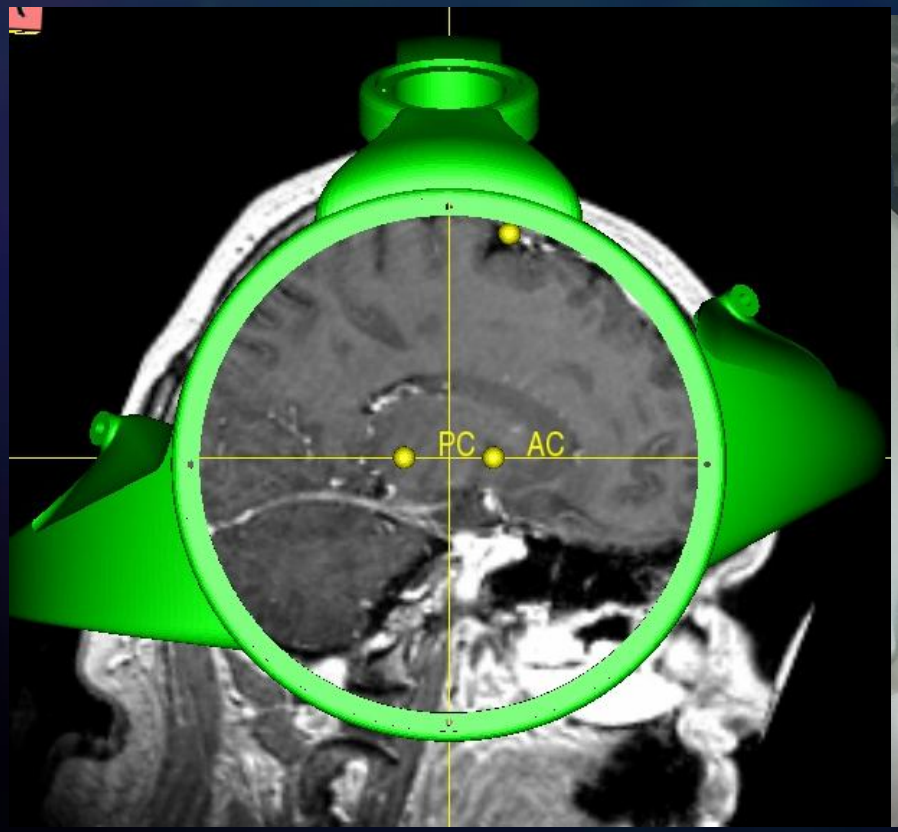
- StarFix techology, FHC Inc
- No adjustable components

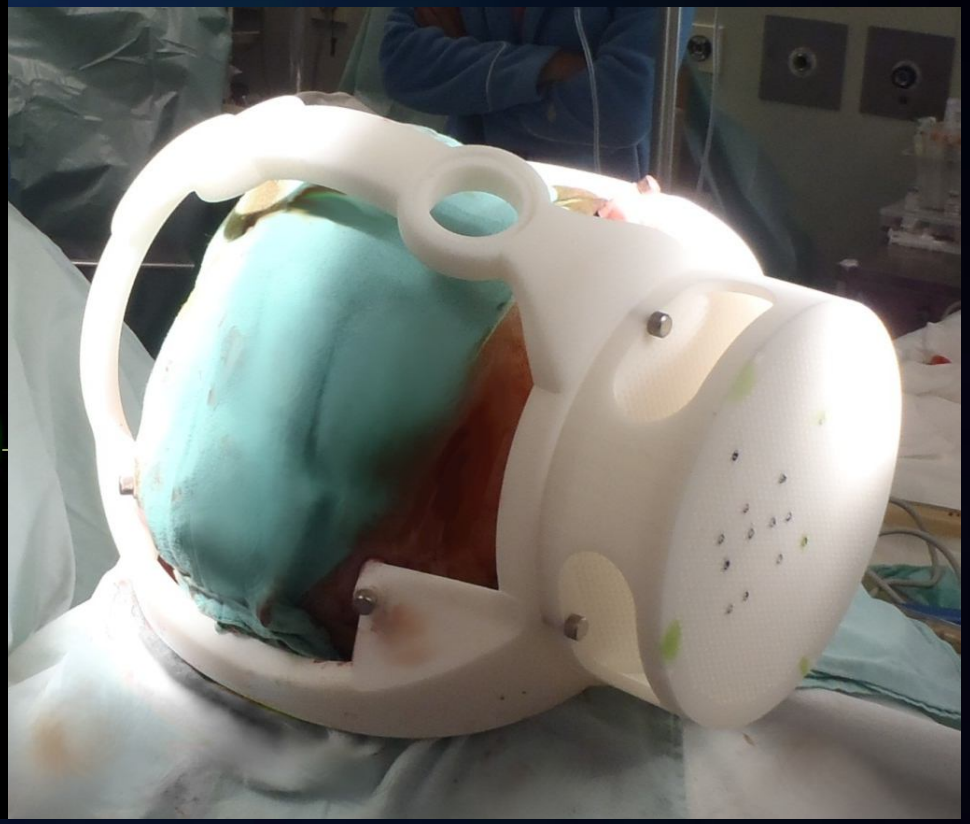


- Waypoint Navigator, FHC Inc

Stereotactic devices

- StarFix, personalized fixture



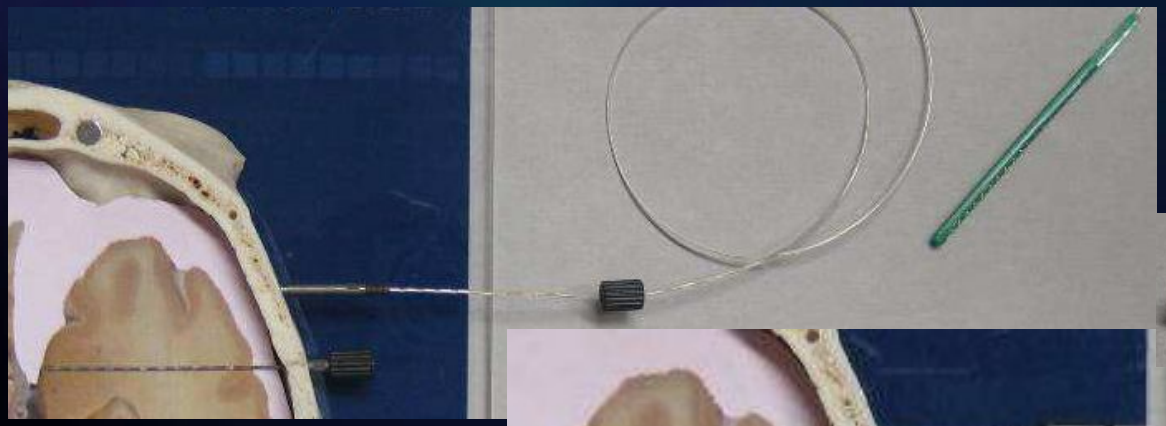


Personalized Stereotactic Frame

- Advantages:
  - Simplicity - no adjustable parts, thus minimizing risk of human error
  - Reduces OR time with a factor of two
  - Two-step procedure (anchor implant, actual surgery) spaced one to two weeks
  - Surgical planning can be performed in the generous interval between the two steps. It does not have to be performed the day of the surgery
  - Frame coordinates match anatomical coordinates (centered on MCP and aligned with mid-plane), making targeting more consistent across patients.

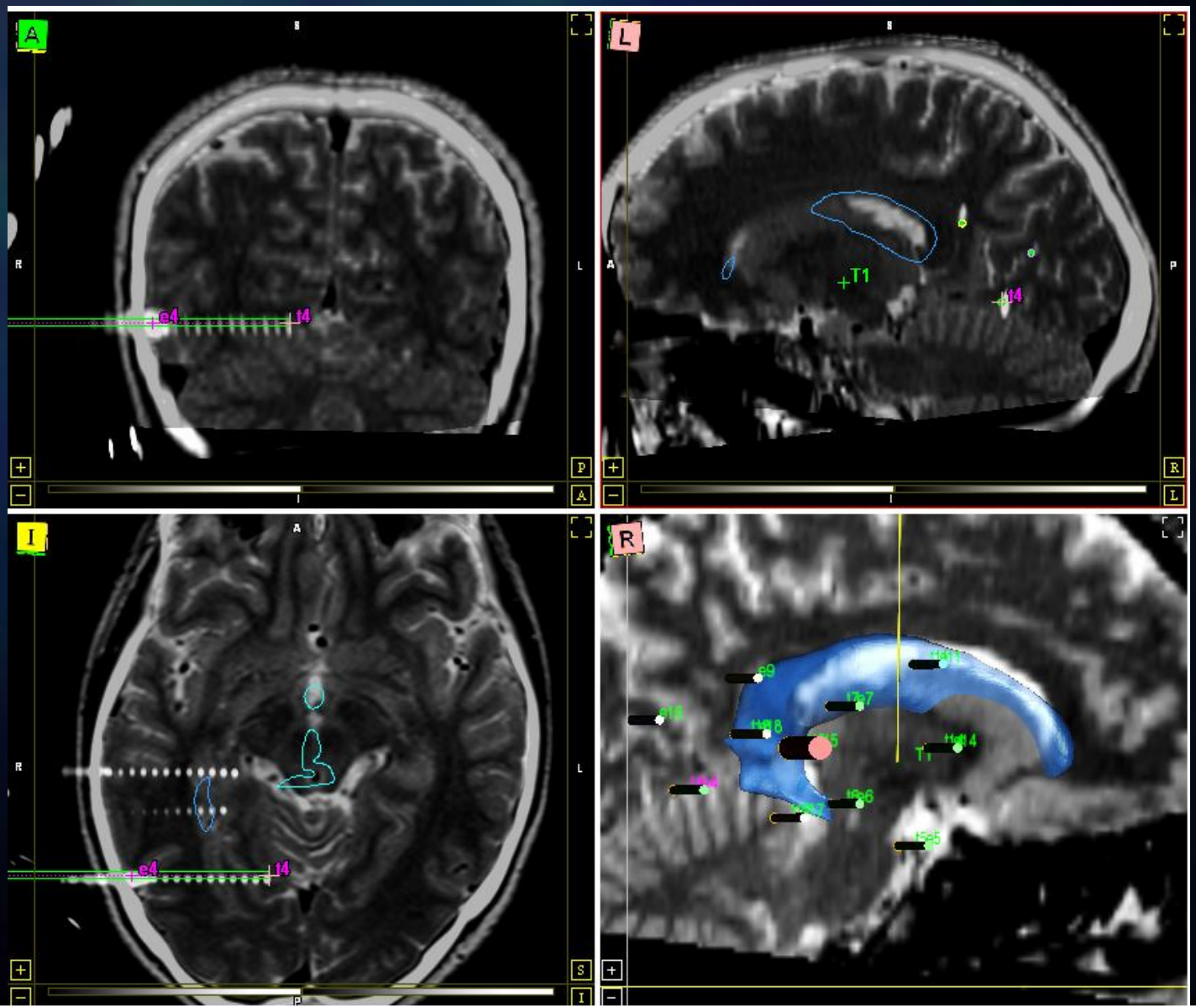
Electrode Implantation

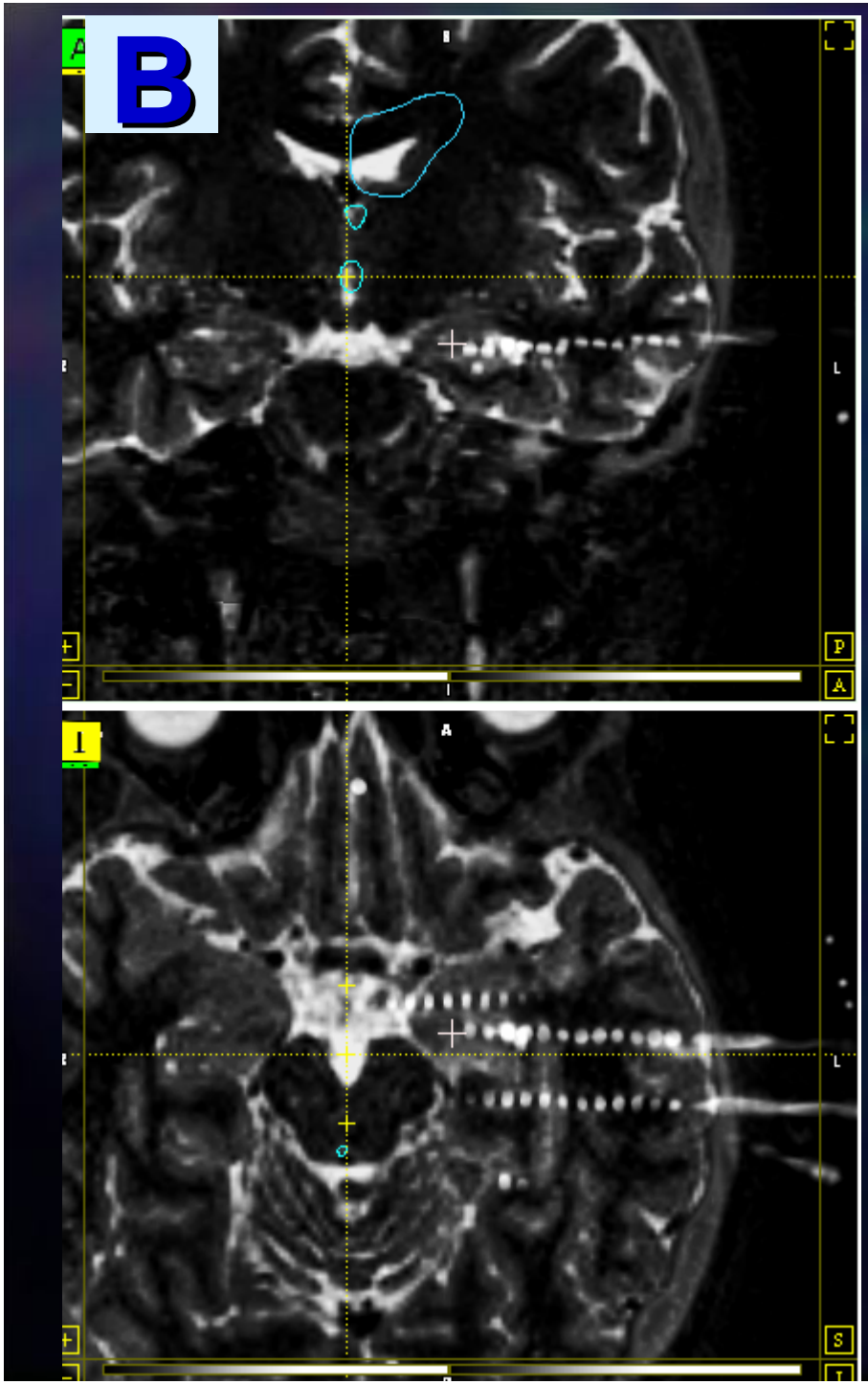
- Percutaneous Hole Drilling
- Dura Electrocoagulation
- Anchor placement
- Stylet insertion
- Electrode Insertion



Postoperative CT

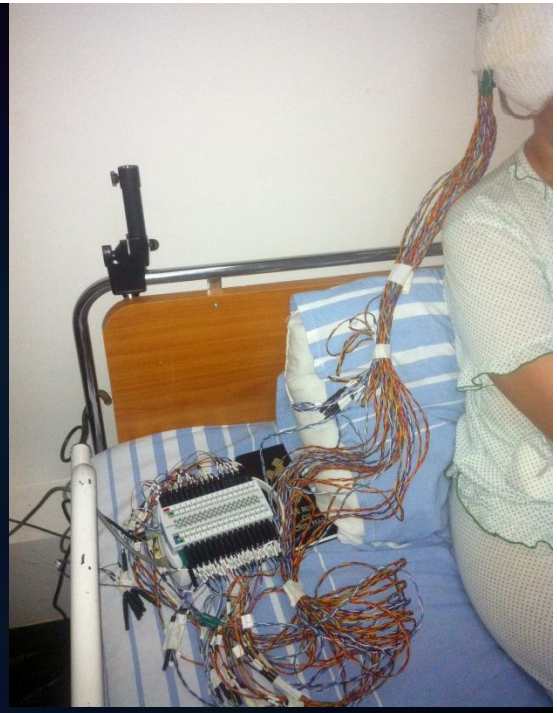
- Verification of electrode position, hemorrhages





- B01-B03 – Hippocampus
- B04-B05 – Parahippocampal gyrus
- B06-B08 – WM
- B11-B12 – Middle Temporal Gyrus (T2)

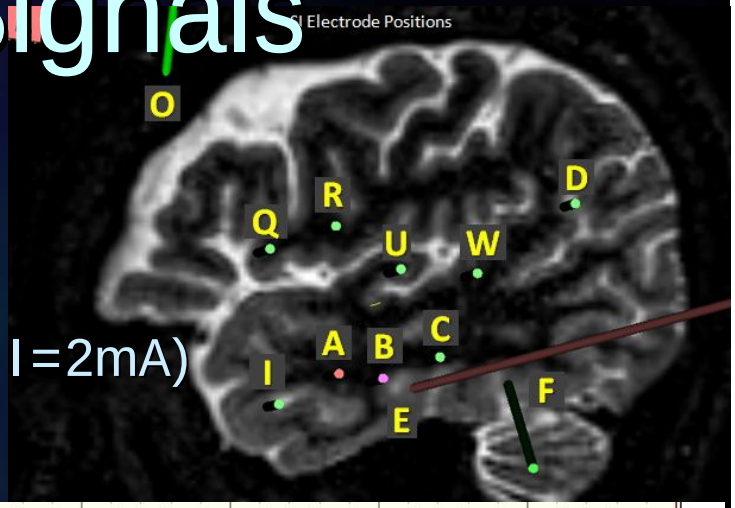
SEEG Recordings and Stimulation

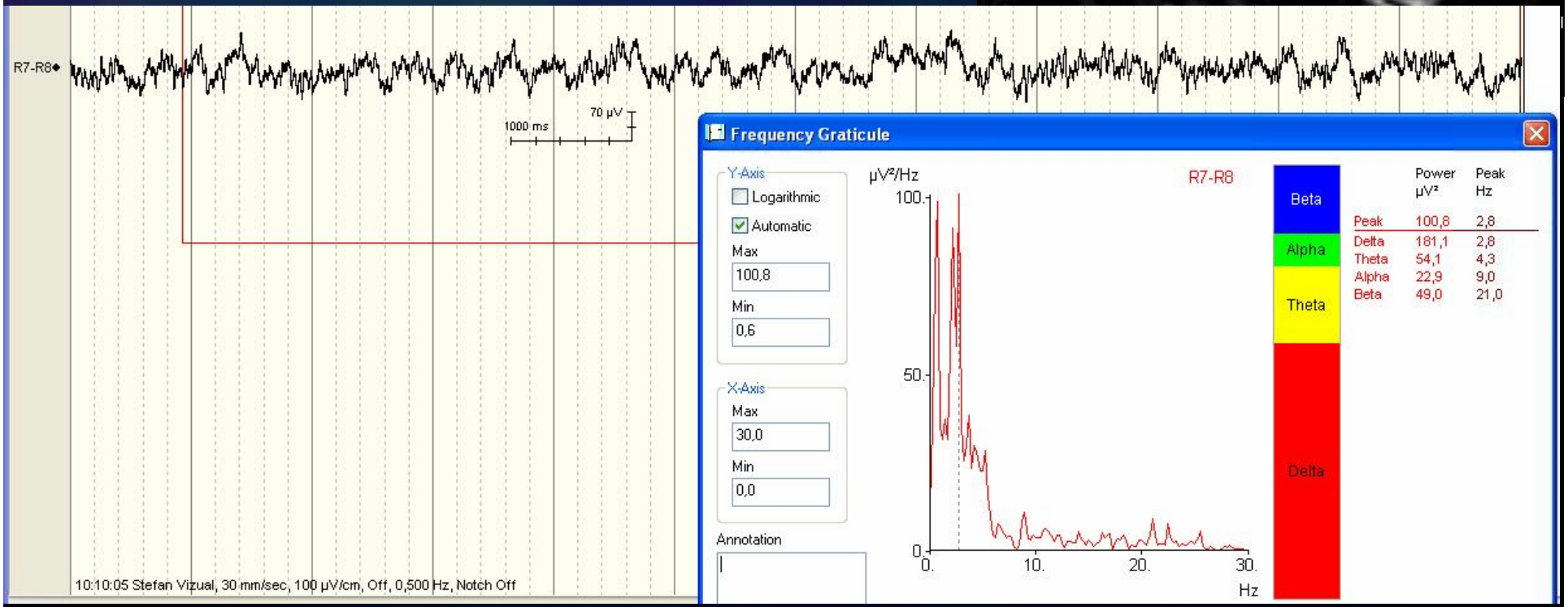


- 1-3 weeks video EEG monitoring
  - Continuous recording using wireless amplifier
  - Several ictal events captured
- Various stimulation protocols for:
  - Eliciting responses characteristic to inter-ictal or ictal patterns
  - Functional mapping of eloquent cortex, to delineate the area that can be resected with minimal deficit

Typical SEEG Signals

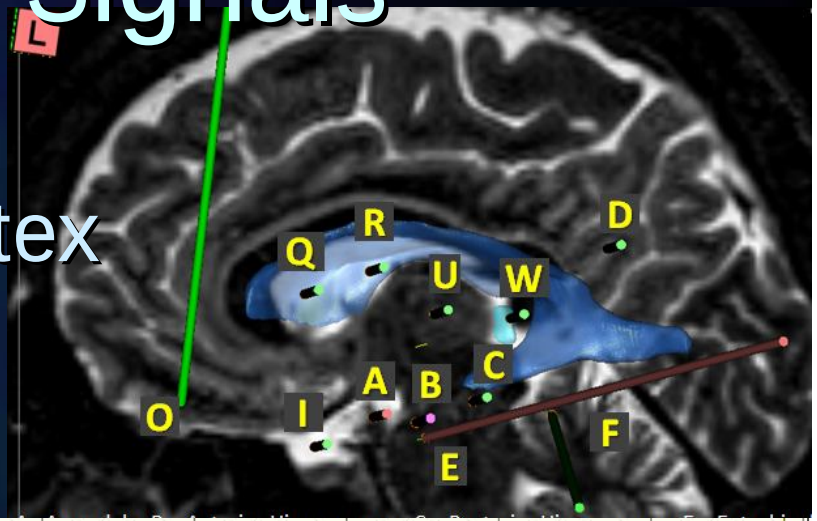
- R7-R8 Broca's area
  - speech arrest on stimulation (f=50 Hz, I=2mA)

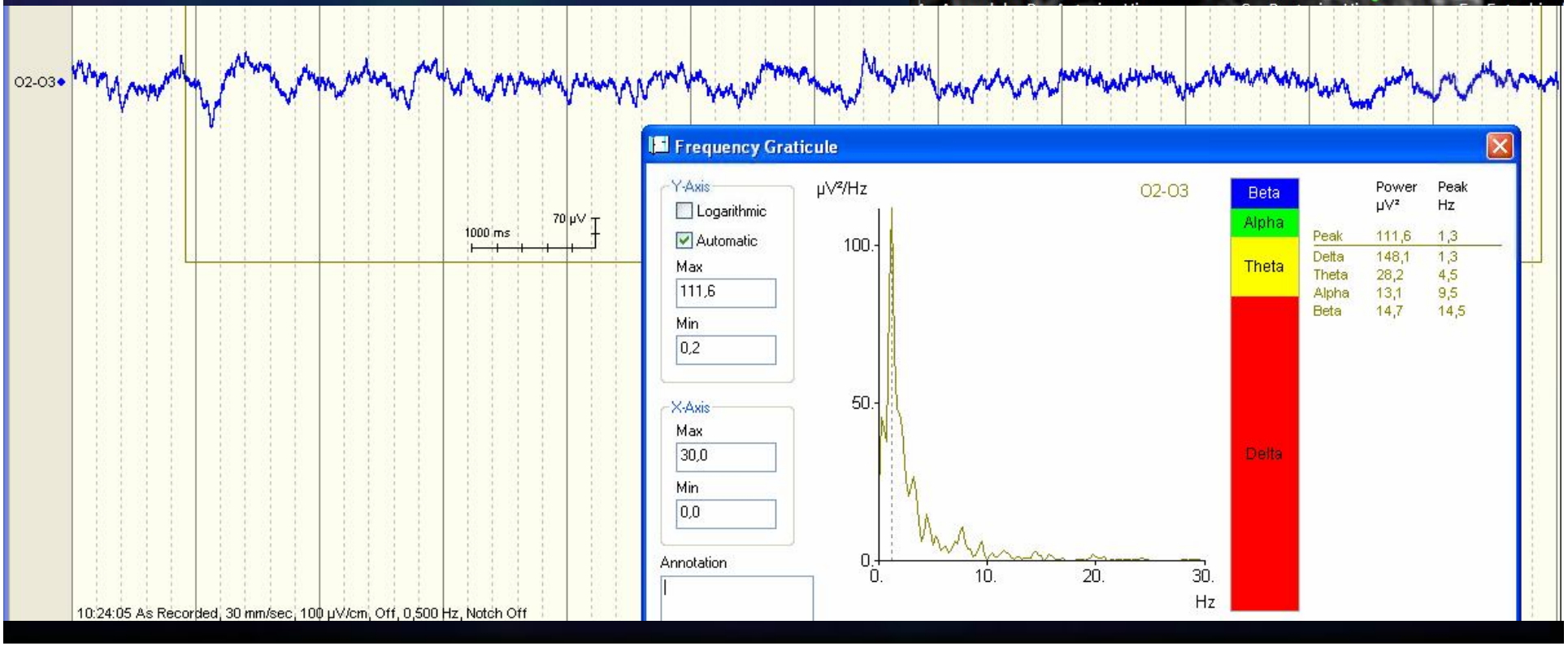




Typical SEEG Signals

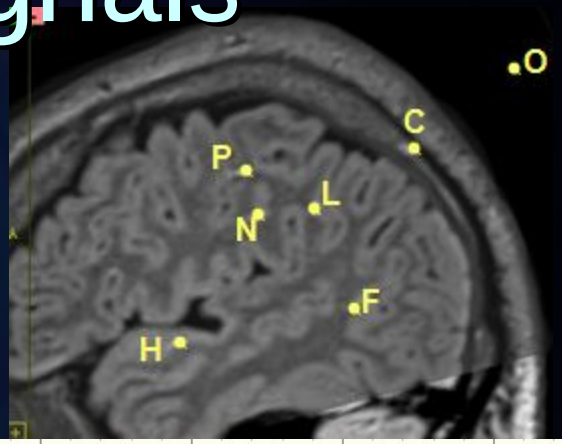
- O2-O3 Orbitofrontal Cortex
  - Low amplitude Delta

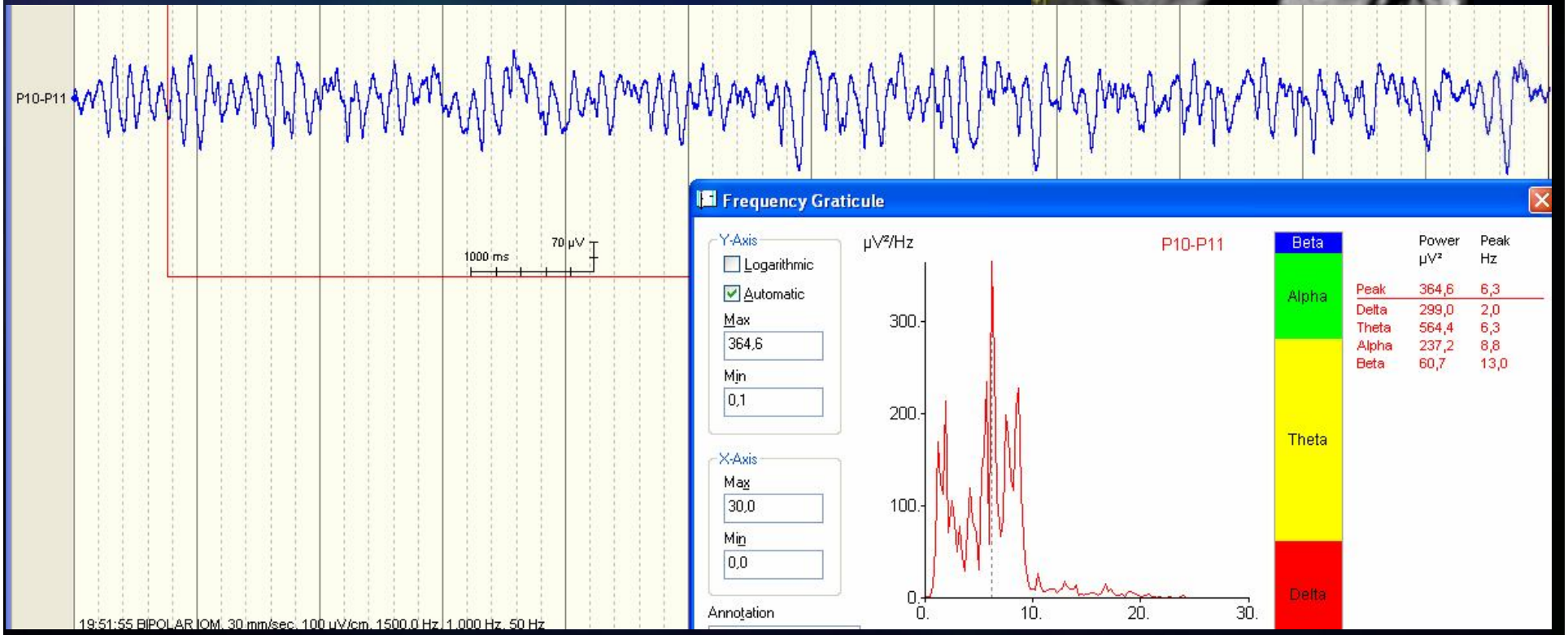




Typical SEEG Signals

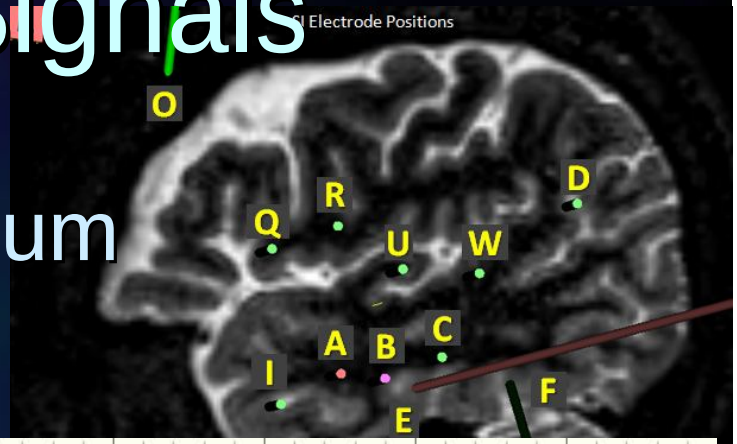
- P10-P1 - Parietal

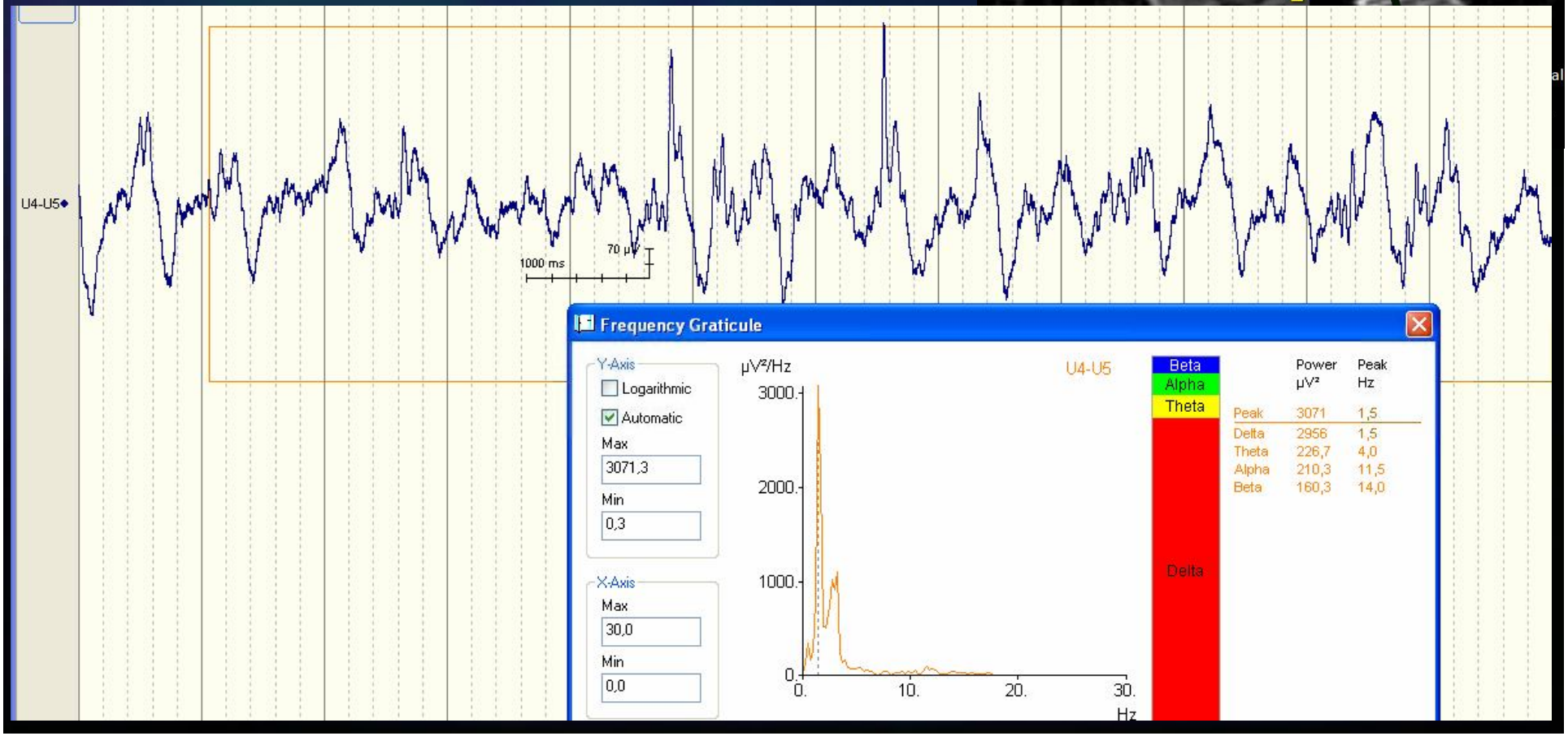




Typical SEEG Signals

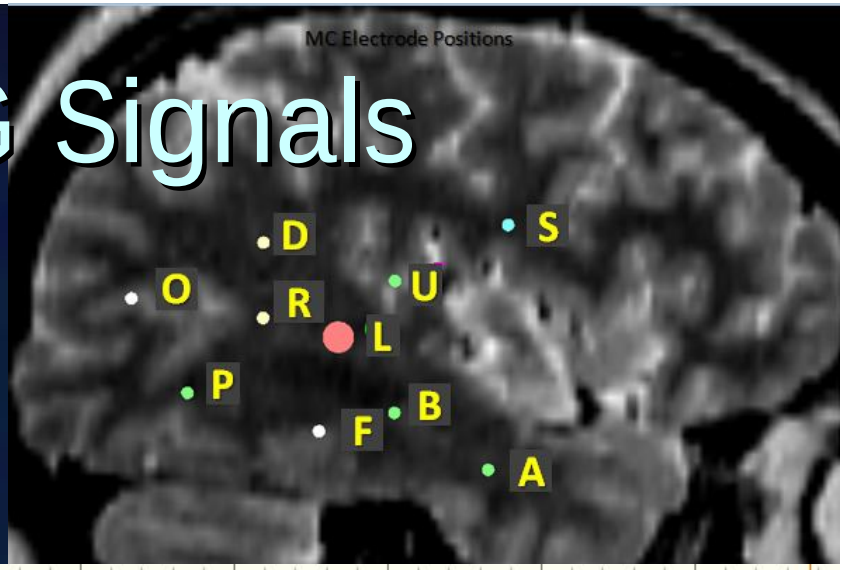
- U4-U5 Infrasylvian Operculum

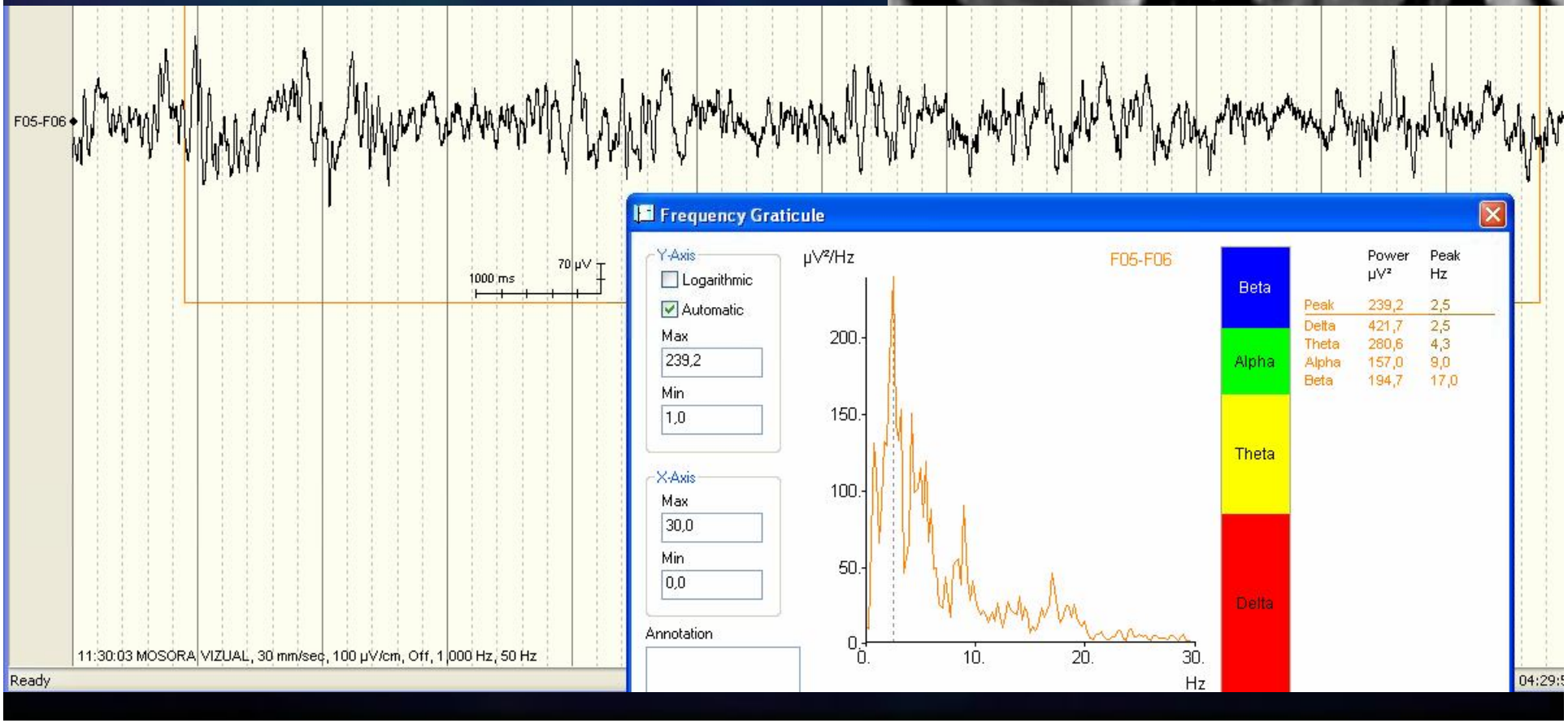




Typical SEEG Signals

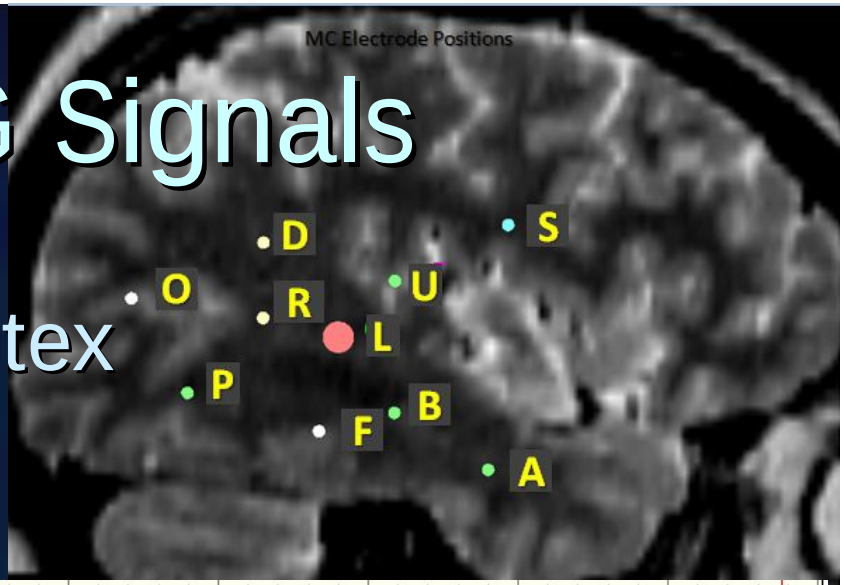
- F5-F6 Fusiform Gyrus

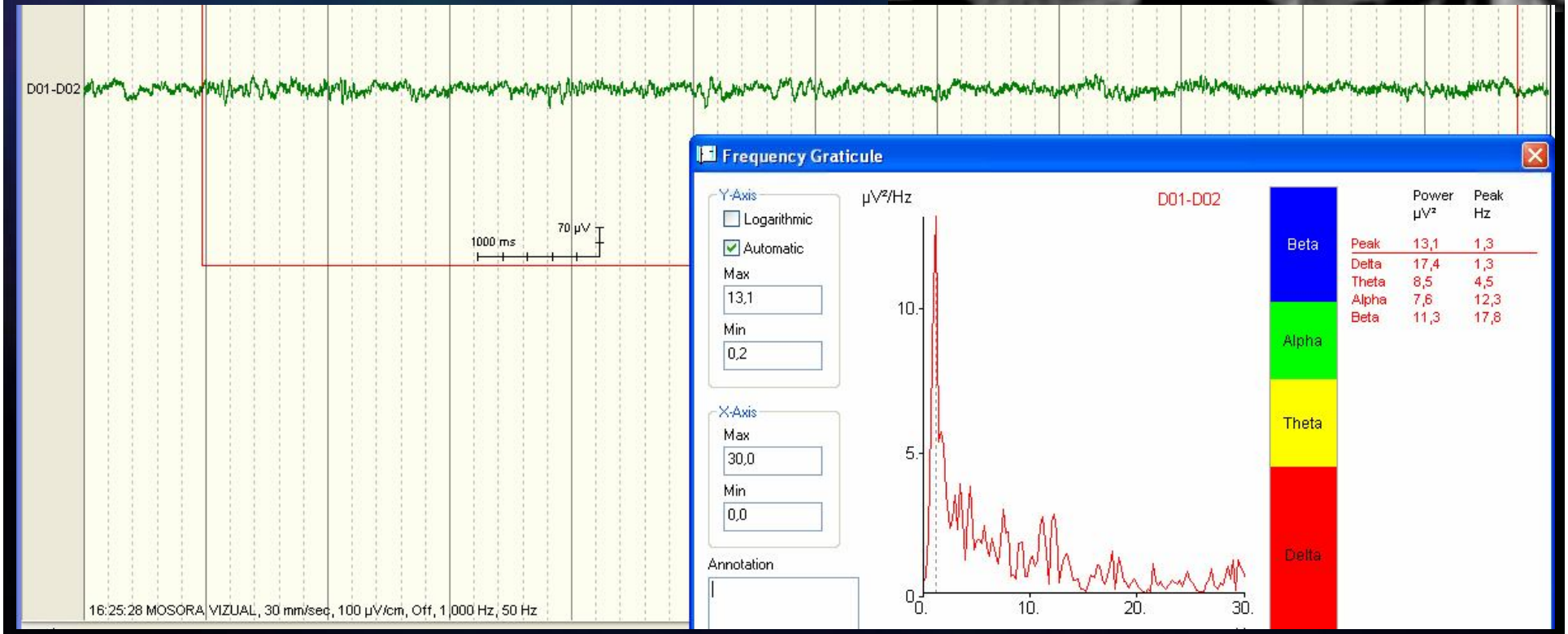




Typical SEEG Signals

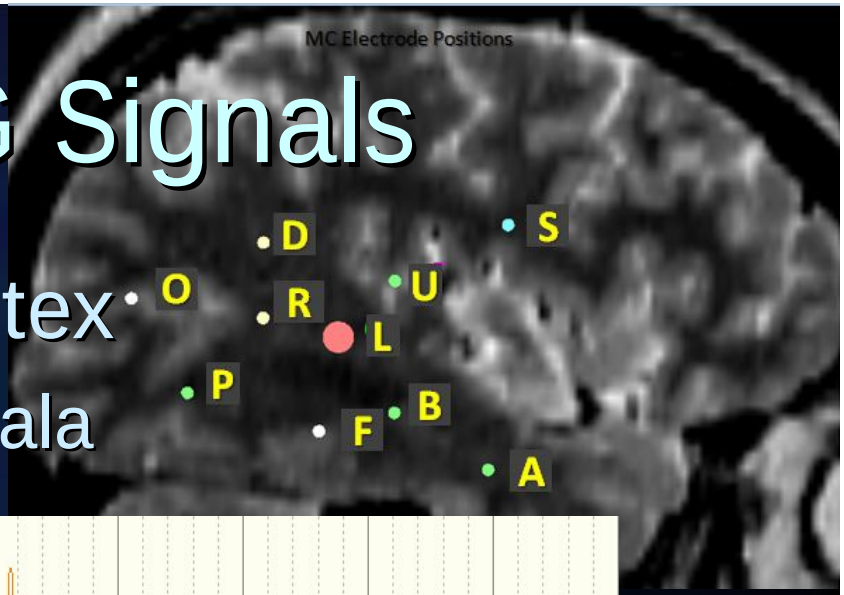
- D1-D2 Retrosplenial Cortex

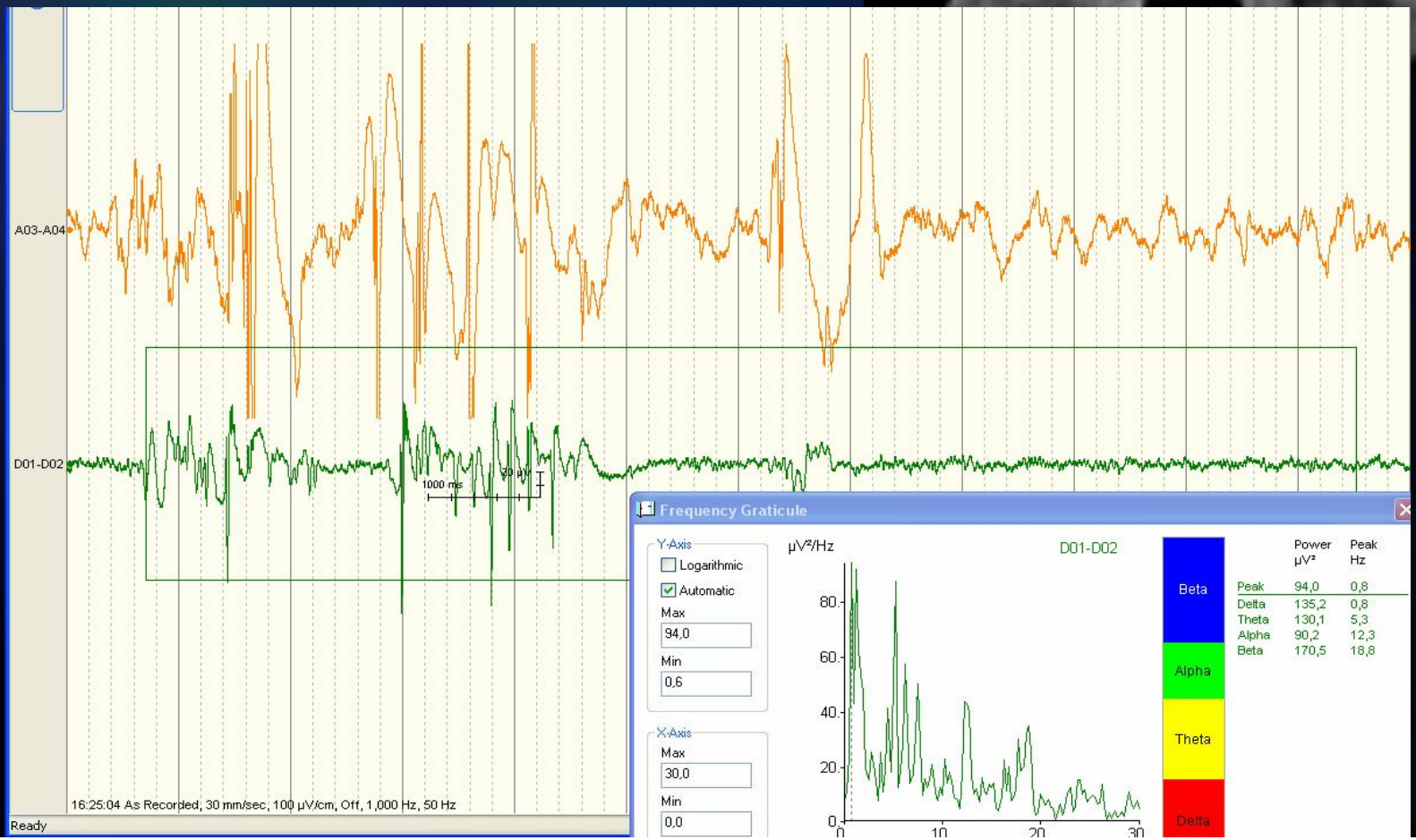




Typical SEEG Signals

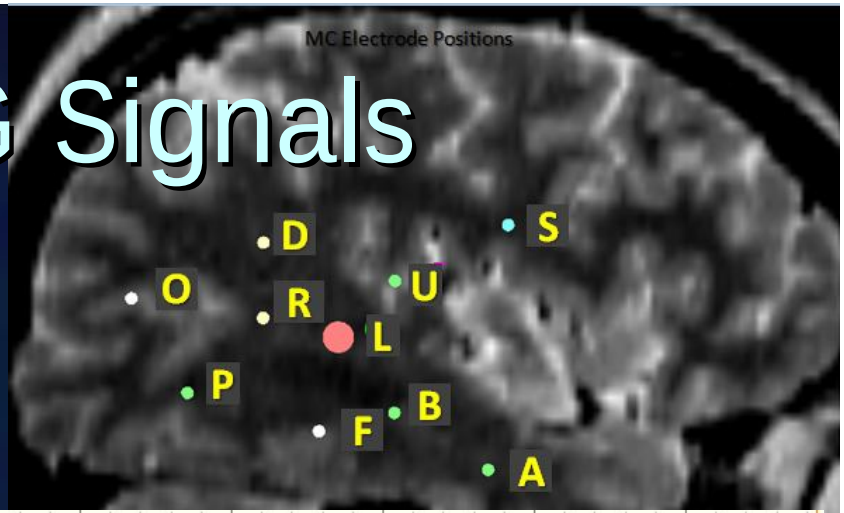
- D1-D2 Retrosplenial Cortex
  - Propagation from Amygdala

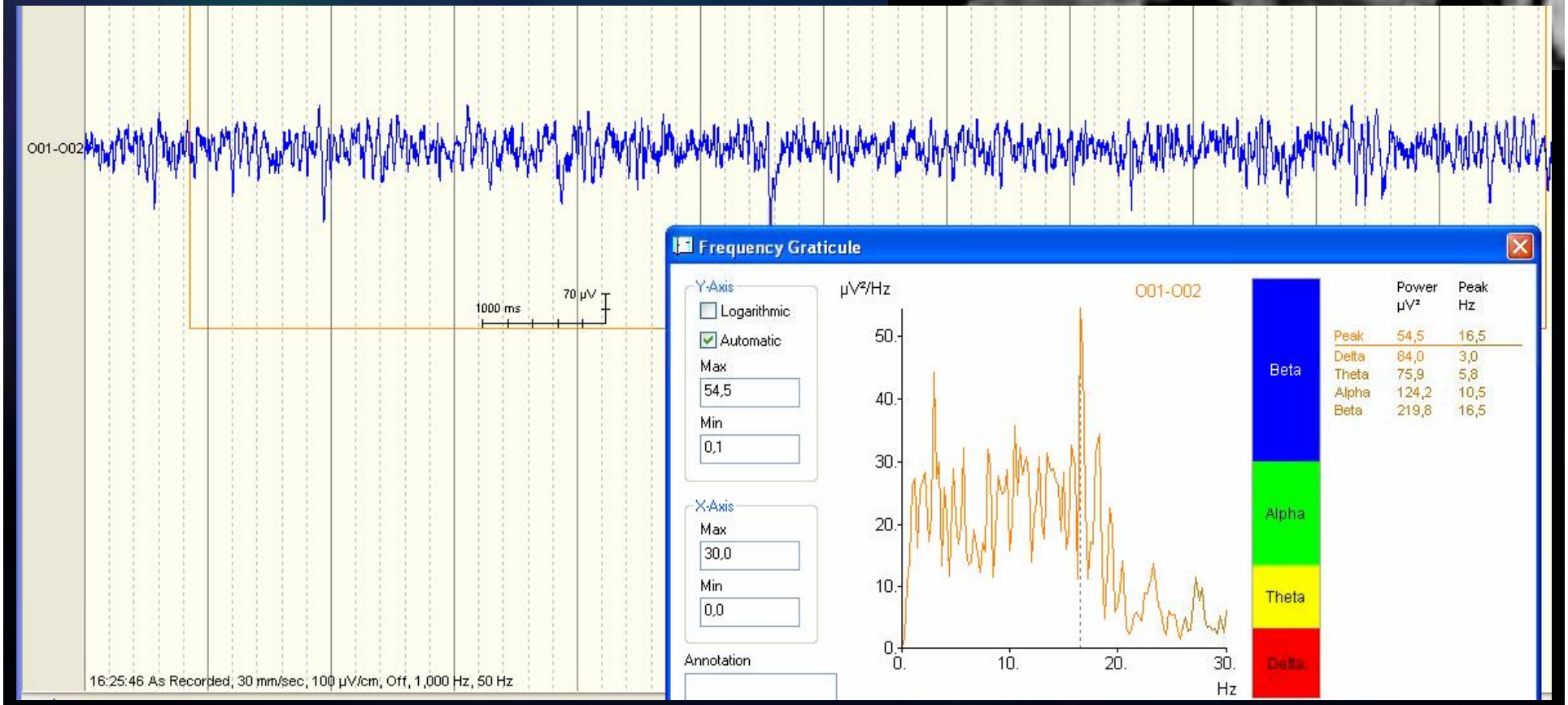




Typical SEEG Signals

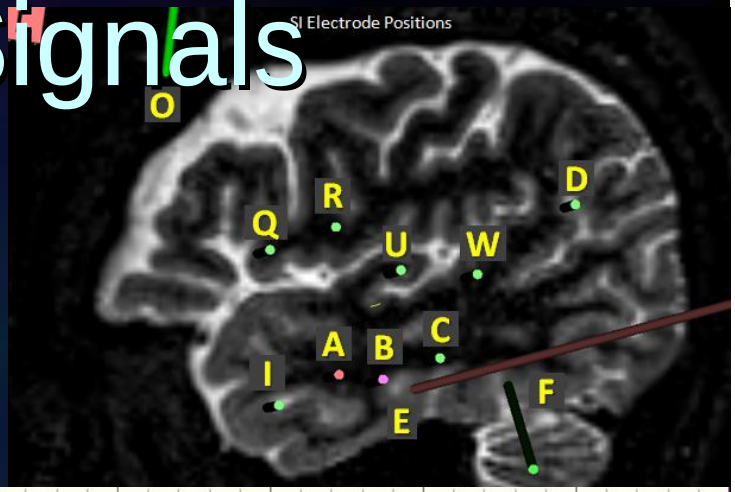
- O1-O2 Supra-Calcarine

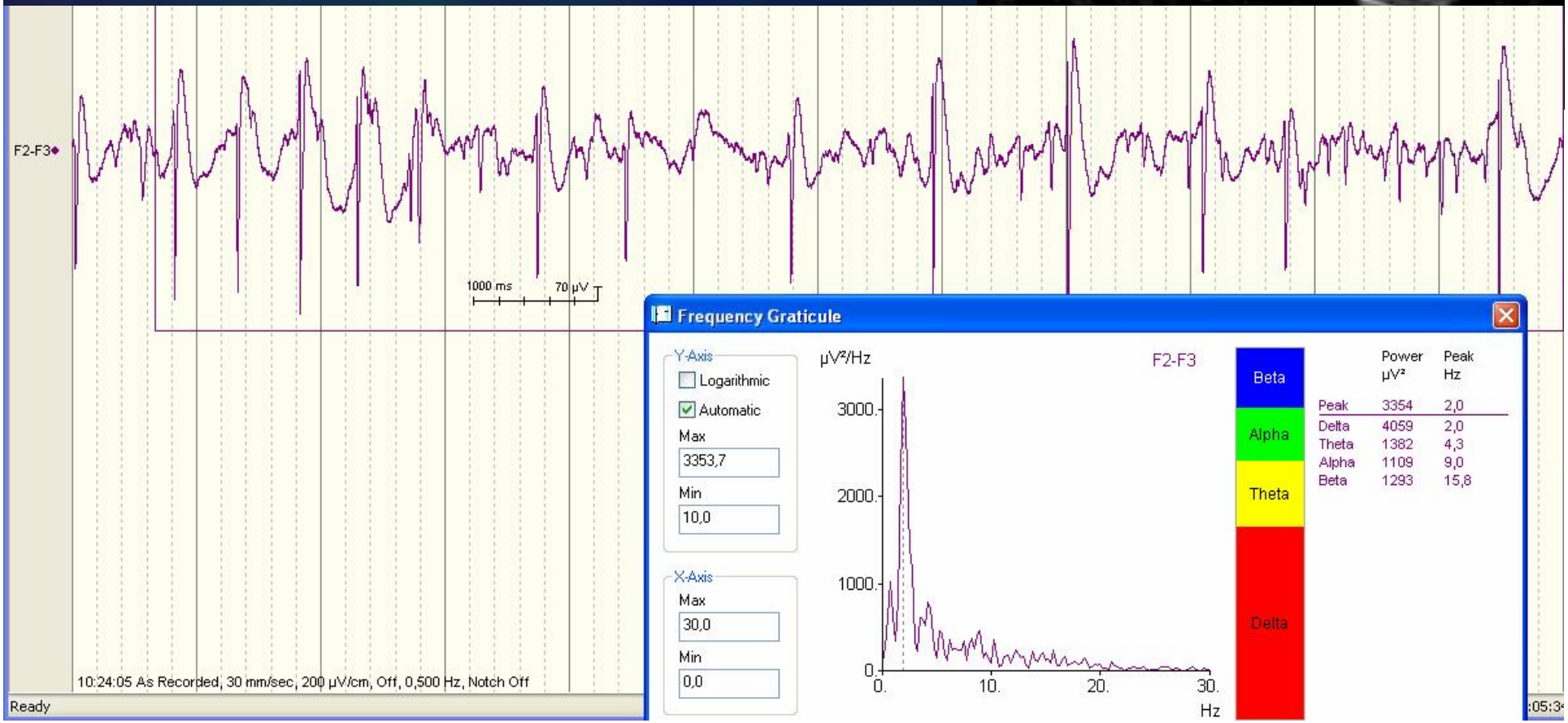




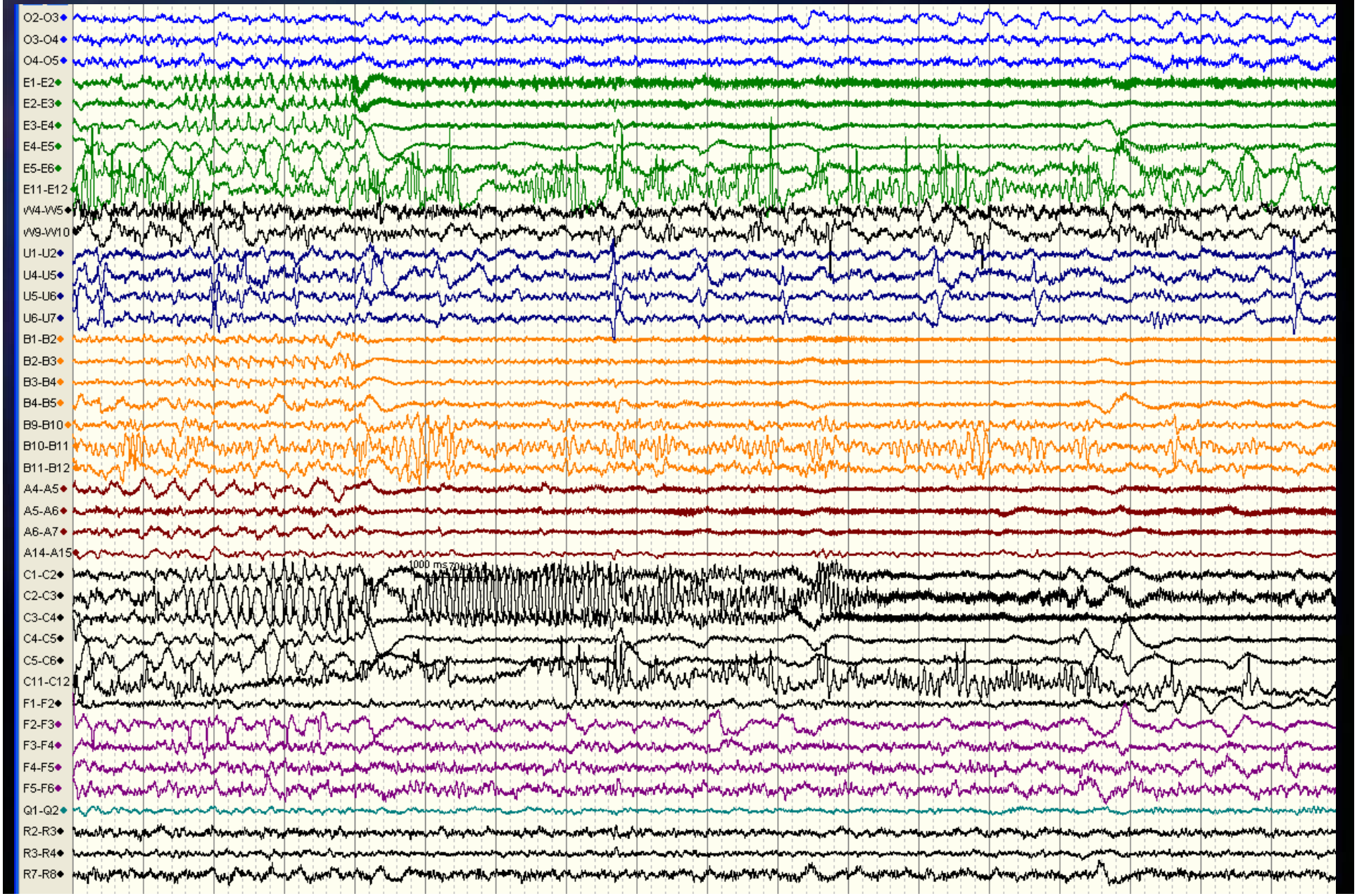
Typical SEEG Signals

- F2-F3 Fusiform Gyrus
  - inter-ictal spikes

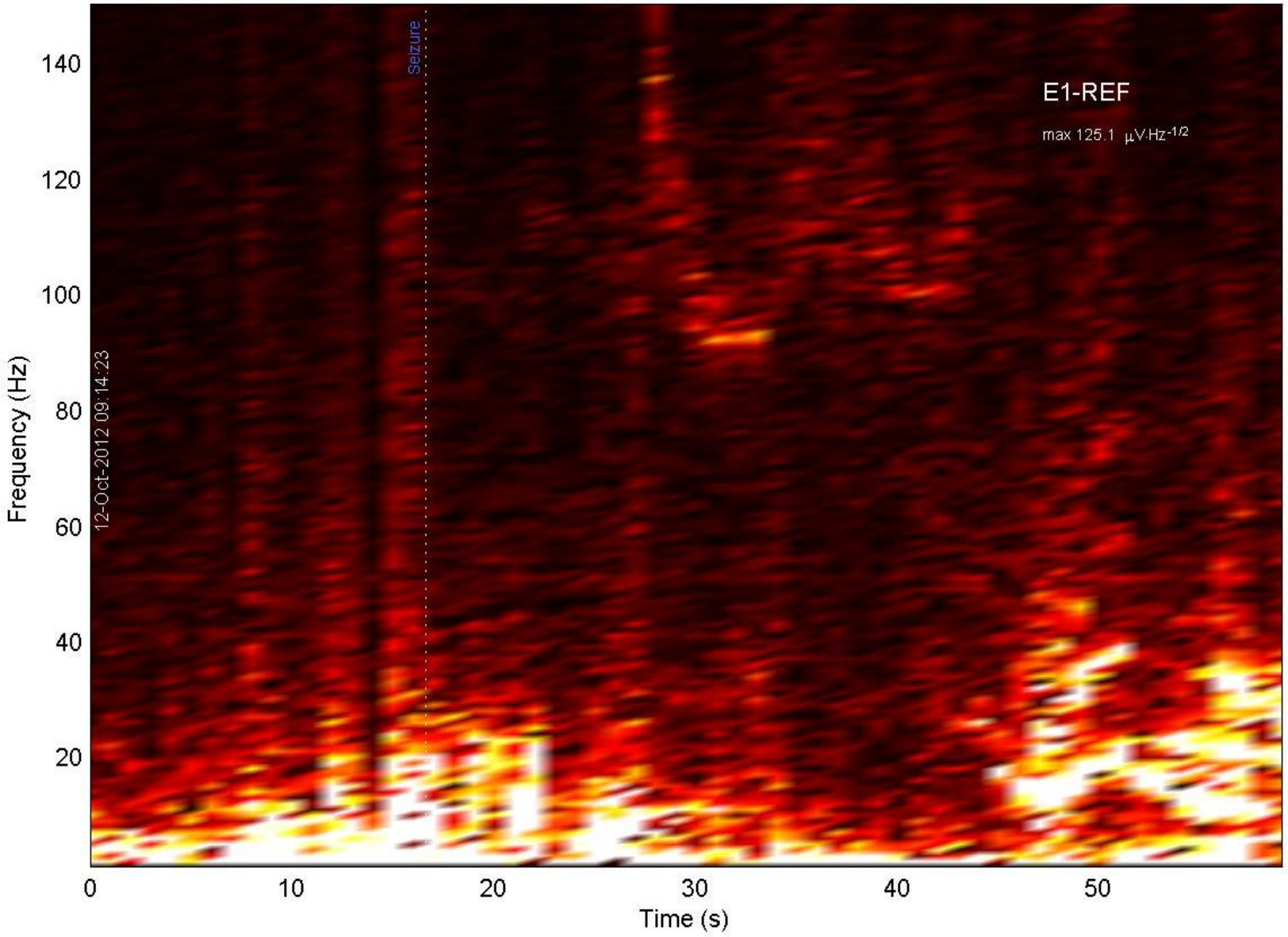




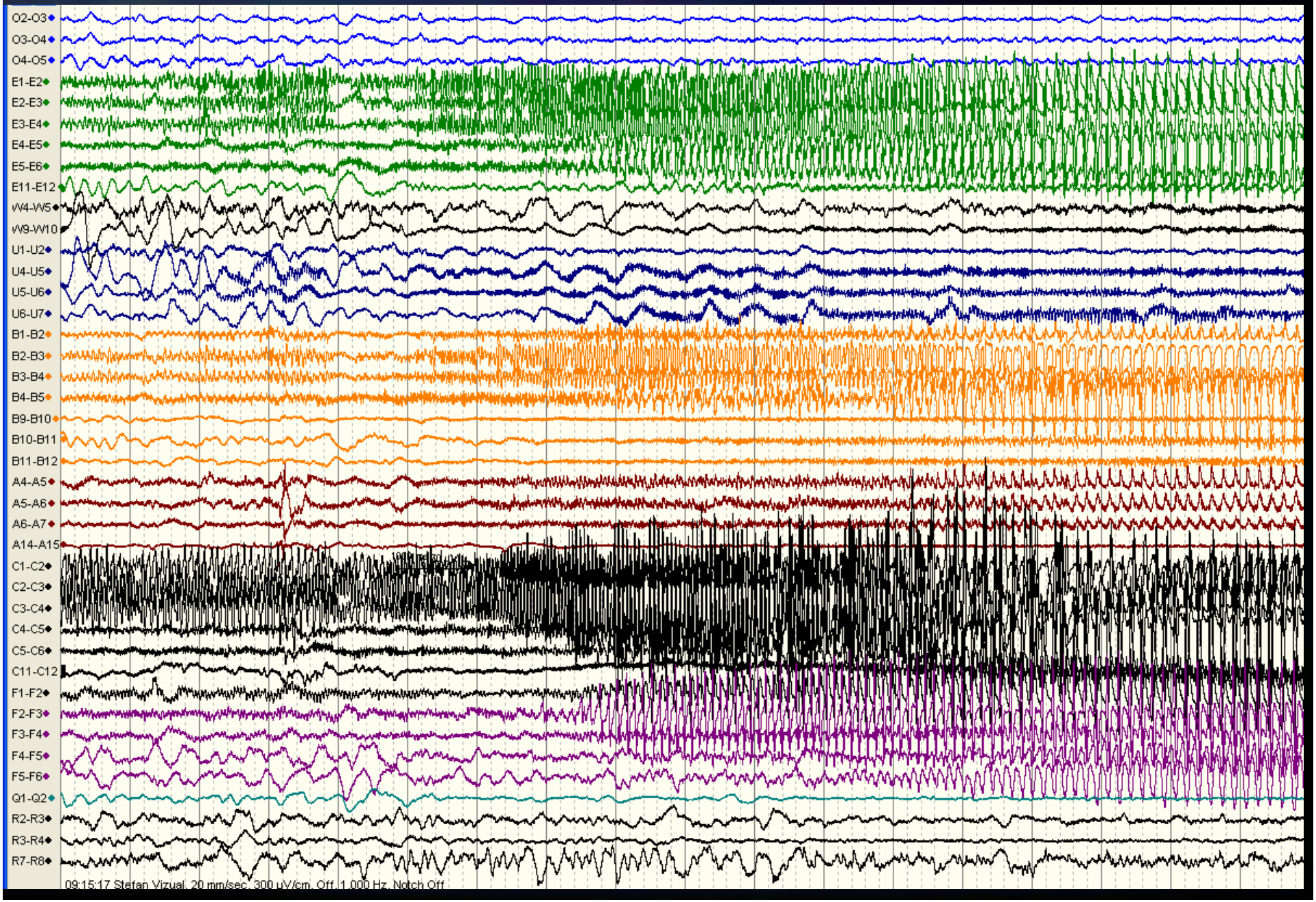
Seizure onset on SEEG



Time-frequency map

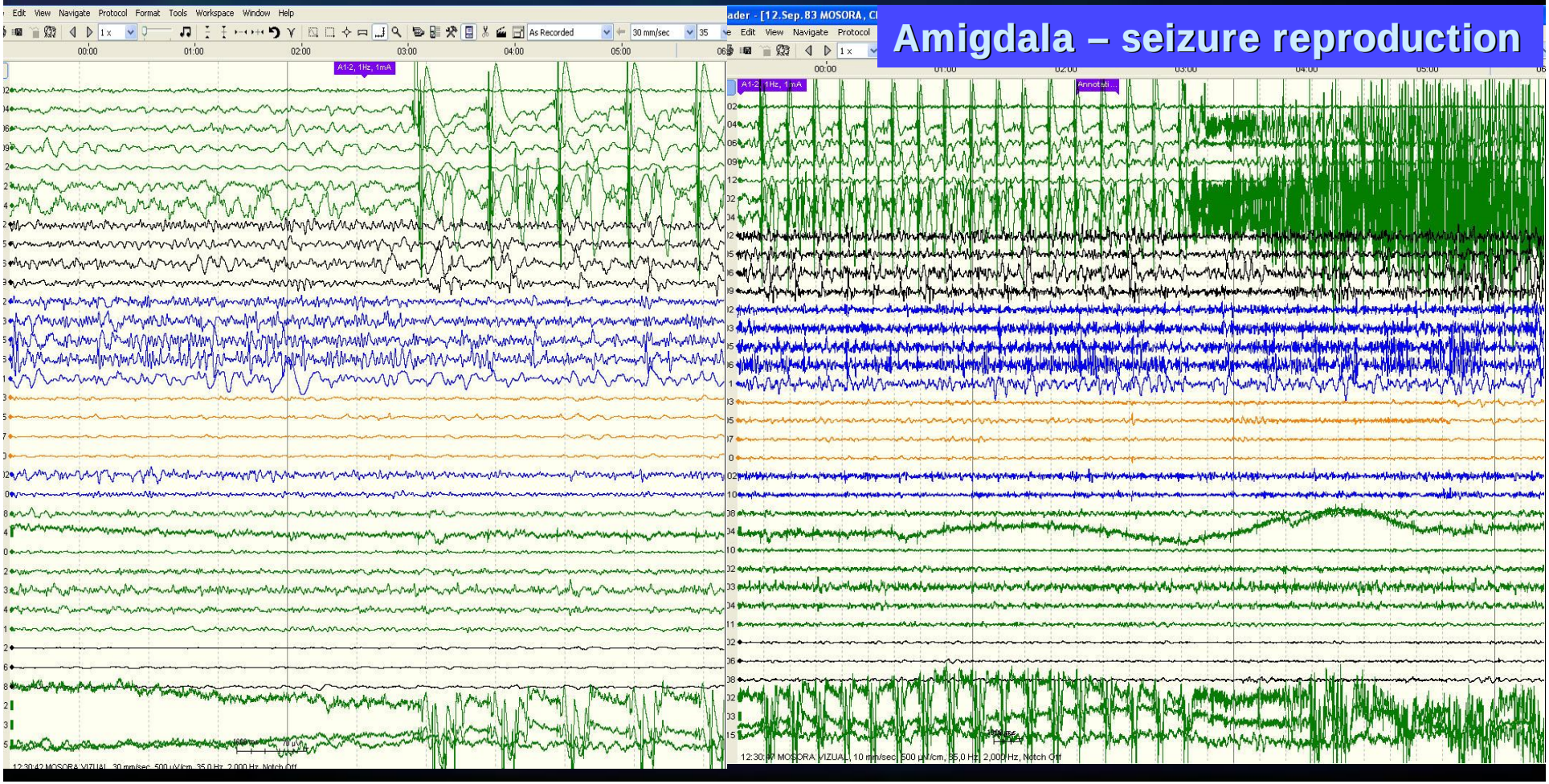


Seizure propagation



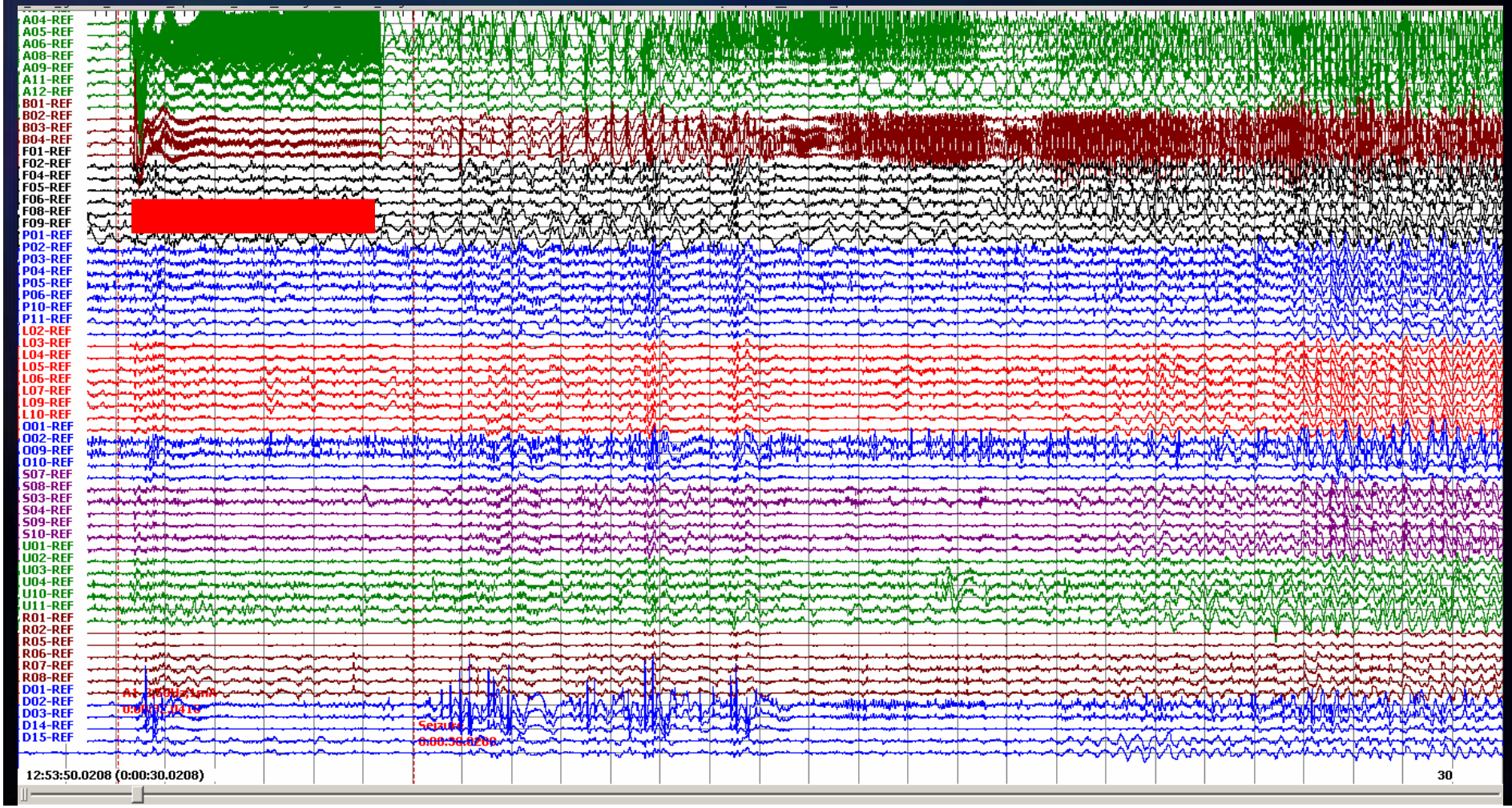
Electrical Stimulation

- Stimulation protocols:
  - 1 Hz, 3 ms biphasic pulses, 1-5 mA, 40 s
  - 50 Hz, 1 ms biphasic pulses, 1-3 mA, 5 s

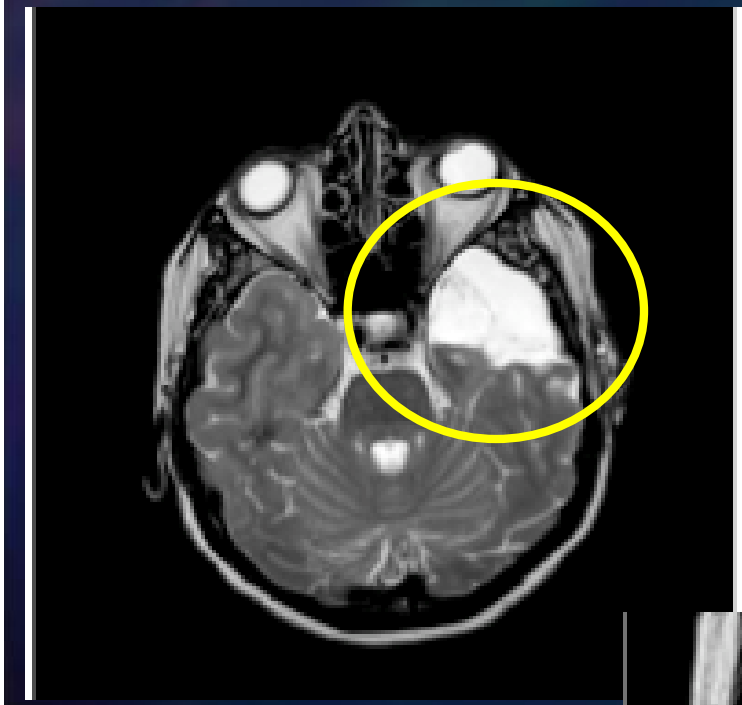


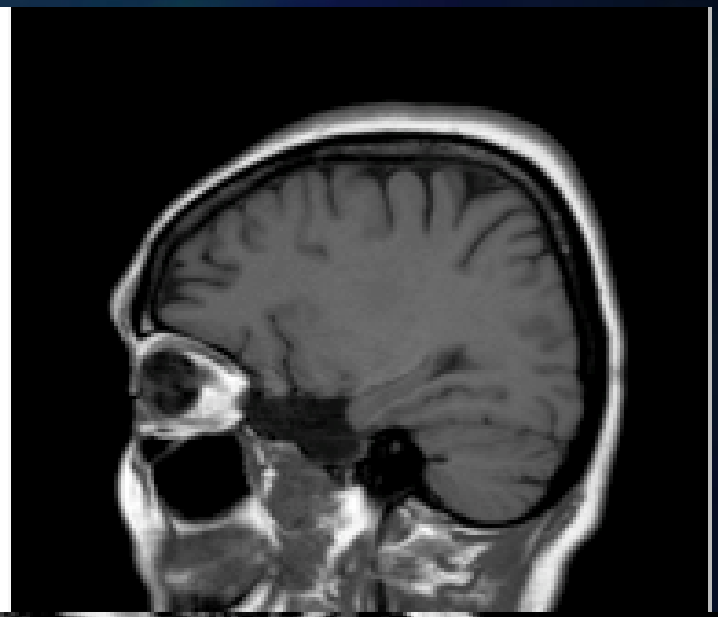
Electrical Stimulation

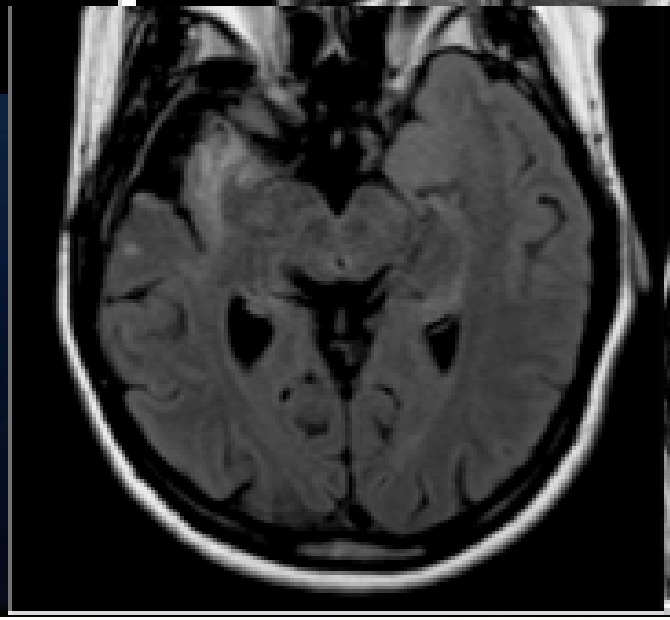
- A1-2 (Amygdala), 50 Hz, 1 ms biphasic pulses, 1-3 mA, 5 s – seizure reproduction



10. Tailored resections







Temporal lobe pole resection

Conclusions

- Despite its complexity, SEEG method can provide invaluable information regarding:
  - 3-D localization of the seizure onset zone in deep brain structures
  - propagation paths of the ictal discharges
  - functional mapping of eloquent cortex for delineating the resection

Acknowledgments

- SEEG Team:
  - Ioana Mindruta, Jean Ciurea, Alin Rasina, Bogdan Balanescu
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  - Ron Franklin
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  - University Emergency Hospital, Bucharest
  - Bagdasar-Arseni Emergency Hospital