# “We’re on the right tract”

## Diffusion tensor imaging assessment of epileptogenic zone using RNS depth electrode locations to investigate white matter networks

**Caleb Fiebig MS,** John Thompson PhD
University of Colorado Anschutz Medical Campus, Aurora, CO

## Background and Rationale

- RNS (Responsive Neurostimulation) delivers stimulation to perturb the onset of ictal activity is an effective therapy to manage seizures especially in drug resistant epilepsy
- Diffusion tensor imaging (DTI) has been used to estimate and model white matter tracts of the brain, allowing for 3D visualization of brain region connections and networks

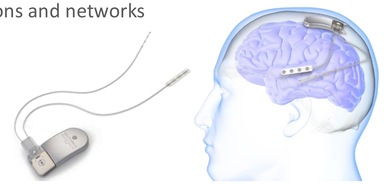

**Figure 1**: RNS neurostimulator with depth and subdural leads (left)[1] and implanted RNS system (right)[6]

## Hypothesis

- Patient brain imaging and data from extracted RNS electrode contacts along with white matter tracts can be used to investigate and potentially locate shared networks across patients with drug resistant epilepsy
- The combination of electrode contacts and white matter tracts can predict susceptible networks.

## Methods

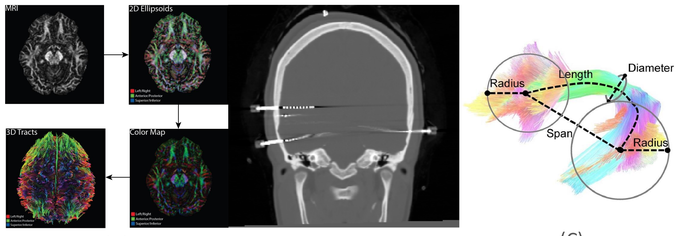


**Figure 2**: (A) Images showing process of model generation from MRI imaging to FA color mapping to 3D tracts. (B) Post-operative CT scan showing depth electrodes within cranium prior to segmentation. (C) Visualization of a few of the shape metrics displayed on a representative fiber bundle. (Figure from Yeh, 2020)[2]

- Obtained pre-operative MRI with DTI and post-operative CT in epilepsy patients (n = 8) managed with RNS systems with.
- Implanted RNS probe contacts were segmented from the post-operative CT images.
- The diffusion images were rotated and scaled to the space of the post-operative CT imaging using DSI studio. Each individual RNS contact within the hippocampal region was used to define unique tract bundles.
- A deterministic fiber tracking algorithm was used with augmented tracking strategies to improve reproducibility

## Results

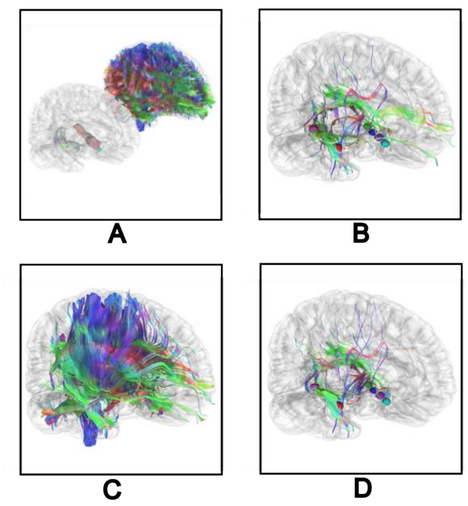


**Figure 3**: Overall process of modelling the hippocampal-contact associated tracts from a representative subject. (A) Hippocampal and RNS contact regions and whole brain tracts. (B) RNS contact associated tracts. (C) Hippocampal associated tracts. (D) Hippocampal- contact associated tracts

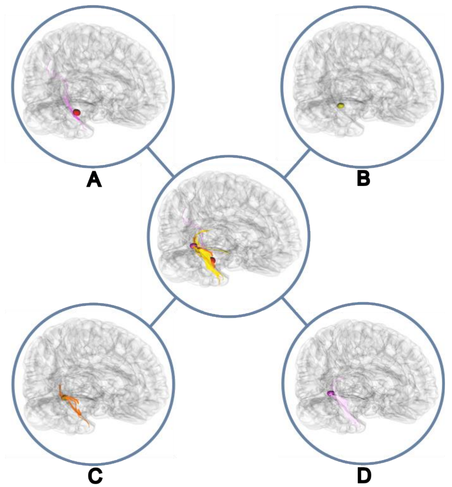


**Figure 4**: Hippocampal-contact associated tracts of the R hemisphere of a representative subject. Individual tracts separated for each individual contact: (**A**) contact 1, (**B**) contact 2, (**C**) contact 3, and (**D**) contact 4

**Table 1**: *Shape analysis results*

| Subject | Tract Name (Contact Number) | Hemisphere | Contact Region | Number of Tracts | Mean Length (mm) | Span (mm) | Curl | Elongation |
|---|---|---|---|---|---|---|---|---|
| 1 | LC1 | L | Anterior | 85 | 58.76 | 46.24 | 1.27 | 23.97 |
| | LC2 | L | Anterior | 1 | 34.00 | 8.52 | 3.99 | 53.59 |
| | LC3 | L | Posterior | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| | LC4 | L | Posterior | 175 | 42.07 | 18.76 | 2.24 | 15.10 |
| 2 | LC3 | L | Posterior | 743 | 103.71 | 45.60 | 2.27 | 19.84 |
| | LC4 | L | Posterior | 977 | 101.33 | 33.69 | 3.01 | 20.70 |
| 3 | LC1 | L | Anterior | 793 | 108.10 | 78.05 | 1.39 | 18.33 |
| | LC2 | L | Anterior | 51 | 63.23 | 35.60 | 1.78 | 28.03 |
| | LC3 | L | Posterior | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| | LC4 | L | Posterior | 2 | 42.00 | 38.24 | 1.10 | 54.45 |
| | RC1 | R | Anterior | 15 | 49.40 | 30.67 | 1.61 | 25.71 |
| | RC2 | R | Anterior | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| | RC3 | R | Posterior | 84 | 38.25 | 31.96 | 1.20 | 15.07 |
| | RC4 | R | Posterior | 457 | 50.95 | 38.03 | 1.34 | 12.62 |
| 4 | LC2 | L | Anterior | 2984 | 122.02 | 45.54 | 2.68 | 13.54 |
| | LC3 | L | Posterior | 3275 | 102.86 | 65.45 | 1.57 | 12.31 |
| | LC4 | L | Posterior | 85 | 68.25 | 33.90 | 2.01 | 19.68 |
| 5 | RC2 | R | Anterior | 16609 | 121.07 | 65.16 | 1.86 | 10.36 |
| | LC1 | L | Anterior | 4554 | 116.98 | 60.13 | 1.95 | 13.06 |
| | LC2 | L | Anterior | 3766 | 85.14 | 69.03 | 1.23 | 14.21 |
| 6 | RC1 | R | Anterior | 1277 | 82.62 | 47.91 | 1.72 | 20.63 |
| | RC2 | R | Anterior | 903 | 38.60 | 31.82 | 1.21 | 7.69 |
| | RC3 | R | Posterior | 2795 | 39.98 | 31.23 | 1.28 | 5.80 |
| 7 | LC1 | L | Anterior | 2452 | 126.92 | 32.00 | 3.97 | 24.31 |
| | LC2 | L | Anterior | 1413 | 92.51 | 29.19 | 3.17 | 19.95 |
| | LC3 | L | Posterior | 250 | 77.04 | 29.30 | 2.63 | 21.45 |
| | LC4 | L | Posterior | 2186 | 86.13 | 32.53 | 2.65 | 16.05 |
| | RC2 | R | Anterior | 7185 | 97.64 | 59.28 | 1.65 | 8.87 |
| | RC3 | R | Posterior | 31 | 70.55 | 22.45 | 3.14 | 37.13 |
| | RC4 | R | Posterior | 21947 | 147.70 | 69.42 | 2.13 | 16.55 |
| 8 | LC2 | L | Anterior | 129 | 97.88 | 84.32 | 1.16 | 44.52 |
| | LC3 | L | Posterior | 3013 | 76.97 | 49.64 | 1.55 | 12.66 |
| | RC4 | R | Posterior | 19 | 53.32 | 39.14 | 1.36 | 30.64 |

**Table 2**: *p values for one-way Anova with Hemisphere (L vs R) and Contact Region as grouping variables.*

| | Grouping Variable | |
|---|---|---|
| | Hemisphere | Contact Region |
| Number of Tracts | 0.191 | 0.756 |
| Mean Length (mm) | 0.462 | 0.225 |
| Span (mm) | 0.908 | 0.142 |
| Curl | 0.172 | 0.605 |
| Elongation | 0.240 | 0.643 |

## Discussion

### Conclusions

- This study was unable to find sufficient evidence for shared fiber tracts between patients with drug-resistant epilepsy
- The combination of DTI tractography along with depth electrode data can bridge the gap between the anatomical and physiological components of the brain
- The combination of these modalities allows us to better understand and study neuropathologies such as epilepsy.
- The utilization of SEEG in conjunction with DTI white matter modeling allows for the functional and anatomical study of seizure propagation

### Future Directions

- Investigation utilizing the physiologic information recorded by the RNS system (cortical stimulation, seizure activity recordings).
- Further investigate the modality of seizure propagation utilizing the methods put forth by this study.

## References and Acknowledgements

### References

[1] Product. NeuroPace, Inc. Accessed November 26, 2025. https://neuropace.com/providers/rns-system-neuromodulation/
[2] Yeh FC. Shape analysis of the human association pathways. NeuroImage. 2020;223:117329. doi:10.1016/j.neuroimage.2020.117329

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### Contact Information

caleb.Fiebig@cuanschutz.edu