Correlating the Effect of the Size and Location of TBI Induced Lesions on the Likelihood of Developing Epilepsy Through Functional Connectivity Mapping

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INTRODUCTION

- TBI is one of most common causes of epilepsy
- Brain imaging acquired after head injury and before onset of seizures may contain information that can be used to develop predictive models of epilepsy risk
- Focus is on analysis of structural and functional MRI data from patients with TBI
- **Goal**: understand how lesions are related to epilepsy risk after brain injury through analysis of functional connectivity networks in the brain

ADVANCED NORMALIZATION TOOLS ECOSYSTEM

ANTS

- ANTs: Advanced Normalization Tools Ecosystem
- Ecosystem supporting multivariate / multiple modality medical image analytics across programming languages
- The ANTsX project focuses on medical imaging processing especially for neuroimaging applications
- Used for image registration, segmentation, and normalization

ANTS Registration

- The major purpose of Image registration is to align two images (the source and target image) together so that their common features overlap and their differences easily stand out
- Reasons to Coregister images
  - Comparing 2 CT/MRI scans over different time periods to compare changes during treatment
  - Lining up a PET scan to an MRI to identify anatomic locations of activation

Registration of FLAIR and T1 sequences

- FLAIR: Fluid Attenuated Inversion Recovery
  - MRI sequence set to null fluids
  - Used in brain imaging to suppress CSF to highlight periventricular lesions
- T1
  - MRI sequence highlighting the presence of fatty tissue
  - Thus creates a clear contrast with grey and white matter
- Why coregister them together?
  - Research shows that co-registration of these sequences highlights (intraoperative) identification of otherwise poorly visible lesions on standard MRI sequences in good spatial resolution

ITK-SNAP

- Segmentation and Visualization Platform for Medical Images
- Enables visualization of neurological lesions for segmentation

ITK-SNAP

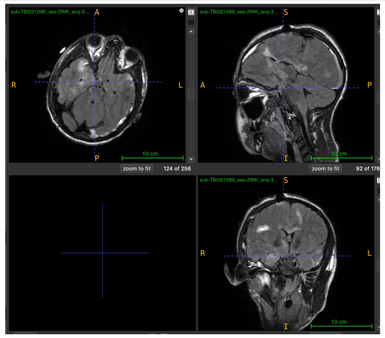

Figure 1: ITK-SNAP representation of a patient's brain scan

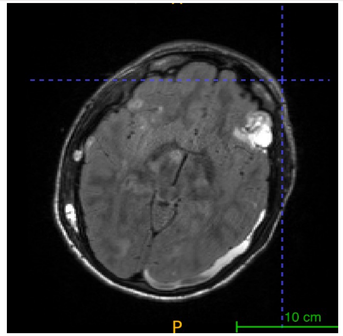

Figure 2: Axial view to begin segmentation

T1

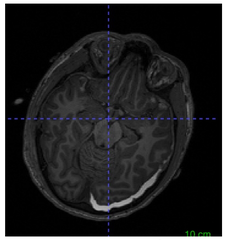

Figure 3: T1 Sequence of patient MRI

FLAIR

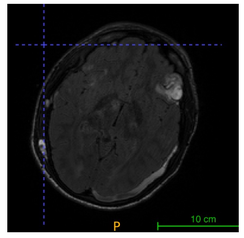

Figure 4: FLAIR sequence of patient MRI

Coregistration

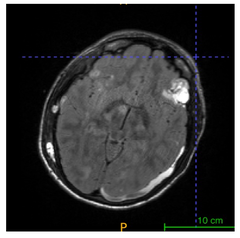

Figure 5: FLAIR + T1 coregistration

SEGMENTATION

Lesion Segmentation

- Employing ANTs for image coregistration for segmentation
- **Data Set**:100 patient sample set with a cohort of additional 600 patients
- Segmentation: manually labeling the lesions in patients with TBI
  - Appear as bright spots in MRI images

2 Weeks

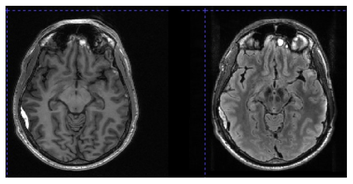

Figure 6: Prelim. Scans of a patient's brain 2 weeks after the TBI incident

6 Months

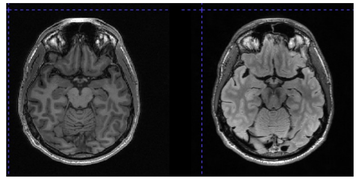

Figure 7: Follow up scans of a patient's brain 6 months after the TBI incident

	Label Name	Voxel Count	Volume (mm3)	Intensity Mean ± SD (001_t2flair)
0	Clear Label	41313308	9.85e+06	31.4152±53.4317
1	Label 1	92689	2.21e+04	327.3577±113.1511
2	Label 2	537043	1.28e+05	224.2977±44.2255

Table 1: Volumetric Analysis of Patient Lesion and edema size 2 weeks after injury

Ex. Patient 1	Lesion 1 - L Frontal	Lesion 2- R Temporal	Lesion 3 - R Frontal	Total
Core	7010	1242	18440	26692
Edema	5169	835.4	2535	8539.4
Ex. Patient 2	Lesion 1 - R Occipital	Lesion 2 - L Temporal	Total	
Core	17380	27370	44750	
Edema	34240	29750	63990	

Table 2: Lobular Volumetric Analysis of Patient Lesion and edema size 2 weeks after injury

FUNCTIONAL CONNECTIVITY

Mapping Lesion-Related Epilepsy to Human Brain Network

- Lesions associated with epilepsy occurred in multiple heterogeneous brain locations, spanning different lobes and vascular regions
- However despite the anatomical variety of lesion locations, results showed that there was pronounced higher likelihood of developing post stroke epilepsy in regions defined by functional connectivity to the basal ganglia and cerebellum
- **Promising results:** DBS site connectivity was associated with improved seizure control

Functional Connectivity Methods

- Case control design
  - Discovery dataset of patients who developed post-stroke epilepsy
  - Control cohort with stroke but no epilepsy
- Lesion Control mapping
  - A method that tests whether lesions associated with epilepsy intersect specific brain regions
- Multivariate Methods: to identify lesions brain regions and individual voxels associated with epilepsy

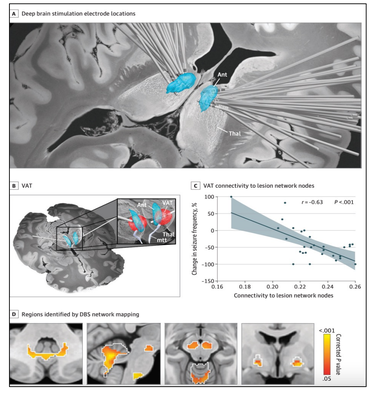

Figure 8: This figure illustrates the DBS treatment that was employed after lesion location

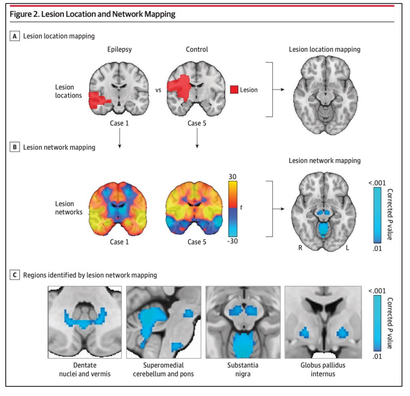

Figure 9: Framework for functional connectivity analysis employing the use of network mapping

Reference: Schaper FLWVJ et al. "Mapping Lesion-Related Epilepsy to a Human Brain Network." JAMA Neurology, U.S. National Library of Medicine,

FURTHER STEPS

- Proceed with functional connectivity analysis through analysis of the human functional connectome
- After patient segmentation, conducting fMRI analysis using FSL
- Will combine functional connectivity with structural connectivity analysis to obtain a complete view of the mechanisms that contributes to epilepsy

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