Resting State fMRI Seizure Networks and Electrographic Seizures in Acute Brain Injury: A Retrospective Analysis

Meitra Kazemi, Benjamin Garside, William R. Reuther, MS, Erika Duran, MD, Emilio Cediel, MD, Varina L. Boerwinkle, MD

UNC rs-fMRI Clinical Service And Neuroscience Laboratory | UNC School of Medicine, Department of Neurology

Abstract

Acute brain injury (ABI) is often accompanied by suppression of consciousness. One of the frequent contributing factors of reduced consciousness and long-term dysfunction are seizures. While the injuries are often deeply located, where seizures may be occurring, electroencephalography (EEG) techniques may miss these because EEG only measures the brain's most exterior few millimeters of brain tissue. Thus, another seizure-activity biomarker without special limitation is needed. Resting state functional magnetic resonance imaging (rs-fMRI) detects seizure networks in those with epilepsy, and by case reports, may be similarly useful in ABI. However, as a first step, determining the prevalence and association of rs-fMRI seizure networks in relation to EEG findings is needed, which is the goal of this study. In ABI patients, we hypothesized that rs-fMRI seizure networks would be more prevalent and associated with EEG positive seizures; and that a smaller but significant portion of those with no seizure by EEG would also have seizure networks.

Background

Epilepsy, characterized by recurrent seizures, is a neurological disorder affecting millions worldwide. Despite advancements in treatment, a significant proportion of patients continue to experience uncontrolled seizures, highlighting the need for a deeper understanding of the underlying pathophysiology. Seizures arise from abnormal synchronized neuronal activity, often propagating through distinct brain networks.

Traditionally, the gold standard for diagnosing and characterizing seizures has been EEG. While EEG provides valuable temporal information during seizure events, it may miss underlying network abnormalities and lacks spatial resolution.

In recent years, functional magnetic resonance imaging (fMRI) has emerged as a promising tool for mapping brain networks involved in epilepsy. Resting-state fMRI captures intrinsic brain activity patterns by measuring fluctuations in blood oxygen level-dependent (BOLD) signals during rest. This technique enables the identification of functional connectivity networks and alterations associated with various neurological conditions, including epilepsy.

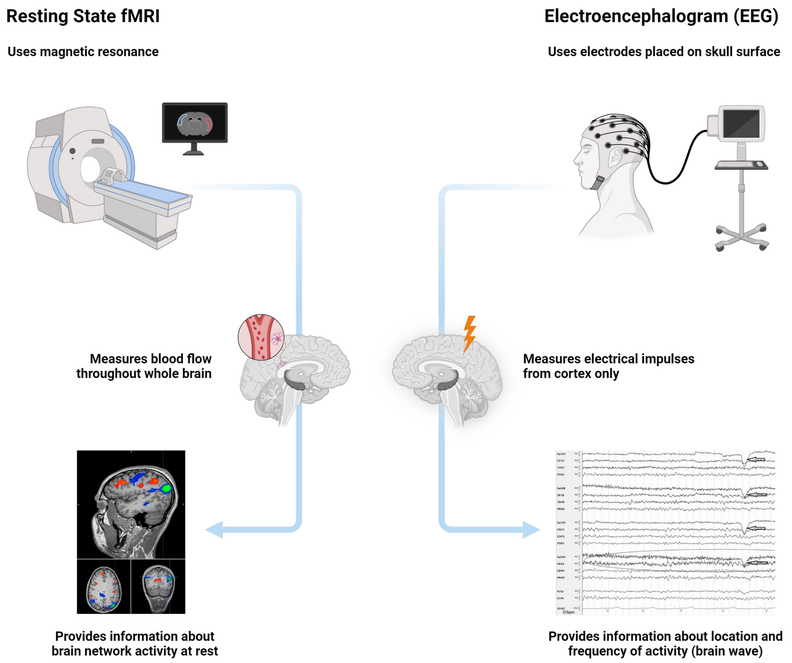

Fig. 1 – Comparison of rs-fMRI and EEG modalities

Methods

This retrospective study includs consecutive ABI patients who underwent both rs-fMRI and continuous video EEG during ICU hospitalization. Data were collected from electronic medical records of patients admitted between March 8th, 2018 and November 12th, 2023. Inclusion criteria encompassed ABI patients of all ages who had both EEG and rs-fMRI within the study period, while exclusion criteria comprised pre-existing epilepsy or lacking both EEG and rs-fMRI data. EEG reports were retrieved and reviewed for seizure presence and localization, while rs-fMRI data were acquired during routine clinical care. After review, 159 patients were included in the final cohort, with an average 14-day interval between EEG and rs-fMRI exams. Data underwent preprocessing for quality and consistency. Functional connectivity patterns were assessed to investigate synchronous network alterations during ictal and interictal states. Statistical analysis will be focussed on identifying seizure networks within rs-fMRI data using EEG-confirmed seizure (EEG+) epochs as reference points.

Demographic and Clinical Data	Results (n = 159)
Age (At admission), range (years)	0 – 60.77
Sex, n (%)	
Male	68 (42.77)
Female	91 (57.23
Ethnicity, n (%)	
Asian	7 (4.43)
Black/ African America	22 (13.92)
American Indian/ Alaskan Native	10 (6.33)
White/Caucasian	74 (46.84)
Hispanic or Latino	36 (22.78)
Other	9 (5.70)
ABI Etiology, n (%)	
Traumatic Brain Injury (TBI)	43 (27.04)
Hypoxic Ischemic Encephalopathy (HIE)	74 (46.54)
Seizures	18 (11.32)
Viral/Bacterial Infection	9 (5.66)
Hemorrhage	15 (9.43)

Fig. 2 – Participant demographic overview

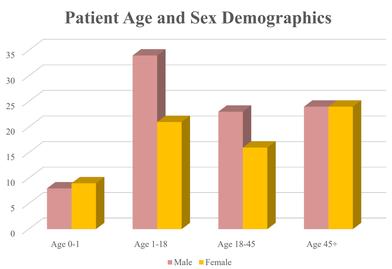

Fig. 3 – Participant age and sex demographic overview

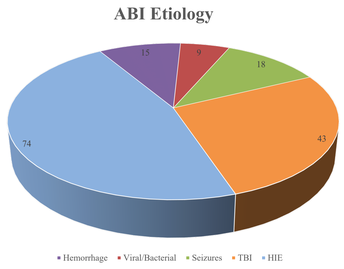

Fig. 4 – Participant ABI etiology overview

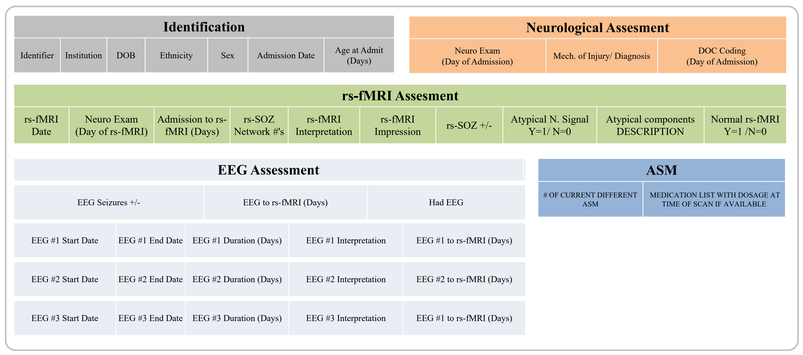

Fig. 5 – Overview of particpant data collection methods

Objectives

1. **Collection of Seizure Frequency Results:** Compile the frequency of seizure networks from two separate and distinct neurodiagnostic modalities, rs-fMRI and EEG, focusing on individuals hospitalized in the ICU following ABI.
2. **Comparison of Seizure Network Prevalence:** Focus on comparing EEG results that show seizure networks (EEG+) and those that do not (EEG-) to rs-fMRI's results showing seizure networks (RS+) and those that did not (RS-).
3. **Collect and Analyze Potential Variables:** By collecting clinical data throughout patients' care timeline, including anti-seizure medication (ASM), follow up visits, time duration between admission and diagnostic testing, we aim to better understand what variables may affect the prevalence of seizure networks in both rs-fMRI and EEG results.
4. **Deepen Understanding of Epilepsy Pathophysiology:** By elucidating personalized seizure network patterns, we seek to contribute to a deeper understanding of epilepsy's network pathophysiology and identify potential targets for tailored therapeutic interventions

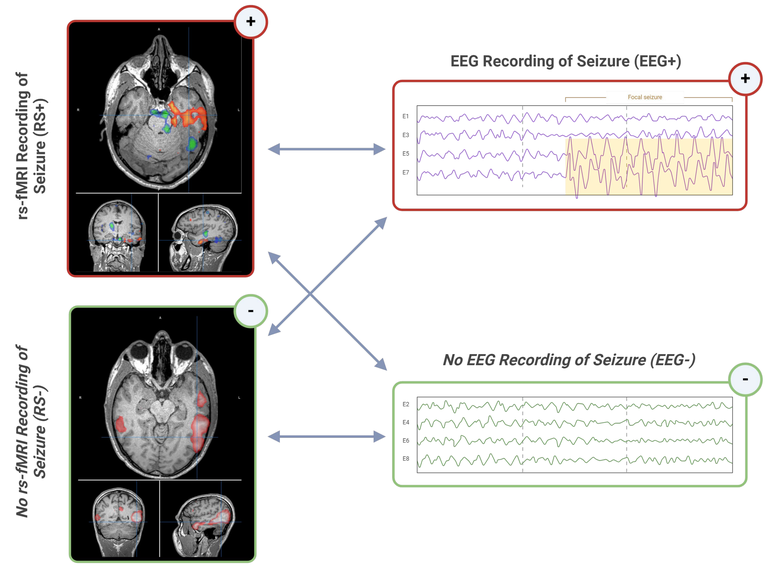

Fig. 6 – Seizure network prevalence inter-modality comparison overview

Discussion

In our ongoing retrospective study, we aim to assess the prevalence and association of rs-fMRI seizure networks in ABI patients in comparison to EEG findings. While our findings to date suggest that rs-fMRI may offer complementary information to EEG, detecting seizure networks beyond the spatial limitations of EEG, it's important to note that this project is still in progress. Preliminary results indicate a significant proportion of ABI patients with rs-fMRI seizure networks even in the absence of EEG-confirmed seizures, highlighting the potential of rs-fMRI as a sensitive biomarker for seizure activity.

References

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