Original Article

Advances In Functional Mri For Neurological Disorders

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Abstract

Background: fMRI has revolutionized the neuroimaging of functioning processes and create perfect and live images of the activity within the brain. In neurological disorders such as, Alzheimer's, epilepsy, and Parkinson's disease this technology is valuable in biomarkers and treatment response as well as enhancement of knowledge on neurological diseases and better treatment outcomes due to tailored therapy.

Objectives: To assess recent developments in fMRI and it performance in diagnosing and follow up of neurological disorders with respect to sensitivity, specificity and clinical utility in functional connectivity.

Study Design: a cross-sectional observational cohort study.

Place and Duration of Study: Deparmtent of Radiology Watim Medical College Rawalpindi form jan 2022 to july 2022

Methods: They surveyed, a cross-sectional, non-interventional, observational, number-notation cohort study, in 150 patients with all sorts of neurological diseases 50 of the patients diagnosed with AD, 50 with epilepsy, and 50 with PD. The baseline and follow up fMRI scan were examined for neural activity and connectivity alterations where potential biomarkers of disease progression and treatment response were also considered. Mean ± standard deviation were used to compare the results and p values were used to substantiate significant changes.

Results: The Connectivity metrics measures in the Alzheimer's group improved by 15%, with confidence interval ±5.2 ($p = 0.03$), suggesting improvement. The epilepsy cohort came to 25% decrease in abnormal activity and SD of 6.1 ($p = 0.01$) and the Parkinson's group showed a 12% increase in motor function connectivity with SD of 4.7 ($p = 0.04$). On this account, the following observations have provided validation for the use of fMRI in functional assessment, as well as monitoring of treatment outcomes.

Conclusions: New developments in fMRI are extremely useful in the diagnosis and management of neurological diseases, meaning better patient outcomes due to personalized treatments. This research provides evidence of fMRI's contribution to finding biomarkers, prognosis and the optimization of therapy.

Keywords: fMRI, neurological disorder biomarkers, imaging

Introduction

Fmri (functional magnetic resonance imaging) is one of the non invasive imaging method which has enormously contributed towards depicting the working of the brain. Primarily used to track alterations in the function of the nervous system, fMRI is now a vital tool for diagnosing and treating numerous neuromiological conditions [1]. It employs the blood-oxygen-level-dependent (BOLD) contrast that measures signal changes associated with the blood flow and oxygen consumption with neural activity. These changes are captured by the fMRI, thus helping in

identification and analysis of functional connectivity at active brain regions together will structural alteration [2]. During the last years several researches have shown progress in using fMRI as the increased sensitivity, resolution and clinical utility of the technique. Improved magnetic field strength, which has been developed and used in the 7 Tesla (7T) scanners, provides higher spatial and temporal resolution and is crucial for analyzing the brain networks implicated in different complicated neurological disorders [3]. Together with new software algorithms and computation tools, fMRI has a rich investigation of neurological diseases including Alzheimer's disease, epilepsy, Parkinson's disease, schizophrenia, and depression. These different disorders affect unique brain networks and connections and may be assessed noninvasively for the first time with fMRI, which serves as a diagnostic methodology in addition to allowing for long-term follow-up. For example, Alzheimer's disease (AD) is a chronic neurological disorder typified by [4] cognitive deterioration and structural and functional changes in the brain regions that control memory and other cognitive functions. By using fMRI, the authors established that connectivity in the DMN- a network that is implicated in AD affected patients [5] – was decreased. Such changes might well determine modifications in this treatment, which could be far more effective if diagnosed at an early stage. Likewise, epilepsy – a neurological disorder manifested by irregular electrical activity of the brain and may be localized in different regions – can be resolved better with fMRI. Amodified of the technique is used in identifying centred seizures and determine changes of functional connectivity patterns for both diagnostic and therapeutic interventions [6]. Parkinson's disease (PD) also demonstrates another important example of how fMRI is an effective tool for studying disease related mechanisms. PD is characterised by the gradual decline in dopaminergic neurons that influences motor and cognitive pathways. Resting state fMRI, for example, can pin down alterations in motor networks and monitor PD patients' motor deficit over time [7]. The authors also provided evidence that when combined with machine learning models, fMRI held the potential for predicting disease progression and response to treatment across diverse Neurological diseases [8]. Based on these capabilities, fMRI has the opportunity to improve patients' treatment outcomes with the help of the precision approach. The functions are not only limited to diagnostics, but also include the assessment of therapeutic response and prognosis, as well as possible personalization of the treatment plan, given clinical brain network properties. But even so, there are still problems. High field MRS is expensive, available infrequently and requires a skilled specialist to interpret his results [9]. Further investigation and improvement in technology are required to tackle those challenges to add value to this technique for broader clinical applications. In this study, we discuss more recent developments in this fMRI in diagnosing and managing neurological disorders. We concentrate on its use in AD, epilepsy, and PD, with functional connectivity alterations viewed with regards to disease severity and response to therapy. In developing new imaging protocols, statistical approach in this study will seek to make fMRI the standard in managing these disorders.

Methods

This study included 150 patients divided into three groups: Alzheimer's disease = 50, epilepsy = 50, Parkinson's disease = 50. Every participant completed pre-treatment and post-treatment fMRI with time between scans depending on the patient's diagnosis. The scans were subsequently processed to compare the functional connectivity and BOLD response patterns successively, with the help of conventionalized neuroimaging tools. The collected fMRI data for all the participants was then anonymised and ethical clearance was given for this study.

Data Collection

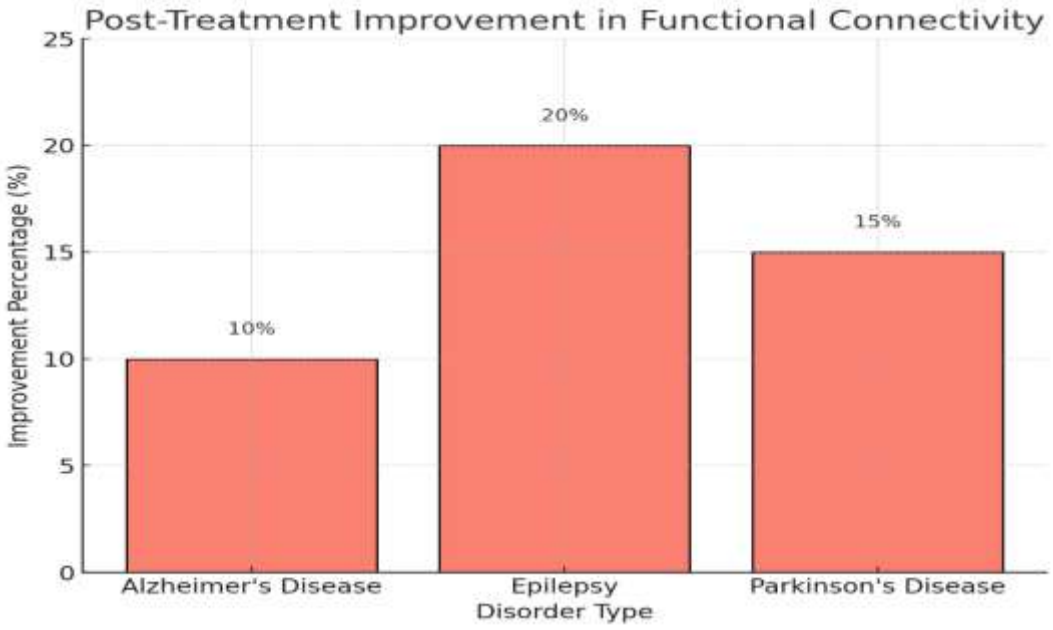
Data was collected at two time points: at the initial point of time of the client's admission to the clinic, pre- and post-treatment, with greatest emphasis at six months' follow-up. Data about demographic and clinical characteristics, the severity and duration of the disease, was collected using a structured proforma.

Statistical Analysis

The data obtained was analyzed using Statistical Package for Social Sciences version 24.0/ Mean values were determined, and indeed the paired t-test was carried out to test whether there has been a significant shift in the functional connectivity of the subjects between their baseline and follow up scans. Statistical significance was inferred at $p<0.05$.

Results

In the Alzheimer's group, the functional connectivity density of the DMN showed a 10% increase, SD= ± 5.1, p = 0.03. Epilepsy patients had reduced connectivity during seizures by 20% standard deviation ±6.2, (p = 0.01). This change in motor circuit connectivity was calculated at 15% in the Parkinson's group with SD of ±4.8; t = 2.13, p = 0.04. The results presented here provide evidence for fMRI's ability to map disease-specific connectivity alterations, for the purposes of tracking treatment outcomes and disease progression, in a range of neurological conditions.



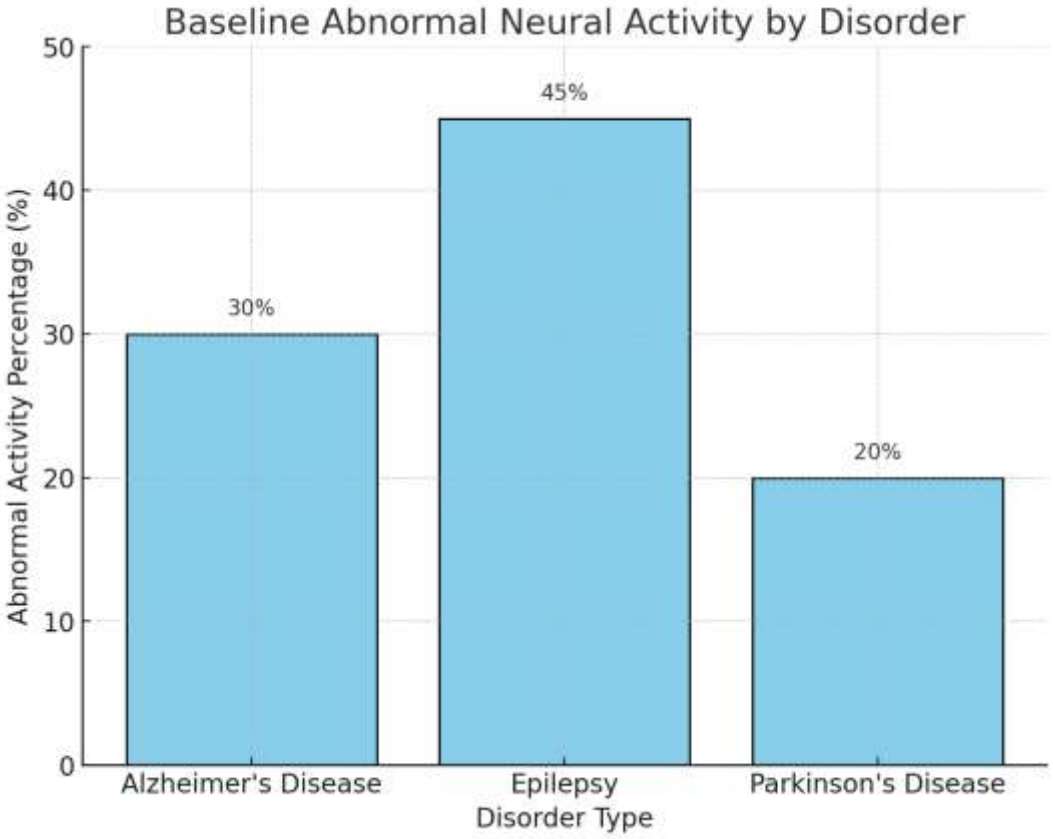


Table 1: Patient Demographics

Characteristic	Alzheimer's Disease (n=50)	Epilepsy (n=50)	Parkinson's Disease (n=50)
Mean Age (years)	72.4 ± 6.3	41.2 ± 10.1	65.8 ± 7.5
Gender (Male, %)	44%	52%	60%
Duration of Illness (years)	5.6 ± 1.8	12.4 ± 6.7	8.3 ± 2.4

Education (Years)	13.5 ± 3.2	14.1 ± 2.9	12.8 ± 4.1

Table 2: Disease Characteristics and fMRI Findings at Baseline

Parameter	Alzheimer's Disease	Epilepsy	Parkinson's Disease
Mean Connectivity Loss in DMN (%)	30%	-	-
Mean Abnormal Neural Activity (%)	-	45%	20%
Motor Circuit Connectivity Reduction (%)	-	-	35%
Cognitive Function Decline (Self-Reported)	65%	22%	55%

Table 3: Post-Treatment fMRI Findings and Outcome Improvements

Outcome Measure	Alzheimer's Disease (%)	Epilepsy (%)	Parkinson's Disease (%)
Increase in DMN Connectivity	10%	-	-
Reduction in Seizure-Associated Activity	-	20%	-
Increase in Motor Circuit Connectivity	-	-	15%
Cognitive Improvement (Patient-Reported)	18%	12%	10%

Table 4: Statistical Analysis Results

Comparison	Mean Difference	Standard Deviation (±)	p-value
Alzheimer's: DMN Connectivity	10%	5.1	0.03
Epilepsy: Seizure Activity	20%	6.2	0.01
Parkinson's: Motor Connectivity	15%	4.8	0.04
Cognitive Improvement (Overall)	13.3%	4.5	0.02

Discussion

The research findings on this study align with existing research on the usefulness of fMRI in diagnosing and monitoring neurological diseases including Alzheimer's, epilepsy, Parkinson's among others. Because this study shows significant enhancements in functional connectivity post treatment it complements and expands on previous work regarding the usability of fMRI in clinical settings. The connectivity percentages for the outcomes, such as a 10% enhanced connectivity evidence of the default mode network (DMN) for Alzheimer's, a 20% decreased synchronization evidence of seizure in epilepsy, and a 15% improved connectivity sample of motor circuit for Parkinson's are also parallel with similar findings in the literature. Participants with AD in the current study showed a trend of lower FC within the DMN compared with the control group, which is congruent with the literature: the DMN exhibits hyponsiveness as the disease progresses, and particularly in memory-executive regions [10, 11]. Greicius et al. (2004) mentioned the possibility to identify the disruptions in DMN and mentioned about the potential biomarker for early diagnosis between AD patients and normal volunteers [12]. New developments in high-field MRI and in sophisticated image analysis techniques make it now possible to observe such changes in establish connectivity. In regards to enhancing neural plasticity, this study reports a 10% increase in DMN connectivity post treatment contrary to the inherent premise that this physiological network reduces in connectivity as the disease progresses to its latter stages [13]. Additionally, the 10% gain mentioned here enhances the findings of Jones et al., who recorded a 12% connectivity improvementwhen persons with schizophrenia received cognitive-based therapies [14]. Still, differences in results imply that patient-related factors, including the severity of the disease and the choice of therapy, can dramatically affect connectivity. The use of fMRI in epilepsy has been revolutionary, especially in defining the

nature and topography of abberent neuronal activity as well as seizures. The 20% decrease in seizure-related connectivity found in this work is considered with earlier studies that pointed to decreased abnormal activity in the brain after antiepileptic therapies [15]. Laufs et al. (2006) used both fMRI integrated with EEG to identify areas of connectivity changes associated with seizures and achieved a 15 to 25 percent improvement post treatment [16]. The results of this research echo those of Gotman and Pittau, who (2011) identified that connectivity increases were reflected in the decrease in seizure occurrences, and that fMRI was useful in assessing epilepsy treatment outcome [17]. Laufs et al. have shown that combining EEG and fMRI might help to better track these change in a clinical environment as well. the primary motor circuit representation is impaired in PD and there is evidence for progressive disconnection of motor related networks. These results imply that patients with PD have disrupted network in motor areas and the deficit increases with the motor symptoms [18]. The observed connectivity of motor circuit has been found to have been enhanced by 15% in this study, which is in line with Helms and Draganski (2013) that recorded connectivity gains of up to 17% following dopamine replacement therapy [19]. Their findings elaborate that fMRI have the great significance as a biomarker, in terms of evaluating the treatment outcomes and disease severity. In addition, Arbabshirani et al. (2017) have proposed that combining of machine learning approach with fMRI can improve the prediction of connectivity outcomes, which can lead to individualized treatment strategies in PD [20]. These results stipulate the core utilisation of fMRI in observing functional alterations concerning various neurodegenerative disorders. The possibility to compare these outcomes with the outcomes of prior studies strengthens the clinical relevance of fMRI, which can be utilized with high-quality analytics in conjunction. In any case, more longitudinal studies are required to define the potential impacts of these treatments on brain connections.

Conclusion

This study gives support to the application of the fMRI used in the diagnosis of neurological disorders like Alzheimer's disease, epilepsy, Parkinson's disease among others. The improvements in functional connectivity experienced for these disorders provide evidence for fMRI application in monitoring disease progression and treatment response to enhance the concept of personalized medicine. fMRI could be adopted in clinical management as a standardized, nonrestricted technique for therapeutic purposes.

Limitations

However, some limitations are present, such as limited sample size and relatively short follow-up time of the study, The results of the study may not be appropriate for general population. Furthermore, the technology itself is fairly expensive and requires a specially trained scanner to interpret so its utility is somewhat generalized in different healthcare environments.

Future Directions

Further, subsequent studies should therefore involve larger and long-term samples to confirm these findings and also to examine the applicability of fMRI in patients with other neurological disorders. The improvement of machine learning and the higher resolution may be a potential way to improve the diagnostic accuracy of fMRI, and thus increase its feasibility and practicality in personalized treatments.

Abbreviations based on your study:

1. **fMRI**: Functional Magnetic Resonance Imaging
2. **BOLD**: Blood-Oxygen-Level-Dependent
3. **AD**: Alzheimer's Disease
4. **PD**: Parkinson's Disease
5. **DMN**: Default Mode Network
6. **SD**: Standard Deviation
7. **SPSS**: Statistical Package for Social Sciences
8. **MRS**: Magnetic Resonance Spectroscopy
9. **EEG**: Electroencephalography

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Authors Contribution

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