Examining motor network disturbances in patients with frontal lobe epilepsy using fMRI

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Frontal lobe epilepsy (FLE) is a seizure disorder that is commonly associated with functional motor deficits. While the source of these deficits is unknown, it is postulated that repeated seizure activity within the frontal lobe may impact the proximal motor network. To examine this hypothesis, motor networks were compared between participants with right FLE, left FLE, and controls using two methods. The first was a task-based fMRI study of brain activation during simple and complex motor tasks, and the second was a resting-state fMRI study of motor network connectivity. Both studies revealed motor network disturbances in participants with FLE, disturbances that were more pronounced in participants with higher seizure burden factors. These results demonstrate that motor networks are altered in patients with FLE, providing a possible underlying cause behind functional motor deficits in these patients.

Keywords: Epilepsy; motor system; resting state; functional connectivity; frontal lobe


Frontal lobe epilepsy (FLE) is the second most common type of focal epilepsy [1], and patients with FLE commonly experience deleterious motor symptoms, including impaired motor coordination, dexterity, and planning [2,3]. Despite the impact on brain function, the mechanisms underlying motor deficits remain poorly understood.

Previous research has suggested that such impairments in children with FLE may be a result of disrupted functional connections within pertinent brain networks [4,5]. Furthermore, the extent of these disruptions was associated with an earlier age of seizure onset [5]. Other studies have demonstrated changes in brain recruitment patterns during motor tasks in patients with FLE, and these changes were reported to change over time [6]. However, no studies have examined a group of adult patients with FLE to examine changes in the organization of, and functional connections between, motor regions in the brain. Additionally, to further our understanding of motor deficits in patients with FLE, we compared the changes we observed to the degree of functional motor impairment, as well as a variety of seizure burden factors to explore possible underlying causes.

In our first study [7], we completed a resting-state fMRI scan on twenty-one participants between the ages of 16 and 65 (seven with right FLE, six with left FLE, and nine non-epileptic controls). Resting-state fMRI compares baseline fluctuations in brain activity as measured by fMRI, and deems regions that are fluctuating together as 'functionally connected'. We examined changes in
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functional motor network connections in FLE by studying resting state connectivity using a region of interest (ROI) within the healthy hemisphere sensorimotor cortex, and comparing to resting state connectivity of every other brain region to this ROI. We found that when compared to controls, patients with FLE had reduced connectivity between left and right hemisphere sensorimotor regions, and that this reduction was exacerbated in patients with a greater number of lifetime seizures.

Our second study [8] examined cortical motor organization using a task-based fMRI approach in twenty-seven participants between the ages of 16 and 65 (eleven with right FLE, six with left FLE, and ten non-epileptic controls). Participants performed two separate tasks with each hand separately, and again with both hands together. The first required participants to tap their fingers in time with a visual stimulus and the second required participants to perform different hand shapes in time with a visual stimulus. Overall, we discovered that while performing tasks, patients with right FLE demonstrated decreased brain activity in the epileptic hemisphere and increased brain activity in the healthy hemisphere when compared to controls. Unfortunately these findings were not found to the same extent in patients with left FLE, possibly due to the low number of participants. Additionally, in both FLE groups we found that these changes directly correlated with the number of months since the patient had last had a seizure. This indicates that patients that had experienced a recent seizure relied more on the sensorimotor cortex of the healthy hemisphere during task performance, compared to patients that were seizure free for a longer period of time.

Both of these studies demonstrate that differences in motor network recruitment and connectivity patterns exist in patients with FLE when compared to non-epileptic controls. Additionally, the extent of dissociation between contralateral sensorimotor cortices, as well as degree of activation during task performance, was directly associated with different factors related to the burden of seizures experienced by patients. Due to the nature of our study, we cannot demonstrate a causal relationship between the two variables. However, an intracortical microstimulation study in rats showed that repeated seizure activity near the sensorimotor cortex leads to impaired interictal motor performance, along with alterations of motor cortex maps, demonstrating a cause and effect relationship between seizure activity and motor performance [9]. This indicates that there may also be the same relationship present in humans. A potential future study to provide further insight into the question of cause and effect would be to repeatedly scan the same individual over time, and determine whether fMRI findings correlated with the number of seizures they had experienced since their last visit, or the number of months they had remained seizure free.

One of the limitations of both these studies was patient inhomogeneity (e.g., duration of epilepsy, seizure frequency, age of onset, etc.). We accounted for left and right hemisphere seizure foci within the frontal lobe, however the precise location of the seizure focus within the frontal lobe varied between patients. Additionally, while we examined associations between our results and factors such as age at epilepsy diagnosis, years since diagnosis, total lifetime seizures, seizures in past year, and the number of months since the last seizure, these variables could still influence the final results.

Our studies emphasize the fact that changes in underlying motor networks likely play a role in the motor impairments experienced by patients with FLE. Additionally, it appears that certain factors are associated with these underlying network changes (i.e., period of seizure freedom, number of seizures in lifetime). This knowledge provides groundwork to continue exploration in a greater number of individuals, which may eventually lead to the development of interventions to reduce the deleterious effects of seizures on motor function.

Conflicts of Interest

The authors declare that they have no conflicting interests.

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