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Investigating Neural Plasticity and Cortical Reorganization via fMRI Following Tumor Resection

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Investigating neural plasticity and cortical reorganization via fMRI following tumor resection

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Abstract

The brain is known to dynamically repair and reorganize itself after sustaining damage. Patients undergoing tumor resection display cortical reorganization, but the specific processes remain relatively unknown. Our longitudinal study investigates the effectiveness of task-based functional magnetic resonance imaging (fMRI) in detecting recovery of eloquent function in brain tumor patients. We assessed the changes in brain activity as the brain recovers from tumor growth and surgery through the correlations between neuropsychological analysis and changes in fMRI activation.

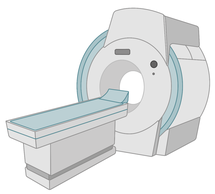
Introduction

- Despite the damage caused by tumors. brain networks display reorganization by redirecting function to healthy areas of the brain.[1]
- fMRI has shown to be a valuable tool in allowing us to visualize pathways and networks formed during recovery.[2-4]
- When motor control is compromised, the brain initiates a shift of hemispheric activation from contralateral to ipsilateral routes.[5,6]
- Hemiparetic patients with hand paralysis showed cortical reorganization accompanied with recovery of the affected hand.[3]
- fMRI language mapping showed a migration of speech supplemental motor area from the dominant left hemisphere to the nondominant hemisphere.[7]
- Increased activation of the right-sided regions corresponding to Broca's and Wernicke's areas has also been observed via fMRI in patients with tumors located near speech centers.[2]
- We hypothesize that fMRIs can detect and provide insight into the recovery and reorganization of eloquent function in the brain following tumor resection.

Methods

- Subjects: 13 patients with tumors located in eloquent areas of the brain
- Patients performed motor tasks, language tasks, and sensory tasks in MRI scanner.
- Patients also underwent neuro-psychological exams evaluating language, memory, speeded processing, executive function, basic attention, dexterity, and quality of life.

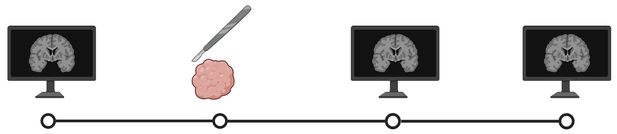
MRI Scanner



Motor tasks:
- Finger tapping
- Foot tapping
- Lip movement
- Face movement

Language tasks:
- Object naming
- Word mapping
- Word generation

Sensory task:
- Administration of electrical stimuli



Pre-operation
- Imaging via fMRI
- Neuropsychological exam

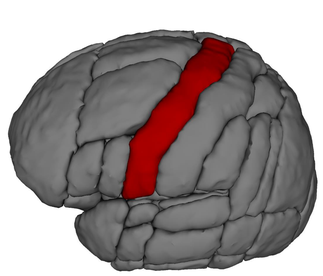
Tumor resection

2 months post-operation
- Imaging via fMRI
- Neuropsychological exam

6 months post-operation
- Imaging via fMRI
- Neuropsychological exam

Results

The laterality of motor activation positively correlated to hand dexterity scores. Healthy individuals are known to have high motor lateralization such that the left side of the brain predominantly controls the right-sided motor movements and vice-versa. In our cohort, brain tumor patients with decreased ability to perform motor movements showed decreased laterality of motor function activation. In these patients the damaged hemisphere was not able to adequately perform motor movements and the opposite hemisphere had to be recruited.



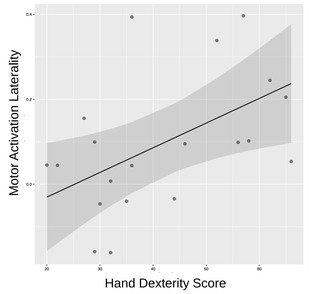


Figure 1. (left) The precentral gyrus is the brain region primarily responsible for controlling motor movement. The laterality of the motor activation was measured as the mean fMRI finger-tapping task activation in the precentral gyrus ipsilateral to the tumor minus the mean activation of the precentral gyrus contralateral to the tumor. (right) The laterality of the motor activation was positively correlated with hand dexterity. This indicates that patients with lower laterality of motor function are not able to perform hand dexterity tasks as well as those with higher laterality.

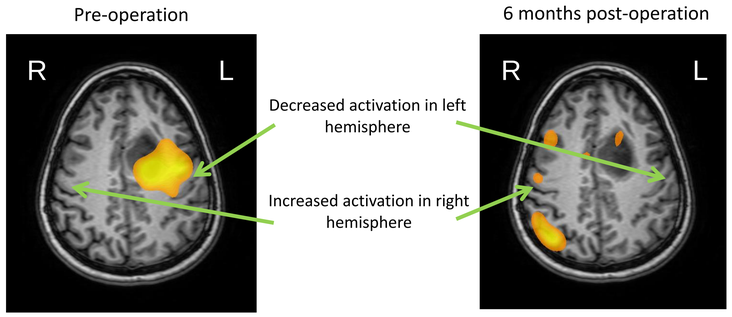


Figure 2. Activation fMRI maps from a brain tumor patient while performing finger-tapping task. (left) This patient had high lateralization of finger-tapping task activation prior to tumor resection. (right) 6 months following resection, this patient had seen markedly decreased lateralization of finger-tapping task activation. This decrease in lateralization corresponded to decreased hand dexterity as measured by performance during neuropsychological testing.

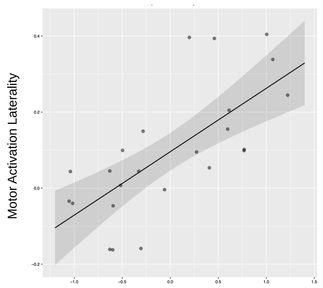
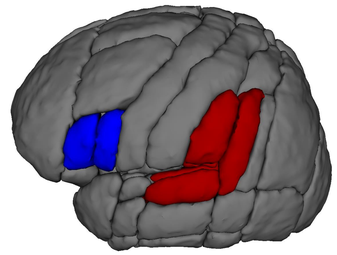


Figure 3. Laterality of motor activation also positively correlated to overall cognitive functioning as measured by the normalized average score of all cognitive domains examined during the neuropsychological evaluation. This indicates that in brain tumor patients the laterality of motor function may be able to serve as a marker for brain damage due to tumor invasion or treatment. While not shown here, laterality was also highly correlated to scores for executive functioning and speeded processing. The relationship between laterality and these processes may be tied to the patient's ability to adequately understand and perform tasks both in the scanner and during neuropsychological evaluation.

Future Directions

- Analysis of the language fMRI data and their correlation to neuropsychological scores is ongoing.
- Initial results may indicate that the laterality of language activation is correlated to language abilities.
- Changes in the laterality of Broca's area during the word mapping task appear to be positively correlated with changes in neuropsychological language scores. For example, one patient with a left frontoparietal tumor, showed recovery from expressive aphasia in clinical exams that corresponded with increased laterality and cognitive scores.



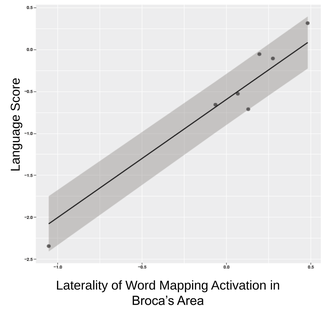


Figure 4. (right) Primary areas of the brain responsible for language function. Broca's area is shown in blue and some of the primary receptive language areas are shown in red. Broca's area is known to be associated with the the ability to speak. (right) Initial results show that the laterality of the Broca's region may be positively correlated to overall performance of tasks associated with language abilities during neuropsychological evaluation.

Conclusions

- Reorganization of function can be observed by measuring the lateralization of fMRI task activations.
- Lateralization of motor activation in fMRI may prove to be a valuable marker for not only motor impairment but also executive functioning, speeded processing, and overall cognitive impairment.
- Future research will aim to explore the reorganization of language activations in these brain tumor patients.

References

1. Duffau, H., Acute functional reorganisation of the human motor cortex during resection of central lesions: a study using intraoperative brain mapping.J Neurol Neurosurg Psychiatry, 2001. 70: p. 506-513.
2. Gębska-Kośla, K., et al., Reorganization of language centers in patients with brain tumors located in eloquent speech areas –A pre-and postoperative preliminary fMRI study.Neurologia i Neurochirurgia Polska, 2017. 51(5): p. 403-410.
3. Jang, S.H., et al., Cortical Reorganization of Hand Motor Function to Primary Sensory Cortex in Hemiparetic Patients Witha Primary Motor Cortex Infarct.Archives of Physical Medicine and Rehabilitation, 2005. 86(8): p. 1706-1708.
4. Voets, N.L., et al., Characterising neural plasticity at the single patient level using connectivity fingerprints.NeuroImage: Clinical, 2019. 24: p. 101952.
5. Yoshiura, T., et al., Increased activity of the ipsilateral motor cortex during a hand motor task in patients with brain tumor and paresis.American Journal of Neuroradiology, 1997. 18(5): p. 865-869.
6. Caramia, M.D., et al., Ipsilateralmotor activation in patients with cerebral gliomas.Neurology, 1998. 51(1): p. 196-202.
7. Chivukula, S., et al., Contralateral functional reorganization of the speech supplementary motor area following neurosurgical tumor resection.Brain and Language, 2018. 183: p. 41-46.