Pre-Surgical fMRI Mapping of Language: Accuracy of Mapping Language Regions in Patients with Mass Lesions

Thrikutam, N. BS, O'Neill, T. MD, Patel, T. MD, Yetkin, Z. MD

UT Southwestern Medical Center

Introduction

Aims: The objectives of this project were (1) To determine the clinical applicability and reproducibility of the proposed language tasks. (2) To document the accuracy of fMRI mapping of language regions compared to surgical outcomes.

Background: A panel of language tasks has been utilized in determining essential language regions and has shown to be more effective than any single test by itself. However, the accuracy and reproducibility of pre-surgical mapping of language in patients with mass lesions near language areas has not been optimized. Prior work completed by this group has since demonstrated the reproducibility of the proposed language tasks. Patients with symptomatic mass lesions are likely to undergo brain surgery to remove the lesions. Language centers are left dominant in a majority of patients. As such, damage to the language centers and thus damage to language comprehension and speech production are complications of brain surgery in the dominant hemisphere. The clinical applicability of using pre-surgical fMRI mapping to determine the location of critical language centers is that this information can be utilized by the neurosurgeon to avoid resection of or damage to critical speech areas. Thus, accurate pre-surgical fMRI mapping of language can avoid the development of any new post-surgical speech deficits.

Methods

We performed a retrospective review of 19 patients with left-sided, intra-axial, space-occupying lesions in whom a battery of language tasks (object naming, sentence completion, reading, word fluency, category fluency, verb generation, object naming and passive auditory) were performed for pre-operative planning. All patients were scanned on a 3T MRI with acquisition of GE-EPI BOLD sequences (TR=1.875 sec, 2 min 15 sec) with a block design consisting of equal and alternating blocks of task and rest, respectively. Activation maps were generated and overlayed on anatomic images and 3D surface rendered images of the brain using Invivo Dynasuite Neuro and AFNI.

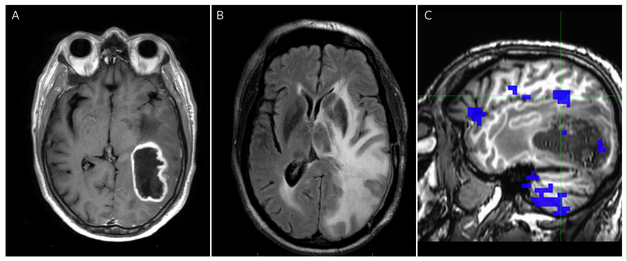

Figure 1. Axial T1 post-gadolinium (a) and axial T2 FLAIR (b) demonstrate a peripherally enhancing, centrally necrotic intra-axial mass with surrounding T2/FLAIR hyperintensity centered in the left temporal lobe. Sagittal T1 anatomic images with overlayed thresholded color activation map of a reading task, p=0.005 (C) depicting Wernicke's activation in the postior left superior temporal gyrus, displaced superiorly by the space-occupying intra-axial mass in the left temporal lobe.

Methods

Pre- and post-surgical language capabilities were determined based on examination of the patient's chart. Any information that could not be obtained from the chart was obtained directly from the operating neurosurgeon. The magnitude of new language deficits was quantified as in Table 1.

Severity of New Language Deficit	Description
None	No changes in language capabilities from pre-surgical to post-surgical documentation. If a patient had a pre-surgical language deficit then the magnitude of the deficit did not change post-surgically.
Mild	Post-surgical language capabilities are worse than pre-surgical language capabilities. However, Speech Language Pathology (SLP) was not consulted and improvements in language capabilities are noted after immediate post-surgical decline.
Moderate	Post-surgical language capabilities are worse than pre-surgical language capabilities. SLP was consulted. However, improvements in language capabilities are noted after immediate post-surgical decline.
Severe	Post-surgical language capabilities are worse than pre-surgical language capabilities. SLP was consulted. No improvements in language capabilities are noted at this time.

Table1. Language deficit severity scale.

If a patient had a pre-surgical language deficit then the magnitude of any new post-surgical language deficits (if present) are compared to the patients' pre-surgical baseline. Magnitude of new post-surgical language deficits in patients with pre-surgical language deficits are not compared normal language capabilities.

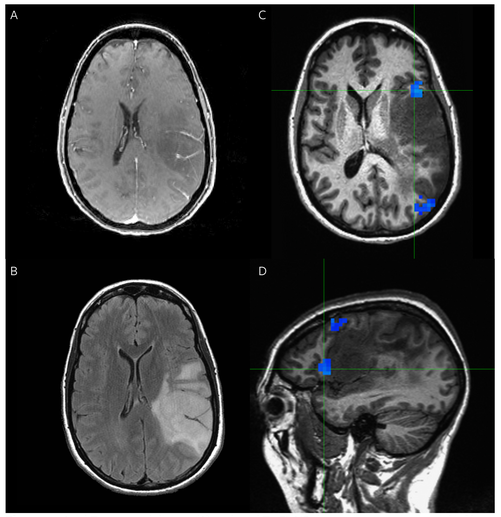

Figure 2. Axial T1 post-gadolinium (A) and axial T2 FLAIR demonstrate an intra-axial infiltrative mass with linear areas of enhancement centered in the posterior left frontal lobe. Axial and sagittal T1 anatomic images with overlayed thresholded color activation map of sentence completion task, p=0.005 (C and D) demonstrate activation in the left inferior frontal gyrus (Broca's area), abutting the anterior maring of the mass.

Results

19 patients, 11 female and 8 male, with mass lesions in the dominant hemisphere were included in this study. Patients in this study ranged from 25 to 64 years of age. Mass lesions in 6 patients were characterized as Arteriovenous Malformations (AVMs). The AVMs were located in the left temporal, frontal, and parietal regions. The remaining patients (13) had mass lesions characterized as tumors (benign or malignant). The tumors were located in the left temporal, frontal, and parietal regions. The tumors ranged from WHO grade 1 through WHO grade 4. Areas determined as Broca or Wernicke's Areas were correlated to surgical mapping and post-surgical outcome. To our knowledge, no permanent deficits have been diagnosed at this time. Of the 19 patients considered, only 13 patients went on to have surgery to remove the mass lesions. The other 6 patients either did not have surgery at all (managed with radiation/chemotherapy), could not be followed-up on (notes were not available), or had gamma-knife radiosurgery (as opposed to excisional surgery).

Subject ID	Age	Gender	Diagnosis/Pathology
1	57	M	left insular infiltrating glioma
2	63	F	left temporal high grade glioma
3	25	M	left frontal AVM
4	49	F	left parietal malignant neoplasm
5	47	M	left frontal glioma
6	37	F	left parietal enhancing lesion
7	49	F	left frontal AVM
8	50	F	left cavernoma
9	53	F	left infiltrating glioma
10	41	F	left posterior frontal AVM
11	45	M	left frontal cavernoma
12	51	F	left frontal AVM
13	49	M	left middle cranial fossa AVM
14	64	M	left temporal WHO grade 2 astrocytoma
15	62	M	left posterior temporal metastasis of lung adenocarcinoma
16	62	M	left temporal glioblastoma
17	59	F	left parietal AVM
18	42	F	left temporal pilocytic astrocytoma
19	26	F	left temporal oligoastrocytoma

Table2. Patient demographics.

Of the 13 patients that had surgery, only one (subject 14) was noted to have severe post-surgical language deficits. A majority of the patients (subjects 1, 4, 8, 9, and 13) did not have any new post-surgical language deficit. Subject 9 had a pre-surgical language deficit. However, post-surgical documentation does not note any worsening of the pre-surgical language deficit. Therefore, subject 9 was classified as having no new post-surgical language deficits. Three subjects (2, 11, 16) had mild new post-surgical language deficits. Finally, 4 subjects (5, 12, 17, 18) had moderate new post-surgical language deficits. In summary, 92% of patients either had no new post-surgical language deficits or had new post-surgical language deficits that later improved.

Conclusions

Functional MRI language mapping has been around for decades, the clinical contribution has not been adequately demonstrated. Preservation of essential language areas is paramount in the surgical resection of space-occupying intra-axial brain lesions in the dominant hemisphere. Language mapping with functional MRI contributes to pre-operative planning and helps the surgeon with patient selection for surgery, surgical approach, and in selecting patients for cortical mapping. Post-operative language deficits following resection of brain tumors in regions involved in language function has been reported in the literature to be as high as 16% in patients that did not have any preoperative language mapping. In our patients who had preoperative language mapping using fMRI with a battery of language tasks, the rate of post-operative language deficits was lower than that reported in the literature. However, these results are limited by a small sample size and limited comparison, but may serve as a baseline for further investigation. Although post-surgical outcomes are dependent on many factors including tumor biology/location/size, patient selection, and surgical technique, language mapping with funtional MRI may contribute to good overall clinical outcomes.

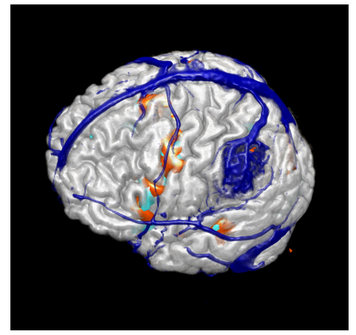

Figure 3. Surface rendered 3D image of the brain with venous overlay demonstrates a hypervascular intra-axial mass centered in the left inferior parietal lobe. Overlayed activation maps (orange = sentence completion, turqoise = word fluency) demonstrate Broca's area in the left inferior frontal gyrus and Wernicke's area in the posterior lateral left superior temporal gyrus.

References

1. Bookheimer S. Pre-surgical language mapping with functional magnetic resonance imaging. Neuropsychol Rev. 2007 Jun;17(2):145-55.
2. Cox RW. AFNI: software for analysis and visualization of functional magnetic resonance neuroimages. Comput Biomed Res. 1996 Jun;29(3):162-73.
3. De Witt Hamer PC, Robles SG, Zwinderman AH, Duffau H, Berger MS. Impact of intraoperative stimulation brain mapping on glioma surgery outcome: a meta-analysis. J Clin Oncol 2012;30:2559-65.
Giussani C, Roux F-E, Ojemann J, Sganzerla EP, Pirillo D, Papagno C. Is preoperative functional magnetic resonance imaging reliable for language areas mapping in brain tumor surgery? Review of language functional magnetic resonance imaging and direct cortical stimulation correlation studies. Neurosurgery. 2010 Jan;66(1):113-20.
4. Holodny AI, Schulder M, Liu WC, Maldjian JA, Kalnin AJ. Decreased BOLD functional MR activation of the motor and sensory cortices adjacent to a glioblastoma multiforme: implications for image-guided neurosurgery. AJNR Am J Neuroradiol. 1999 Apr;20(4):609-12.
5. Mueller WM, Yetkin FZ, Hammeke TA, Morris GL, Swanson SJ, Reichert K, et al. Functional magnetic resonance imaging mapping of the motor cortex in patients with cerebral tumors. Neurosurgery. 1996 Sep;39(3):515-20; discussion 520-1.
6. Nadkarni TN, Andreoli MJ, Nair VA, Yin P, Young BM, Kundu B, et al. Usage of fMRI for pre-surgical planning in brain tumor and vascular lesion patients: task and statistical threshold effects on language lateralization. Neuroimage Clin. 2015;7:415-23.
7. Roux F-E, Boulanouar K, Lotterie J-A, Mejdoubi M, LeSage JP, Berry I. Language functional magnetic resonance imaging in preoperative assessment of language areas: correlation with direct cortical stimulation. Neurosurgery. 2003 Jun;52(6):1335-45; discussion 1345-7.
8. Ruff IM, Petrovich Brennan NM, Peck KK, Hou BL, Tabar V, Brennan CW, et al. Assessment of the language laterality index in patients with brain tumor using functional MR imaging: effects of thresholding, task selection, and prior surgery. AJNR Am J Neuroradiol. 2008 Mar;29(3):528-35.
9. Sollmann N, Ille S, Hauck T, Maurer S, Negwer C, Zimmer C, et al. The impact of preoperative language mapping by repetitive navigated transcranial magnetic stimulation on the clinical course of brain tumor patients. BMC Cancer [Internet] 2015 [cited 2016 May 24];15. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4404089/
Zacà D, Nickerson JP, Deib G, Pillai JJ. Effectiveness of four different clinical fMRI paradigms for preoperative regional determination of language lateralization in patients with brain tumors. Neuroradiology. 2012 Sep;54(9):1015-25.

The authors have no financial disclosures.

Correspondence: Nikhitha.Thrikutam@UTSouthwestern.edu