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Presurgical mapping using functional magnetic resonance imaging (fMRI) in patient populations with neurological impairment can be challenging. Some of the challenges and potential solutions are discussed here within the context of our experience with presurgical fMRI mapping of adults and children at Barrow Neurological Institute at St. Joseph's Hospital and Medical Center in Phoenix, AZ.

Because of Barrow's philosophy of providing minimally invasive surgical interventions, presurgical mapping using fMRI has become an integral part of surgical planning for patients with brain tumors, aneurysms, anterior venous malformations, and other lesions that may impact cognitively eloquent regions.

All fMRI scans at Barrow are done on a 3.0T GE Signa HDxt scanner using an 8-channel head coil. Patients are referred for fMRI both as outpatients and inpatients, with most referrals received on an outpatient basis within one week of the planned surgery. For each exam, it is important that the patient understands and is able to participate with the tasks. Tasks are modified using step-down versions or other alterations depending on the level of impairment and other factors that can vary among patients. The structural scans used for neuronavigation within the surgical suite are acquired

## Special Considerations When Using Functional MRI as a Presurgical Mapping Tool



Dr. Leslie Baxter

Leslie Baxter, PhD, is an associate staff scientist and clinical neuropsychologist and directs the Neuropsychology Neuroimaging Laboratory in the Section of Clinical Neuropsychology at Barrow. She is also the principal investigator for the Barrow site of the multi-institutional Arizona Alzheimer's Research Consortium. Dr. Baxter received a bachelor's degree from the University of Michigan, a doctorate in Clinical Neuropsychology from the Chicago Medical School, and she completed a post-doctoral fellowship at Dartmouth.

Using state-of-the-art neuroimaging techniques, functional MRI and Diffusion Tensor Imaging, the Neuroimaging Lab studies both functional recovery and deterioration of the brain. Dr. Baxter also uses these techniques for clinical purposes to map cognitive functioning in brain tumor patients before they undergo surgery. She personally performs all of the exams to ensure that the patient understands and is able to participate with the tasks.



#### About the facility

The Barrow Neurological Institute of St. Joseph's Hospital and Medical Center in Phoenix, AZ, is internationally recognized as a leader in neurological research and patient care. Established in 1962 under the auspices of Dr. John Green, Barrow has been brought into the twenty-first century under the guiding influence of Dr. Robert Spetzler.

A 430,000 square foot tower dedicated to neurosciences opened at St. Joseph's in 2006. With 11 neurosurgical operating rooms and the first 3.0T GE intraoperative scanner, the Barrow has a focus on providing state-of-the-art neurosurgical interventional care.

Barrow treats patients with a wide range of neurological conditions, including brain and spinal tumors, cerebrovascular conditions, and neuromuscular disorders.

*U.S. News and World Report's* 2009 "Best Hospitals" ranking once again includes St. Joseph's Hospital and Medical Center.

in the same imaging session. fMRI data is analyzed and co-registered to the stereotactic image (either T1 or T2 scans) and uploaded to a Picture Archiving and Communication System (PACS) and sent to the operating room (OR). These evaluations are typically done several days prior to the surgery to allow for review and consultation with the treating physicians.

## Scanning strategies for maximum results

### Stimulus presentation

There are several commercially available choices for presenting the tasks to patients. These range from back-projection systems, in which the stimuli are presented so that the patient can see the information on a mirror attached to the head coil, to a number of different goggle and headphone packages. The preference at Barrow is to use a goggle/headphone system for a number of reasons specific to working with patients, especially children. Unlike research volunteers, many patients have MRI-related anxiety, or even mild claustrophobia, and some have not previously had a scan without the use of sedating medication.

We have found that many of these people are more relaxed when they have a limited view of the interior of the scanner. We have pictures of outdoor scenes (as well as a variety of "themed" pictures depending on the person's interests) that help the patient focus on something other than the scanner and also give an illusion of being in a more open environment. For children, we have had the best results when playing a cartoon or movie through the goggle system. Sometimes, it is best to have the movie running prior to sliding the head coil over the head of the child. We have found in our research study of children with traumatic brain injury that playing a children's movie, such as "Shrek," allowed us to perform approximately 45 minutes of structural scans, including a 10 minute high-resolution T1 scan, without any movement difficulties. (In fact, children with Attention Deficit Disorder were some of the least fidgety participants when they are watching movies.) Headphones allow for easier communication with the patients and the ability to present tasks aurally.

### Participant cooperation and quality control

At our center, patients are given a short visual task that consists of blocks of scenic pictures alternating with a crosshairs to produce real-time images of fMRI activity in the occipital lobe. This task accomplishes several goals for us. First, we take advantage of the BrainWave RT "real time" feature on the GE scanners to provide us with real-time quality control. The activation associated with the primary visual cortex is quite strong and generates good occipital lobe activity even with one "on-off" cycle; therefore, if a lack of activity is detected, we can immediately investigate any possible reasons, including equipment failure, patient cooperation (movement, somnolence, etc.), or other factors that can be corrected.

Because it requires no cognitive cooperation from patients beyond keeping their eyes open, it allows us to make these basic system checks without confounding cognitive factors. This task is also relaxing to most patients, which allows them to acclimate to the scanner noise and fMRI procedure. Since pediatric patients are frequently anesthetized during MRIs, this may be the first time they experience the scanner environment and they often benefit from this acclimation period.

## Task choice

Task choice varies across institutions, but in general, presurgical referrals tend to be for motor, language, and vision mapping. There are considerations for the development of fMRI tasks for clinical use that differ from research applications based on the fact that patients who need presurgical mapping are more likely to have difficulties tolerating the MRI procedure. Therefore, the goal is to design a task that activates the cognitive target in the shortest possible amount of time to maximize patient cooperation. This is especially important with children due to their limited attention span. At Barrow, we have developed a number of tasks with “step down” versions so that we can attempt to elicit responses in patients who may be somewhat compromised but still able to be examined. (Although it may be possible to assess certain abilities such as motor and vision function in patients who have limited language skills through vocal directions, a general rule of thumb is that a basic understanding of language and ability to independently perform a task for a short period of time is necessary to successfully obtain fMRI results.)

## Task analysis and interpretation

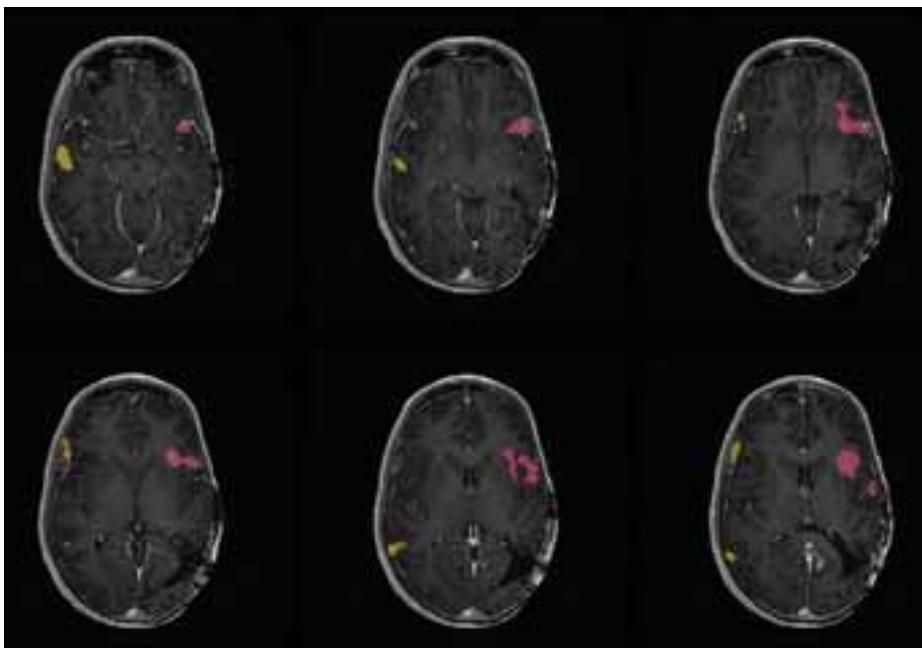
fMRI results for presurgical mapping are overlaid on high-resolution 3D T1-weighted post-contrast scans that are used for neuronavigation in the OR. We load these images to the PACS prior to surgery to allow for presurgical planning by the referring team. fMRI may provide the treating team with information that could determine whether surgery is feasible. For example, in a patient with a longstanding lesion that causes seizures, determining language dominance

(which may be reorganized in younger children) may provide a better estimation of the potential for language deficits after surgery. In other cases, surgical approach may be reviewed based on the location of eloquent functions relative to the lesion.

Data analysis requires close attention to issues related to data quality and coregistration, including assessing for the presence of excessive movement. Although some tasks obtained on the 3.0T scanner, particularly motor tasks, show very robust results within a relatively short amount of time, we choose to obtain two runs of each task in order to provide some redundancy to ensure repeatable results. This, of course, does not ensure that the patient consistently and correctly followed directions, and the clinician should interpret the results within the context of what is expected from the task. However, two runs of each task helps to reduce the interpretation of random activation. Other issues to consider in clinical mapping, which may differ from research applications, include the degree of smoothing and the issue of false negative findings vs. false positives. These issues do not differ based on the age of the patient, but may be important considerations especially in children, who may be more likely to have reorganized functions if their lesions occurred during critical windows of brain development.

## Summary

With the significant improvement in MR imaging, obtaining high-quality functional and structural images for cognitively impaired children can be done consistently and with a minimal amount of distress to the patient. ■



**Figure 1.** fMRI images show activation associated with expressive (pink) and receptive (orange) language in a right handed patient who had resection of a tumor at age three. Patient shows evidence of crossed language dominance with expressive language in the predicted left frontal lobe while receptive language (comprehension) is solely in the right hemisphere. This bodes well for language preservation if further resection is required in this region (for seizures).