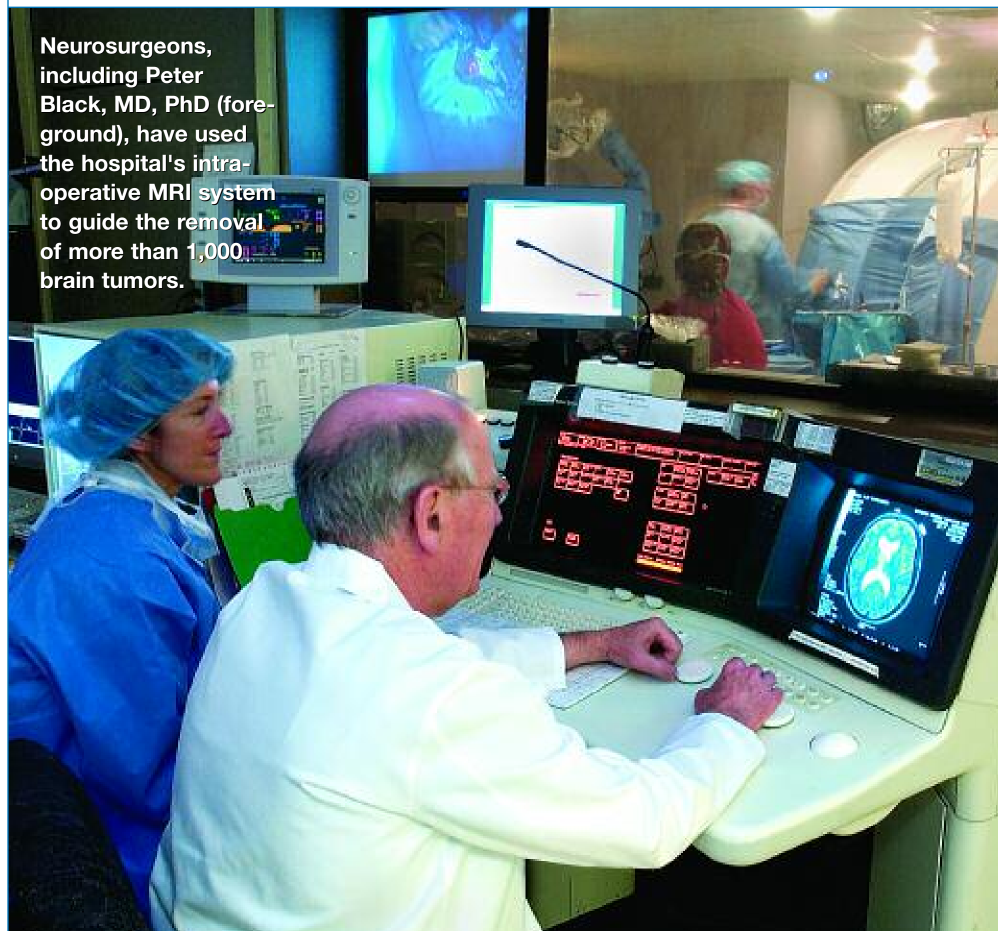
“Hit or miss” no more

BRAIN IMAGING, MAPPING TECHNIQUES HELP SURGEONS SEE WHAT’S BENEATH THE SURFACE



Neurosurgeons, including Peter Black, MD, PhD (foreground), have used the hospital's intra-operative MRI system to guide the removal of more than 1,000 brain tumors.

THE MALIGNANT BRAIN TUMOR looms on the monitor as a creamy brown mass, lodged deep within the 29-year-old man’s left temporal lobe, a key language area. If neurosurgeons take out too much tissue when removing the tumor, the patient might have difficulty speaking, reading or comprehending language. If they don’t take enough tissue, they risk leaving cancer cells behind.

Simply looking at the brain’s pinkish-gray, rippled surface, however, yields no clues about the tumor below or the best way to access it.

“You can only operate on what you can see,” says Brigham and Women’s neurosurgeon Alexandra Golby, MD. “Without sophisticated imaging techniques, you can’t see what’s below the surface.” That’s why, until relatively recently, brain surgery was a hit-or-miss proposition.

FIRST GLIMPSES

The first brain “map,” an illustration by Wilder Penfield, MD, a one-time apprentice of famed neurosurgeon Harvey Cushing, MD, was published in 1951. Called Penfield’s homunculus, the diagram shows distorted body parts on the brain’s surface; the size of each body part indicates the relative amount of cortical brain tissue devoted to motor function and sensation for that part.

The homunculus grew out of Penfield’s treatment of epilepsy patients. By stimulating sections of the brain with a mild electrical current, he could map the areas that played a role in seizures and operate on them. He could also see which areas controlled specific functions. But his map and others that followed proved too general. They could not, for example, predict how the brain might shift or rewire itself in a particular patient if a tumor began to grow.

In the mid-1980s, MRI, short for magnetic resonance imaging, burst onto the scene. By harnessing radio waves, a powerful magnet and a sophisticated computer software, the device created cross-sectional images of bone and soft tissue, giving physicians their first real window into the brain. Its downside: it could only be used for diagnostic purposes because patients typically lie in a enclosed narrow tube during the scan, putting them beyond the reach of physicians’ hands and tools.

Although pre-operative MRI images were useful, says Golby, they didn’t take into account how the brain can shift during surgery, whether due to gravity, draining fluids or the removal of bits of tissue. That meant that neurosurgeons were, in essence, relying on an outdated roadmap.

To solve that problem, Brigham and Women’s Ferenc Jolesz, MD, director of MRI and Radiology’s Image-Guided Therapy Program, teamed up with GE Medical Systems to unveil the world’s first intra-operative MRI system in 1993. The traditional cylindrical magnet had been split in half, creating two donut-shaped pieces separated by a small space where surgeons could operate.

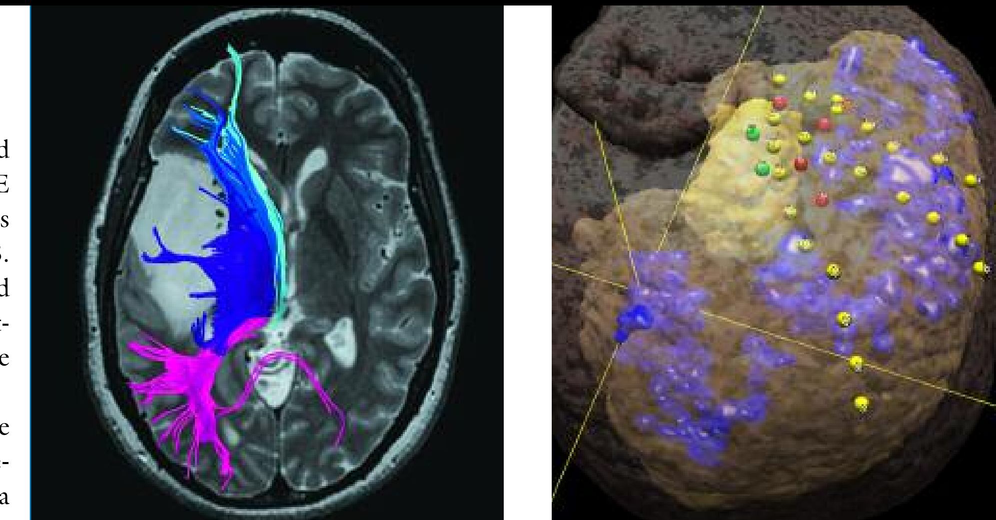
For surgeons and radiologists, the benefit was clear. They could scan and re-scan the treatment area throughout a painstaking procedure, obtaining up-to-date pictures of the terrain at various depths and angles. They could also fuse cross-sectional images into a 3-D model, which could be moved around on a computer screen to exactly match the patient’s position on the operating table. The device could even be used to monitor treatment, such as the placement of radioactive seeds to treat prostate cancer and the ablation of malignant and benign tumors, including uterine fibroids, with focused ultrasound.

“What we started became big—really big,” says Jolesz. In fact, at the end of August 2006, BWH neurosurgeons performed their 1,000th intra-operative MR-guided craniotomy to remove a brain tumor, and Jolesz estimates that 60 medical centers around the world now offer intra-operative imaging.

NEW FRONTIERS

More breakthroughs in imaging and brain mapping are on the horizon. For example, Golby’s surgical brain-mapping laboratory has been using functional MRI to see which areas of the brain are responsible for critical functions such as speech, motor skills and memory. Researchers guide patients through a series of exercises during scanning, such as naming objects and counting. Images taken during the exercises show which areas of the brain are active when the patient performs a task.

Golby also uses diffusion tensor imaging, or DTI, which highlights the white-matter tracts that transmit messages from one area of the brain to another, and Intracranial Electrical Stimulation Testing, which uses electricity to stimulate discrete areas of the brain and map their function while the patient is awake. She is now working to fuse the data generated by the various methods to better guide the removal of lesions and preserve as much brain function as possible.



To assess which areas of the brain control critical functions and determine the best “route” for tumor removal, neurosurgeon Alexandra Golby, MD, uses different types of mapping techniques. DTI (above left) shows the white-matter tracts that help send messages from one part of the brain to another and their relationship to the tumor (light gray mass). A 3-D rendering (above right) integrates information from functional MRI and electrocortical testing. The creamy tan mass on the left is the tumor. Purple/blue spots show brain activity. Red dots indicate areas where the patient had language difficulty; green dots, no difficulty. Yellow dots mark electrode placement.

These imaging techniques, especially functional MRI, are proving useful in the study of other neurological disorders, including Alzheimer’s disease. Neurologist Reisa Sperling, MD, used the technology to show that an area of the brain called the hippocampus, which plays a key role in forming new associations like matching names and faces, is functionally impaired in Alzheimer’s patients. She is now employing functional MRI to determine whether drugs are hitting their targets and improving cognitive abilities.

Meanwhile, Jolesz is leading the creation of AMIGO, the Advanced Multimodality Image-Guided Operating Room, a high-tech, three-room suite. The middle room will be designed like a traditional operating room with the addition of X-ray, angiography, ultrasound and optical imaging. The adjoining rooms house an MRI machine as well as a PET/CT unit. (PET/CT provides pictures of a patient’s anatomy and shows how the body is functioning.) Sitting on a track that spans all three rooms, the operating table can slide into either machine for real-time scans.

The planned project would improve upon the intra-operative MRI with a closed 3.0-Tesla magnet instead of an open 0.5-Tesla magnet, making it faster and better able to image smaller structures like blood vessels. And because the plans call for the magnet to be separated from the operating area, surgeons would not have to use the special, non-metallic tools that are required when they step into the intra-operative MRI.

“It’s an amazing innovation,” says Steven Seltzer, MD, chairman of Radiology. “What’s so special about Brigham and Women’s is our commitment not only to using, but also developing, the world’s best technology to improve patient care.”◆