National Institute of Biomedical Imaging and Bioengineering

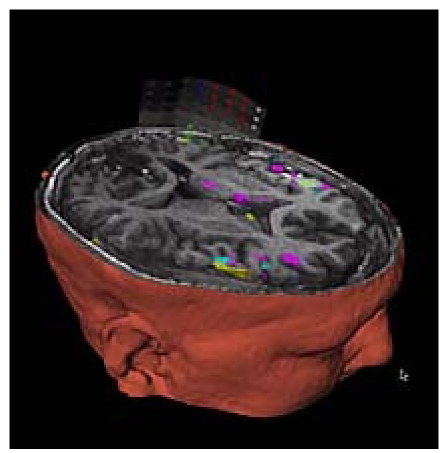
Integrated Imaging May Improve Epilepsy Surgery

For those with epilepsy, seizures can disrupt daily routines, whether going to school, holding a job, or driving a car. Medication offers relief for most patients, but for the small percentage whose seizures are debilitating and untreatable, surgical removal of damaged brain tissue may be the best option. A new imaging system now being developed by an interdisciplinary team of researchers may shorten surgery times and greatly improve the success rate of this sometimes-risky procedure by allowing surgeons to more precisely pinpoint, and then remove, seizure-causing brain regions.

The new system integrates detailed information about brain anatomy, biochemistry, and electrical changes that occur during seizures, explains Dr. James Duncan, professor of diagnostic radiology, biomedical engineering, and electrical engineering at Yale University. As principal investigator of a five-year, $7.1 million research project funded since 2002 by the National Institute of Biomedical Imaging and Bioengineering (NIBIB), Dr. Duncan heads a multi-institutional team of engineers, scientists, and physicians located at Yale, Albert Einstein College of Medicine, the University of Minnesota, and BrainLAB, Inc., a German company that specializes in image-guided surgery. Dr. Duncan presented early results of this ongoing research project at a January 2004 meeting of the NIBIB Advisory Council.

Shorter Surgery Times

Typically, removal of seizure-causing brain tissue requires patients to undergo two seven-hour surgeries. During the first surgery, electrodes are placed on or inserted into brain areas suspected of causing seizures, usually detectable as sudden and intense bursts of electrical energy. Information gleaned from electrode monitoring allows surgeons to map the source of the seizure activity. During the second procedure, performed a few weeks later, surgeons follow the map to the damaged brain tissue, which is carefully removed.



Researchers are developing an imaging system that may lead to better surgical treatments for epilepsy patients. This image shows normal brain activity.

Image courtesy of Dr. James Duncan, Yale University.

With the new imaging system, the first surgery might eventually be omitted, since high-resolution images of the brain's anatomy, biochemistry, and electrical activity would be integrated before and during the operation. This detailed information would help surgeons to plan and perform the procedure with greater precision.

Neurosurgeon Dr. Dennis Spencer reports that the new prototype system provides a much more precise placement of electrodes and accurate anatomical correlation with chemical abnormalities and function. Dr. Spencer, acting dean of the Yale School of Medicine and a co-investigator on the NIBIB grant, has used the prototype imaging system on more than 50 patients, about half of whom are children. "The earlier you can correct their symptoms, the better," he notes.

Pinpointing Brain Activity

With the new imaging system, surgeons can correlate a wide variety of pre-operative brain images, including biochemical information obtained via magnetic resonance spectroscopy (MRS) and computerized assessments of electrical activity obtained via electrode monitoring. Magnetic resonance images (MRI) taken prior to surgery are also available by way of pull-down screens in the operating room, along with projected displays of microscope-based images during the surgery. The MRI provides anatomical details and reveals important functional areas of the brain, like language regions, that must not be damaged during the operation. The researchers are also beginning to acquire and integrate images that represent blood flow in the brain. "By coregistering blood flow, electrical activity, and biochemical activity, we can more precisely see where brain activity is abnormal," says Dr. Spencer.

Brain anatomy is also monitored during the surgery, since brain tissue tends to decompress by as much as 1 centimeter when exposed during the operation. Even a small shift of brain tissues can throw off the surgeons' calculations for locating seizure-causing areas. To avert such problems, Dr. Spencer and his colleagues have set up stereotactic cameras in the operating room that track the movement of the exposed brain surface from slightly different angles, thereby adding a perception of depth. Images from the cameras are then coupled with a computerized model, developed by Dr. Duncan and his colleagues, that predicts how the entire brain volume is shifting. This rapid modeling may allow surgeons to account for brain tissue deformation.

"Using imaging and stereotactic cameras in the operating room is much less expensive than installing a $3 million MRI system in the operating room," as is done for some other image-guided surgery efforts, says Dr. Spencer. In contrast, he says, the cost for the modeling system developed by the Yale team and their colleagues is about $100,000.

What's Next

Over the next several years, Dr. Spencer expects the research team will develop a neurostimulator that could be implanted in the brain to short-circuit seizures and thus reduce symptoms. The neurostimulator would be programmed to shock the brain when a seizure-associated electrical pattern occurs. The pattern location would be determined by the prototype imaging system now under development, Dr. Spencer explains. The team's 10- to 15-year-goal is to develop a procedure in which surgeons insert a biosensor along with a drug-delivery system into the brains of epilepsy patients. The system would trigger release of a drug that blocks seizures before they begin.

By taking a look at the entire brain – its chemistry, anatomy, and electrical activity – surgeons are better able to tackle epilepsy at its source. "This multi-dimensional approach is leading to a better understanding of the biochemical, functional, and anatomical changes in the brain that epilepsy creates," Dr. Duncan notes.