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The MR examination of medial temporal structures has recently been pushed to the limits of current technology, with some hope of uncovering the secrets of intractable epilepsy. The specific MR imaging features of one important source of seizures, mesial temporal sclerosis, have been well described. These include a small hippocampus with abnormal signal on T2-weighted scans, but many other findings in the temporal lobes and limbic system have been reported.

These careful investigations of brain anatomy have occurred without a critical examination of the hippocampus of nonepileptics to determine if these findings might be encountered as incidental findings in healthy patients, or at least in patients without epilepsy. This is not a simple task because high-resolution imaging in the coronal plane is essential for this diagnosis. In this issue of the *AJNR*, Moore et al (page 1609) report on the temporal lobe findings in 207 cases without known epilepsy in an attempt to determine the positive predictive value of the MR findings of mesial sclerosis.

In this retrospective study of patients with hearing loss, the authors identified two patients out of the 207 with abnormal hippocampal formations. In both cases, further investigation of the clinical history uncovered a history of epilepsy. The other 205 patients had normal medial temporal structures; ie, they found no cases with hippocampal abnormalities without epilepsy. The authors conclude that the findings of mesial sclerosis are ''uncommon and significant.''

Although their observations are impressive, one should be aware of two important caveats. The first concern is how representative is the study sample? There can be little argument that this finding is uncommon. Of the patients referred from our epilepsy service with a suspected epileptogenic focus, MR studies are abnormal in approximately 25% of cases. With this experience in patients at risk, there can be little doubt that the occurrence of hippocampal abnormalities will be considerably less among nonepileptics. With an uncommon imaging finding, an important question is the number and composition of the study cases needed in order to reach a valid conclusion. It is essential that the cases in the study group are representative of the patient population (1). Ideally, this control group should include cases with a different disease process in the same anatomic location as well as patients with the same disease (epilepsy) but of nontemporal lobe origin. The outcome might have been different if the authors had decided to study patients with previous head trauma, near drowning, or herpes encephalitis, because all of these groups have a much higher likelihood of having temporal lobe abnormalities.

The cases of near drowning or anoxia are particularly relevant because these patients may have abnormalities limited to the hippocampus, attributable to a phenomenon referred to as ''selective vulnerability.'' It has been long recognized that specific regions of the brain might be injured with even brief episodes of hypoxia. Although vascular causes have been considered, the characteristic injuries seen in certain circumstances could only be explained by some pathophysiologic process unique to those cells. Selective vulnerability can be evident in many regions of the brain but is most commonly seen in the CA 1 sector of the hippocampus and the Purkinje cells of the cerebellum. This phenomenon has been attributed to the local release of excitatory neurotransmitters, and one likely candidate is glutamate, with secondary influx of calcium into the postsynaptic cells and subsequent injury. Another disease besides epilepsy and hypoxia that may selectively involve the hippocampus is limbic encephalitis, a rare paraneoplastic disease that in many respects resembles herpes encephalitis histologically.

The second caveat concerns the degree of statistical precision. A useful rule of thumb for estimating the upper bound of the 95% confidence interval around the probability of a rare event after N negative observations is 3/N (2). Using the data from this study, assuming that all of the patients with normal MR studies did not have epilepsy, the upper bound on the false-positive rate is 1.5% or 3/205; the lower bound on the specificity is 98.5%. Although this value is high, it must be considered in the context of the prior probability of disease. Among patients with suspected lesional epilepsy in whom the probability of finding disease is at least 10%, this specificity of 98.5% would yield a positive predictive value of at least 96%. In the general population, however, where the prevalence of epilepsy is approximately 8/1000, the positive predictive value could be no more than 40%. In fact, even at a prior probability of .008, a positive predictive value of 89% would require a specificity of 99.9%. To achieve this lower-bound estimate of 99.9%, Moore et al would have needed to review scans of 3000 subjects without finding a single hippocampal abnormality that was not associated with epilepsy. Although this would be a substantial undertaking, it would be of considerable interest to include some subjects with a history of anoxia in any such study group.

The authors are to be commended for their use of an existing data set to address this problem—a sort of scientific recycling. Their study provides

solid evidence that the findings of mesial temporal sclerosis are significant in the clinical setting of epilepsy. The sample size, however, is neither large nor diverse enough to predict the true significance of these findings in the general population.

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The Neurosurgical Operating Room of the Future: Has the Future Arrived?

In the rapidly changing world of neurosurgery, image guidance has gained an increasing role in a wide range of surgical procedures. These techniques include frameless and frame-based stereotactic guidance, intraoperative computed tomography, and, most recently, intraoperative MR imaging. The goals of these methods have included guidance to the site of an abnormality, reduction of the necessary craniotomy size, and avoidance of damage to nearby critical structures.

During the past several years, a number of series have been published describing the utility of intraoperative MR imaging guidance for neurosurgical procedures (1–4). These have suggested many benefits derived from the excellent soft-tissue contrast resolution and near-real-time scan acquisition of intraoperative MR imaging. In addition to the capabilities of conventional stereotactic techniques, intraoperative MR imaging can also guide surgery in the presence of changing levels of brain shift, document the completeness of tumor resection, and monitor the development of intraoperative complications such as hemorrhage while the craniotomy remains open. Although several of these prior reports have described large numbers of patients, the evidence of clinical usefulness has remained largely anecdotal. In order to promote more widespread clinical acceptance of intraoperative MR imaging, and to justify the associated equipment costs, more scientific proof of the effectiveness of this technology and impact on patient outcome is necessary.

The article by Knauth et al in this issue of the *AJNR* (page 1642) is a highly significant first step toward the scientific proof of efficacy. In this prospective investigation, the authors studied 41 neurosurgical procedures performed with a neuronavigation system based on preoperative MR data. When the operating neurosurgeon believed that all enhancing tumor had been removed, an intraoperative MR imaging set was obtained on a 0.2-T system. Further resection was performed, if necessary and feasible, until all enhancing tumor visible on intraoperative MR images had been resected. After surgery, an early postoperative MR imaging examination at 1.5-T was performed. The authors document a highly statistically significant increase in the success of complete resection of enhancing tumor through the addition of intraoperative MR data, increasing from under 37% after stereotactic neuronavigation alone to over 75% after the addition of intraoperative MR imaging information.

Documentation of the ability to provide more complete resection of enhancing tumor is an essential step toward the acceptance of intraoperative MR imaging techniques into the mainstream neurosurgical community. Nevertheless, before intraoperative MR imaging is accepted as a standard of neurosurgical care, proof of improved patient outcome will be necessary.

With this in mind, the choice of resection of high-grade gliomas as an initial clinical application must be examined, as extension of tumor beyond the enhancing margins is well documented for these tumors. For this reason, this investigation by Knauth et al may be most significant as a proof of concept rather than as a recommendedation of therapy for high-grade glioma. The conclusions of their investigation suggest that the use of this technology for intraoperative monitoring and guidance during resection of low-grade gliomas, metastases, and other better-localized intracranial lesions through the use of intraoperative MR imaging might also significantly benefit the patient. It is these applications, for which complete tumor resection is not only possible but can result in cure, that likely will further drive the dissemination of intraoperative MR imaging technology. There may also be some benefit in improving resection for high-grade glioma. Several neurosurgical series, referenced in the article by Knauth et al, suggest that patient survival or a progression-free interval or both is increased when removal of all enhancing tumor is possible.

An additional issue that merits discussion is the time needed to obtain intraoperative MR images. In this report by Knauth et al, intraoperative imaging required approximately 25 to 30 minutes of scan time and 30 to 35 minutes of setup time. Clearly, if this extra hour of procedure time eliminates the need for repeat craniotomy, it is acceptable. This long imaging time, however, limited in-