I. Diagnostic Tools

Magnetic Resonance Imaging and the Epileptic Focus

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Nuclear magnetic resonance provides us with a new imaging modality which can be used not only to analyze the structure and structural pathology, but also to some extent the pathophysiology of the central nervous system. A large magnetic field and radio frequency pulse sequences are used to generate a signal consisting of several basic parameters of nuclear magnetic resonance: (1) proton density, (2) $T_1$ constant or spin-lattice (longitudinal) relaxation time, and (3) $T_2$ constant or spin-spin (horizontal) relaxation time. The resulting signal can be weighted for each of the parameters by altering the radio frequency pulse sequences. The most commonly used sequences are called inversion recovery (IR), which emphasizes $T_1$ constant and provides gray-white matter contrast, and spin echo (SE), which emphasizes $T_2$ constant and shows pathology. The signal is spatially encoded and computerized in a manner similar to computerized tomography (CT). For a detailed description of the technique, see Lauterbur (1973) and Pykett et al. (1982).

Magnetic resonance imaging (MRI) is a noninvasive technique which does not require the use of ionizing radiation. The ability to obtain high-resolution images in any plane, such as coronal and sagittal, allows better analysis of neuroanatomical relations than axial images alone. MRI is of particular interest to the study of neurological disease because of superior tissue contrast allowing better visualization of gray-white contrast and brain-CSF contrast. Variations in the proton MRI longitudinal and spin-spin relaxation times in biological tissue allows us to probe the nature of the molecular environment that is not seen in any other imaging modality. Good correlation between the relaxation times and water content has been demonstrated in tumor tissue and in stroke (Spetzler et al. 1983), and in demyelinating diseases of the brain (Lukes et al. 1983). Epilepsy, in contrast to these pathologically well defined conditions, is often a disorder of neuronal cell function in the absence of gross anatomical changes. However, seizures are accompanied by a number of morphological, physiological, and biochemical changes, as well as by several pathological features which could produce altered MRI properties.

In the investigation of focal epilepsies in consideration for surgical resection, pneumoencephalography and CT scanning show abnormalities in only about one-third of such cases (Engel et al. 1982; Wyler and Bolender 1983). Computer tomography with metrizamide enhancement increases the preoperative yield of temporal lobe abnormalities (Wyler and Bolender 1983) as does positron emission tomography (PET) (Engel et al. 1982). Most of these abnormalities are changes related to atrophy: enlarged lateral ventricle, enlarged sulci, and small temporal lobe. CT scanning is less able to detect small lesions in the temporal lobe than in other cortical regions due to the bone artifacts from middle cranial fossa edges. Unlike CT, such bone “artifact” does not appear on MRI. The former procedure requires intravenous contrast and only adds information about the edges of the temporal lobes without adding any direct information concerning temporal lobe tissue changes. The latter is only available at a few centers.

Our current results from MRI on 16 patients with uncontrolled temporal lobe epilepsy (TLE) and 10 normal controls suggest that this procedure is probably more effective than CT scanning in revealing atrophic changes in the temporal lobe in a selected population (McLachlan et al. 1984). Specifically, MRI reveals asymmetries in temporal lobe size, mesial temporal margins, temporal horns, and hemispheres as has also been shown by others (Sussman et al. 1984; Spencer et al. 1984, Abou Khalil et al. 1984; Riel et al. 1984; Schoerner et al. 1984). Theodore et al. (1985) compared CT, PET, and MRI.
Twenty-six patients had all three tests; ten had only CT and MRI. Seventeen patients had a localized EEG focus. PET was the most commonly positive modality (13 out of 14 cases). MRI was abnormal in nine and CT in four. In three out of eight patients with unilateral EEG focus, PET hypometabolism, and normal CT, the SE showed increased signal intensity; in one case, MRI had increased signal but normal PET; in another case, the signal was increased on the opposite side of the focus. Other reports of MRI in epilepsy are anecdotal or descriptive and none of them have as yet used a “blind” evaluative technique.

Subjects

We selected 16 patients, aged 17–54 years, who were surgical candidates for resection of a seizure focus on the basis of having uncontrolled, focally originating seizures from the temporal lobe, despite the use of adequate medications, as defined by McNaughton and Rasmussen (1975). Patients with gross lesions such as infarcts, haemorrhages, arteriovenous malformations, or tumors were also studied as a separate group.

Patients being considered for surgery undergo extensive investigation to verify the seizure focus, based on the recommendations of the Montreal group (McNaughton and Rasmussen 1975). Computer-controlled EEG telemetry provides us with both interictal and ictal data to localize the focus of electrical discharge, this being the primary standard. In some patients, subdural electrodes were inserted and left in place on the surface of the brain better to demonstrate the seizure focus. Neuropsychological assessment was also performed to localize cortical areas of functional deficit. Finally, skull X-rays and CT scans were obtained on all patients. Routine contrast enhancement was done in all cases and high-volume delayed contrast-enhanced scans are carried out in selected individuals with suspicious, but indefinite, changes using the standard procedures.

Imaging

Magnetic resonance imaging was carried out on each patient using a Technicare 0.15-tesla imager using a 256 x 128 matrix (pixel size 1.1 x 2.2 mm) displayed as a 256 x 256 image. Initially, a 28-cm-ID cylindrical receive/transmit radiofrequency coil was employed to obtain images approximately –15° to the orbitomeatal line according to the following protocol: the brain was surveyed using an anisotropic volume SE technique to obtain 32 T1-weighted images in the axial plane [slice thickness (SLT) 1.7 cm; echo time (TE), 60; cycle repetition time (TR), 1000; all time measurements are given in milliseconds] and 20 T1-weighted images in the coronal plane (SLT, 1.7 cm; TE, 30, TR, 250). Additional single axial slices through the middle of the temporal lobes were also collected by both SE (TE, 120; TR, 1000) and IR techniques (inversion time, 450; TE, 30; TR, 1500). Total imaging time was 1 h.

Installation of new hardware and software later on in this study, including a half-saddle (25-cm-ID) receive coil, allowed multi-echo multislice collections which made possible a more comprehensive survey with better image quality in a shorter time. In the new protocol, the SE technique was used to yield 13 T1- and T2-weighted images in the coronal plane (SLT, 1 cm; TE, 30, 60; TR, 1060) and 15 T1-weighted images in the horizontal plane (SLT, 0.75 cm; TE, 60, 120; TR, 2120) in approximately 30 min of imaging time. Half of the TLE patients and all control subjects were imaged using this protocol.

The MRI findings of the patients were compared with those of a normal control group consisting of 10 volunteers from hospital personnel (age range 20–40 years) and a control group of 18 multiple sclerosis (MS) patients. We used two independent observers who judged the scans for atrophy and for the presence or absence and the location of the T1 or T2 changes on the IR and SE images. These judges viewed all the scans in randomized order, in other words, they did not know if it was an epileptic or a control subject. They were also blind to the side of the seizure focus or the clinical type of the seizure. Disagreements were resolved by joint viewing. Judgments concerning anatomical symmetries in the size of the temporal lobes, the temporal horns, the mesial temporal borders, the Sylvian fissures, and the hemispheres were made on both coronal (TE, 30) and axial (TE, 60) slices. In addition, any increase in signal intensity on the T2-weighted axial images was classified as localized or diffuse throughout the temporal lobe. These changes were further categorized as unilateral or bilateral. Comparisons of these findings were made in a nonblinded fashion to those obtained from 18 patients with MS. The results were then interpreted with respect to the electrographic and CT (GE 8800; SLT, 0.5 cm) findings in the TLE patients.

In the second phase of our study presently under way, we project these images by using a photoenlarger after randomly reversing the sides. The projected images are traced by two observers who are