Identification of Various Pathological Conditions of the CNS by Nuclear Magnetic Resonance (NMR) Imaging

F. Aichner, F. Gerstenbrand, N. Grčević, U. Mayr, K. Noever, and G. Reuther

Introduction

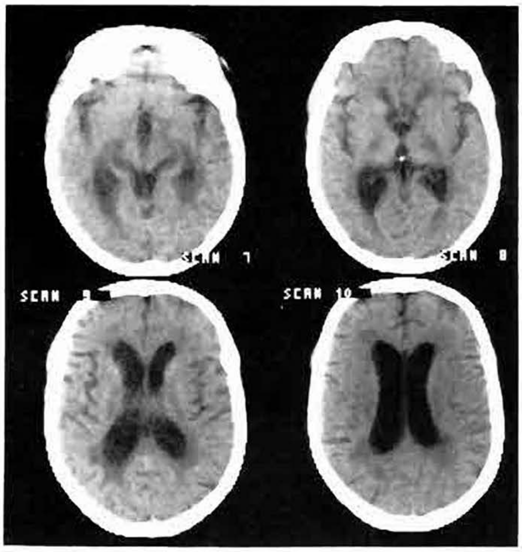
NMR tomography is based on the magnetic resonance behavior of protons as they occur predominantly in tissue water or in fatty acids. NMR imaging (NMRI) produces images that represent one or more of four parameters. These are proton density, the state of motion of protons, and the tissue relaxation time T_1 and T_2. Because detailed expositions of the NMR theory are available in standard texts and introductions to the principles of NMR imaging have been published recently, no comment on the physical basis of NMRI will be made here (23, 24).

The ability of NMRI to demonstrate pathological conditions of the CNS, which could not be visualized by any other imaging methods, has been revealed by several recent studies (2, 4, 6, 8, 9, 12, 19, 20, 26, 28). The T_1 and T_2 relaxation times are very sensitive in the detection of abnormalities within tissues. However, the significance of these alterations is not always evident and further experience is needed (11).

This study is a survey of our preliminary experiences with NMRI in the investigation of various pathological conditions of the CNS. Identification of various cour-

Table 1: The diagnostic entities of 26 patients classified

Diagnosis	Patient
Periventricular leucomalacia	1
Multiple sclerosis	3
CO poisoning	1
Tumor of the brain	7
Severe head trauma	4
Locked-in syndrome	1
Parkinson's disease	3
Focal epilepsy	2
Hydrosyringomyelia	1
Myelitis	2
Neurinoma C6/7	1



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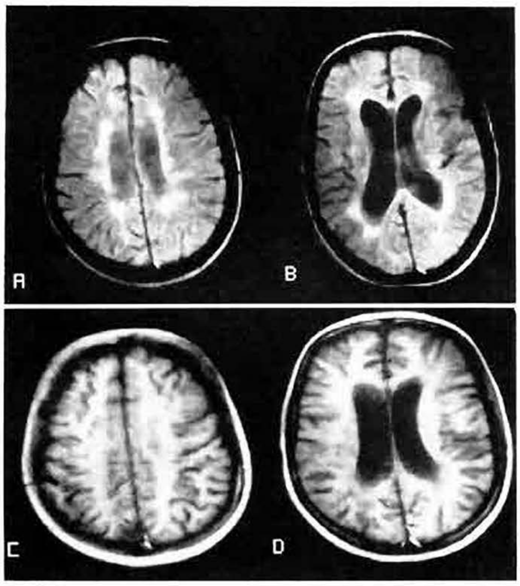

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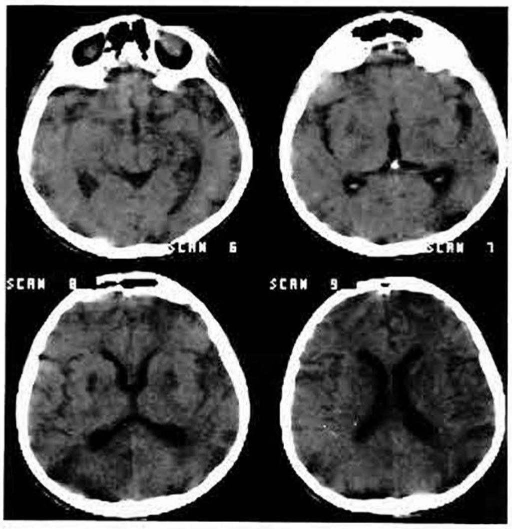
Fig. 1a + b: Comparable CT (1a) and NMR (1b) SE scans at ventricular level in a patient with multiple sclerosis. The two posterior lesions and the two anterior periventricular lesions seen on CT scan are also evident on the NMR scan. NMR scan shows additional multiple lesions which line the lateral walls of the ventricles (1bA). $T_R = 400$, T_E 30/60 msec.



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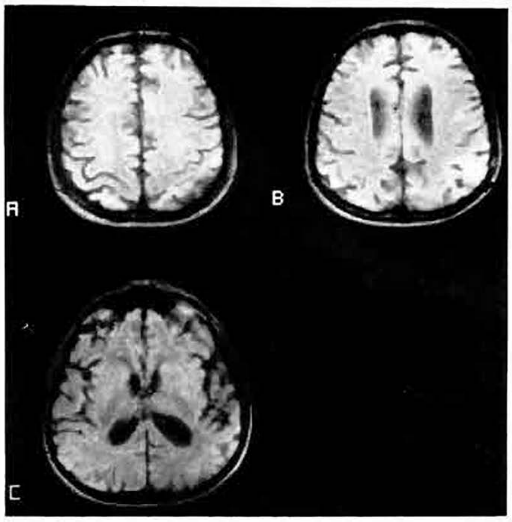

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Fig. 2a: Unenhanced CT scan in a patient three months after acute carbon monoxide poisoning. There are bilateral areas of low density in the globus pallidus. Further lesions are present in the parietooccipital areas.

Fig. 2b: NMR spinecho images done shortly after CT show a different pattern. There is a reduced signal intensity in both thalami and no changes are demonstrated in the globus pallidus. T_R = 1,500, T_E 30/60 msec.

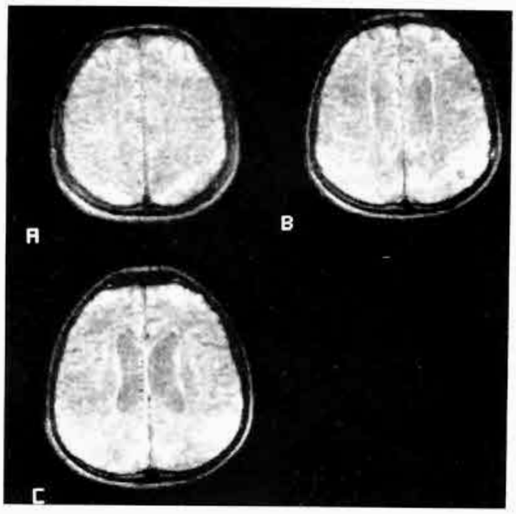


Fig. 2c: NMR inversion recovery images at a higher level show bilateral parietooccipital lesions with altered image intensity. $T_R = 1{,}600$, T_E 30 msec.

ses of diseases was achieved by clinical information, by CT, and NMR appearances; in some patients the findings were confirmed by surgery and histological examination. NMR images were obtained on the SIEMENS MAGNETOM (0,35 tesla, ppm =< 20) system using spinecho (SE) and inversion recovery (IR) techniques. CT examinations were performed on a SIEMENS DR2 scanner using a matrix of 256 x 256.

Case Reports

Twenty-six patients with selected cerebral or spinal pathology were examined with CT and NMR tomography. Table 1 shows the clinical diagnosis of the patients studied. Since this contribution is intended as a survey of our clinical experience, we will limit ourselves to illustrating cases depicting the potential of NMRI.

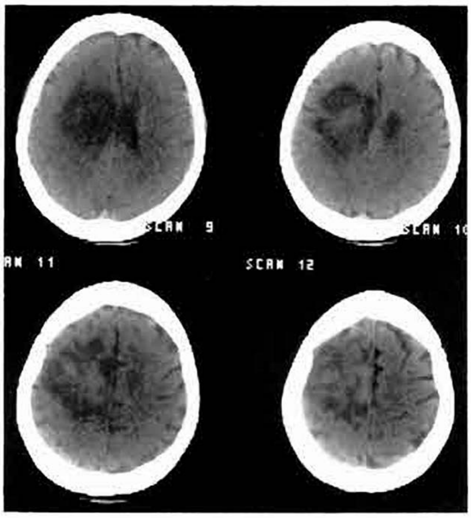
Case 1, T.R. An 18-year-old woman was admitted to our hospital because of right facial weakness and ataxia. On examination there were signs of dysfunction of the brain stem such as right peripheral facial paresis, nystagmus, and cerebellar ataxia. Furthermore, a spinal cord lesion was found at the level of D12.

The CSF cell count was normal as was the total protein content. Agargel-electrophoresis showed the presence of oligoclonal IgG band. The patient fulfilled the criteria for a diagnosis of «clinically definite» multiple sclerosis (MS) (18).

It was not possible to perform a complete NMR examination of the brain, because the patient did not cooperate well enough. Only the white matter of the hemispheres could be tested (Fig. 1a and b).

Case 2, P.C. This 19-year-old man was admitted to our hospital after he had undergone acute carbon monoxide (CO) poisoning two months earlier. He had developed an apallic syndrome with partial remission.

a



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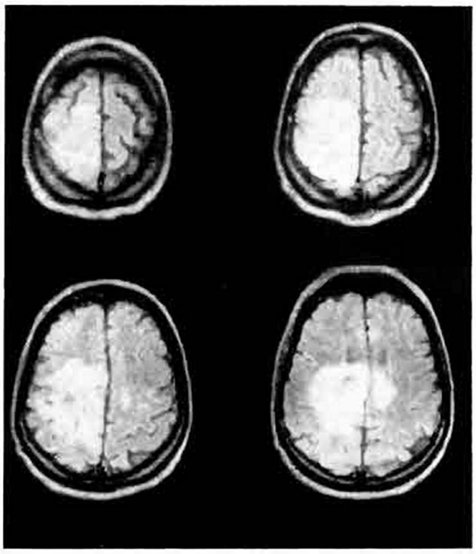
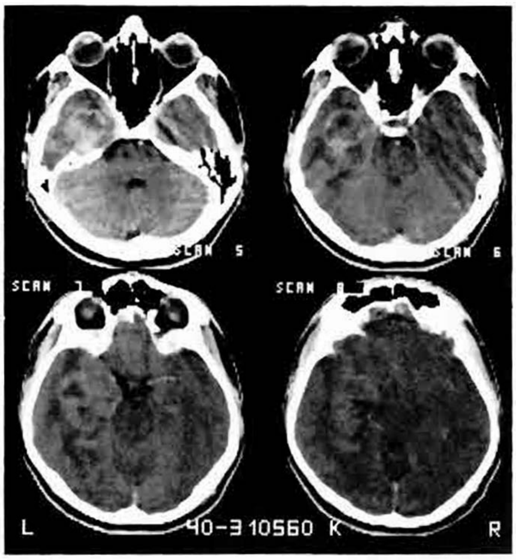


Fig. 3a: Unenhanced CT scans in a patient with allergy to contrast medium shows a lesion occupying a large space of the left parietal region with extending through the corpus callosum into the right hemisphere. The appearances are of a low grade astrocytoma.

Fig. 3b: NMR spinecho scans revealed a delineated area of decreased signal intensity at the same location. The cortical sulci are obliterated. The tumor itself seems to be better delineated by NMR than by unenhanced CT. The extension of the tumor to the right hemisphere is also better visible by NMR.



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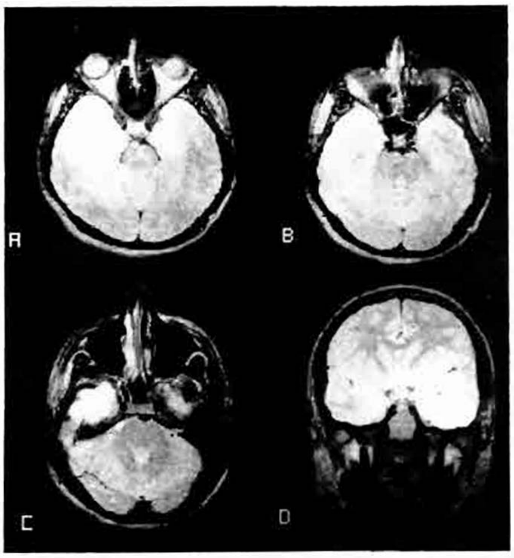

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Fig. 4a: There is a large irregularly enhancing mass in the left temporal lobe displacing the left middle cerebral artery anteriorly and encroaching upon the tentorial notch. A CT diagnosis of glioblastoma multiforme was made and was confirmed by surgery.

Fig. 4b: On NMR examination the mass seems larger reaching to the left occipital lobe. The differentiation of the tumor and the surrounding edema was not possible with imaging parameters applied in this case (SE, T_R = 1,600, T_E 60 msec).

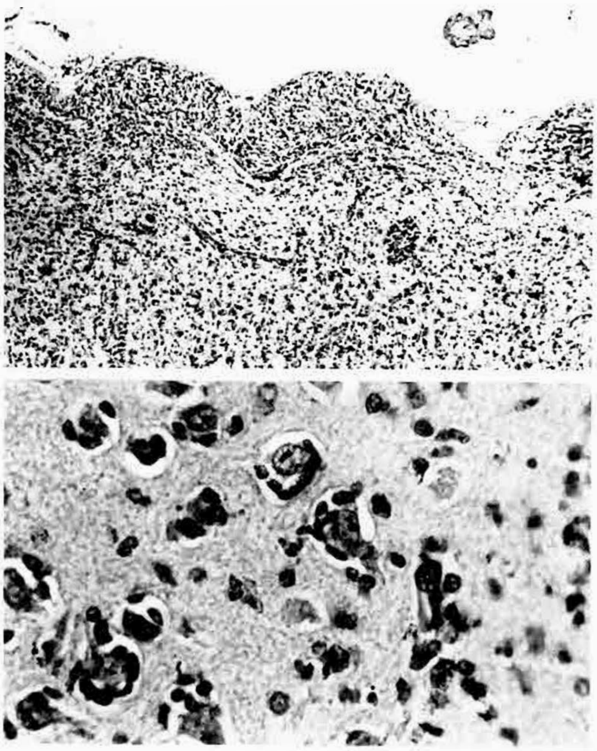


Fig. 4c: Clinical spread of the tumor with typical «warts» (upper picture) and tumoral «pseudosatellitosis» (lower picture).

During an observation period of three months and after many special tests a complex neuropsychological disorder became evident including agnosia, apraxia, dysphasia, alexia, agraphia, amnesia and a disturbance of spatial orientation.
Choreatic movements were an additional problem, but the patient responded well to Haloperidol® therapy. The patient was left with a slight residual akinesia. The full scale score of the Wechsler Adult Intelligence Scale (WAIS) was 61. CT and NMR findings are demonstrated in Figure 2a, b, c.

Case 3, P. A. This 53-year-old man has had sporadic right-sided clonic fits for three years. He was admitted to our hospital after a first generalized tonic clonic seizure which was followed by a slight, persistent nonfluent aphasia and a moderate right-sided hemiparesis. The EEG showed pseudoperiodically repeated spikes in the left central region. CT and NMR (Fig. 3a and b) were followed by angiography which confirmed the presence of an avascular mass of the left central parietal region.

Case 4, H. W. A 23-year-old man. The patient was admitted to the hospital because of a slowly progressive disorder of emotional behavior and diplopia. During examination there was a slight organic brain syndrome. However, we were not able to detect any oculomotor disturbances. Within a few days the patient developed a palsy of the left abducent nerve and had difficulty in finding words during conversation.

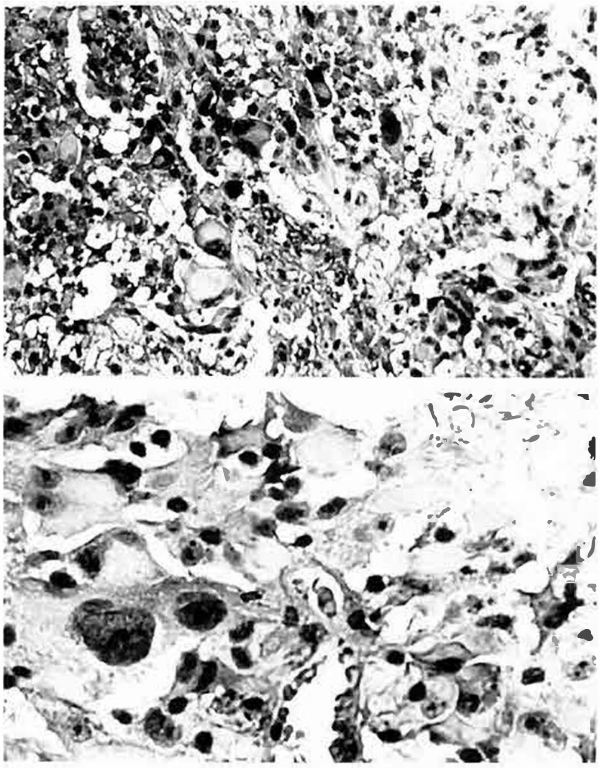
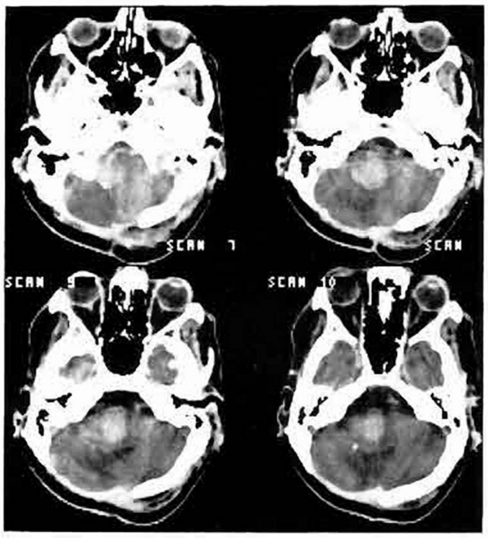


Fig. 4d: Subcortical mostly astrocytic tissue with giant protoplasmic cells and necrosis.

The EEG and the CSF findings were normal. CT and NMR were consistent with a large malignant glioma (Fig. 4a and b).
Cerebral angiography revealed an avascular mass of the left temporal lobe with elevation and lateral displacement of the middle cerebral artery and with a slight midline shift to the right. By operation the tumor could be removed only partially and the histological examinations confirmed the diagnosis of glioblastoma multiforme (Fig. 4c + d).
Histological examination showed a malignant mixed oligodendroastrocytic tumor, corresponding to the «transitional» (Grcevic), or Grade III (Kernohan) category. Tumoral tissue showed a typical tendency to spread along the cortex («warts» and «pseudosatellitosis») indicating oligodendrogliomatous origin of the neoplasm. However, considerable portions of the tumor in the deeper areas were built of protoplasmic and giant astrocytic elements intermixed with proliferated vessels and necrotic foci. In some places cellular pleomorphism was quite conspicuous. The pronounced cortical NMR activity, as a contrast to the CT scan (Fig. 4b), is interesting to note in view of the above stressed fact of cortical spreading of the tumor, which may remain invisible in the CT but might be definite enough to appear on the NMR image.



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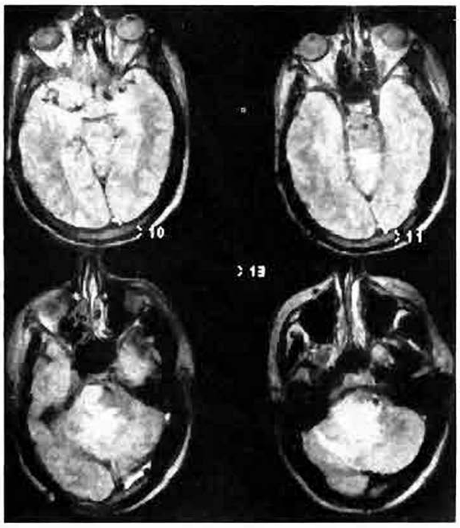

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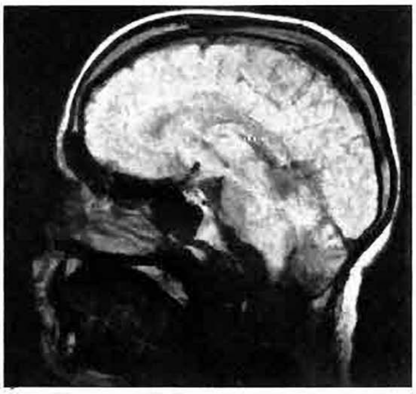

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Fig. 5a: Enhanced CT scans of a patient with brain stem glioma and posterior displacement of the fourth ventricle. There is a small calcification in the left posterior part of the tumor. A bone defect is present due to previous surgery.

Fig. 5b: NMR spinecho ($T_R = 1,600$, T_E 60) in axial planes show corresponding CT findings in every detail apart from not demonstrating any calcification.

Fig. 5c: Spinecho images in sagittal plane visualizing brain stem glioma.

Case 5, J. E. This 36-year-old man was known to have a brain stem glioma since 1977, and in the same year he was operated on in another hospital. The operation was followed by radiation therapy. He was left with multiple cranial nerve dysfunctions and a moderate right spastic hemiparesis. His state remained unchanged. Several CT examinations since 1978 did not show any progression of the tumor (Fig. 5a, b and c).

Discussion

In spite of the fact that NMR images were obtained using a prototype system, the results in detecting various pathological conditions of the CNS demonstrate the high sensitivity of NMRI using several pulse sequences.

The contrast between the grey and white matter provides excellent anatomical detail and for the first time has allowed the normal process of myelination to be observed in vivo (13). In demyelinating conditions NMR has distinct advantage over X-ray CT. The potential of NMR in diagnosis of MS needs little emphasis. The distribution of NMR lesions at the corners of the anterior and posterior horns and periventricular regions is congruent with the location of plaques at autopsy (17). NMR tomography is also useful in demonstrating very small lesions in the brain stem; however, plaques of the spinal cord have not yet been demonstrated by any investigator. Both IR and SE techniques can be used for the detection of any MS plaque. The lesions appeared as high-intensity foci on the SE technique designed to emphasize prolonged T_2 relaxation times.

IR images detected fewer lesions than did the SE images (3, 15, 27, 28).

In future, NMR tomography will be the standard technique in diagnosing MS and it will be used to monitor the effectiveness of therapeutic regimen.

One patient was examined by NMR which showed localized round low proton density at the angles of the posterior horns on both sides. This was interpreted as periventricular leukomalazia. Binswanger's disease has been adequately recognized by NMRI and the correspondence between CT and NMR was close (28).

We have examined one patient after an acute CO poisoning using both IR and SE techniques. Most studies on morphological changes due to CO poisoning are based on CT and autopsy (10, 21, 25). The characteristic CT findings are bilateral low density lesions in the globus pallidus and diffuse decreased density in the white matter of the cerebral cortex due to ischemic necrosis. As pointed out in Figure 2, CT and NMR showed a different pattern. It seems that NMR provides complementary as well as additional information, the significance of which is not yet established. The NMR findings may reflect the direct cytotoxic effect of CO.

In seven patients with tumors studied by CT and NMR the lesions were demonstrated with either method. Surprisingly, case 4 did not show temporal tumor on NMR using a pulse sequence of 30 msec, and the tumor became visible only after changing the pulse sequence. This means that small variations in the pulse sequence can yield a much better resolution of pathological changes. The tumors were seen as high intensity areas on SE images. Tumors are detected either by their increase in T_1 and T_2 or that of the associated cerebral edema as well as by mass effects (4, 5, 6). Determining what part of the lesion was tumor as opposed to surrounding edema was problematic with NMR, but the tumors were better delineated in NMR than in CT imaging (22). Resolution in brain and spinal cord images is about the same as that of X-ray CT, and the soft tissue contrast is superior.

Three patients with Parkinson's disease were investigated using both IR and SE techniques. These patients had unilateral Parkinsonism. Preliminary evaluation indicated that NMR and CT showed similar findings and NMR provided no additional complementary information regarding the region of substantia nigra and upper mesencephalon. Similar findings are also reported in other movement disorders (16), apart from Wilson's disease (13).

At present, no reports are available on NMRI of patients with epilepsy. Two of our patients with partial epilepsy and a definite epileptic focus in the EEG did not show any change either on NMR or CT. Further NMR studies of epileptic patients are needed in order to assess the role of NMR in epilepsy research.

Four patients in the remission stage of a traumatic apallic syndrome were examined by NMR. In all four cases studied loss of grey-white matter contrast was evident within the traumatic lesions. In the hemispheres, traumatic foci could be better delineated by NMR than by CT, and more lesions could be found by NMR. As to the brain stem, a traumatic pontomedullary lesion was seen by NMR which had not been detected by CT.

NMRI of a patient with a locked-in syndrome revealed a circumscribed area of reduced signal intensity in the pars ventralis of the pons which corresponded well to the location of a clinically suspected infarction. This case has been published elsewhere (1).

NMR tomography of the spinal canal offers new prospects since sagittal tomograms permit the investigation of up to 15 segments in a single section. The spinal cord and adjacent structures can now be visualized without the use of intrathecal contrast material (2, 8, 20). NMR spinecho images of a patient with syringomyelia defined an intramedullar region of low intensity corresponding to the syrinx cavity. This patient has been described elsewhere (2).

In two patients with a clinical diagnosis of myelitis of the thoracic cord CT with intrathecal contrast material and NMR (using the body coil without a zoomer) did not show any pathological change. NMR is presently the examination method of choice for the diagnosis of syringomyelia and Chiari malformation. According to the rapid development of NMRI we expect it to become the most important modality in diagnosing spinal cord diseases.

Summary

NMR images were obtained in 26 patients with various neurological diseases and compared with CT and clinical data. The following advantages of NMRI became evident (1). No ionizing radiation is used (2). No biological hazards of NMR are known at the currently used magnetic field strengths and radiofrequency pulse sequences (3). NMR is a noninvasive method (4). The tissue resolution is comparable with high resolution CT (5). Images in various planes such as sagittal, coronal and transversal, and even obliqued planes are easily obtained (6). Several varieties of sequences are possible (7). Optimal differentiation of changes of the white matter is ensured due to the high level of grey-white matter contrast (8). Bone artefacts are absent.

The main disadvantages are the high purchase and maintenance costs of NMR imaging systems, rather long examination time as compared to CT, limited spatial resolution at the present time and lack of bone details. Patients with pacemakers, aneurysm clips, artificial joints, and large metallic implants cannot be examined with NMR.

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F. Gerstenbrand
N. Grčević
F. Aichner

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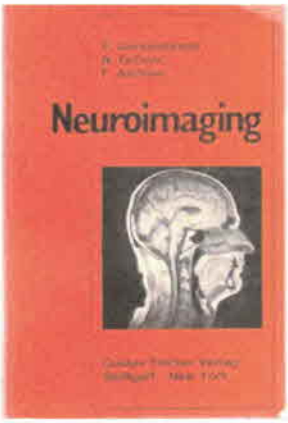
F. Gerstenbrand; N. Grcevic; F. Aichner



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