MAGNETIC RESONANCE IMAGING (MRI) OF THE CENTRAL NERVOUS SYSTEM: DIAGNOSTIC AND THERAPEUTIC IMPLICATIONS

J.WILLEIT, E.SCHMUTZHARD, F.AICHNER, F.GERSTENBRAND
G.BIRBAMER

FROM THE NEUROLOGICAL DEPARTMENT OF THE UNIVERSITY HOSPITAL INNSBRUCK (HEAD: UNIV.-PROF.DR.F.GERSTENBRAND)
AUSTRIA

CORRESPONDING-ADRESS:
DR.J.WILLEIT
UNIV.-KLINIK FÜR NEUROLOGIE
ANICHSTR. 35
A-6020 INNSBRUCK
AUSTRIA

1. INTRODUCTION

The basics of nuclear magnetic resonance were described in 1946 independently by BLOCH and PURCELL (1,2), however, its clinical implications and its role in imaging CNS structures were recognized only in the seventies (3,4). But to its rapid technical improvement within in the past few years, this method was developed to a level which renders it to the diagnostic procedure of the first choice for certain neurological disease (5,6,7,8). In contrast to the conventional neuroradiological methods, including computertomography (CT), additional and new informations concerning tissue composition can be gained by using different measurement-parameters. In future it will be possible to get insight into the metabolism by using high magnetic field strength and spectroscopy. The aim of this paper is to discuss the results of 200 MRI examinations with various neurological diseases. The advantages and disadvantages of this method as well as its diagnostic and therapeutic value in various CNS disorders will be analyzed.

2. MATERIAL AND METHODS

The diagnosis of all the 200 patients are listed in table 1 a and b. Prior to MRI all patients had undergone thourough clinical/neurological and neuroradiological examination. Neuropathological results are added when available, i.e. in

cases of surgically removed brain or spinal cord tumors. The examinations were carried out on 0,15, 0,5 and 1,5 Tesla magnets respectively. In all cases the spinecho sequence (SE) was chosen with repetition times (TR) of 500, 2000 respectively 3000 msec. and echotime (TE) of 43, 86 and 120 msec.. Additionally multiechosequence (10) was used in patients suffering from brain tumors for more detailed differentiation of the various tissue structures in order to increase the specifity of this method. The slice thickness was 5 to 10 mm, the matrix 256. The slice-orientation was usually axial and frontal, occasionally also coronar.

3.RESULTS

Tables 1 a and 1 b list the various disease-groups with particular respect to those cases in which the MR tomography provided additional information respectively lead to final diagnosis.

3.1. Multiple Sclerosis (MS)

Thirtyfive pätients have been included; according to the criteria given by MC DONALD et al (11) they were divided into the groups: suspected, probable and definite MS (Tab. 2).

In all 18 cases suffering from definite MS the MR tomography showed multiple "plaques" in the spinecho sequence (T2-weighted, RT 2320 msec., TE 80 msec.). According to various authors (12,13,14) the sensitivity for cerebral demyelinating lesions is 85 %. In CT-scan plaques can be

visualized only in 20 to 30 % of definite MS, even after high dose contrastmedium-application and delayed studies (15). Thus, it seems realistic to demand, that MRI has to be implemented in diagnosing MS; in particular, in patients, who do not reveal multiple lesions by careful clinical and electrophysiological examinations. In 9 out of 17 patients with non definite MS (Tab. 1a, 2) an upgrading to the next level of probability of MS (11) was gained possible by MRI.

Fig. 1 shows the demyelinating lesions (plaques) with high signal intensity, seen in the T2 weighted MR image. The most important differential diagnosis of these high signal intensity lesions are listed in table 3.

3.2. Brain-tumors

For examining patients with brain tumors both T1 weighted (TR 500 msec., TE 40 msec.) and T2 weighted (TR 2000 msec., TE 120 msec.) sequences - with the spinecho-method - were used. Out of the total of 32 brain tumor-patients 30 were proven already by CT-scan; one brainstem glioma (Fig.2) and one temporally located astrocytoma could only be visualized by MR tomography (table 1a). Thus, in our series, the sensitivity in detecting intracranial space-occupying lesions by means of MRI is higher than by CT scan (16,17). To improve the specifity an additional multiecho sequence was used in various patients with brain tumors. A specification, respectively differentiation of necrosis, edema, CSF and normal brain was thus made possible in 90 %.

Fig. 3 shows the T2 calculated image of a metastasis of a hypernephroma. The central necrosis, the solid part of the tumors, the perifocal fingerlike edema, normal brain tissue and CSF can be separated easily from each other.

3.3. Epilepsy

Fourteen patients were examined. Seven suffered from idiopathic epilepsy with generalized seizures, seven from temporal lobe epilepsy due to perinatal brain injury with typical changes in EEG pattern. In all cases CT scan was normal. In 4 patients additional information could be gained by MRI-technique: twice temporal atrophy, one case showed high signal intensity in the hippocampus and in one patient a temporobasal tumor could be visualized, which was histologically identified as astrocytoma.

3.4. Parkinson disease

Two different types of patients were examined, i.e. 6 patients after stereotactic intervention and 4 patients with a clearly defined hemiparkinsonian syndrome. In all former patients the stereotactic lesion could visualized in coronary and axial views. In accordance to other authors (18,19) the sensitivity is higher in MRI than CT scan (4 mm slice thickness). In cases of hemiparkinsonian syndrome no pathological changes whatsever could be detected, in particular, no unilateral lesion was to be found within the basal ganglia; LUKES et al (20) and DESSAN et al (21) did not find either any T1 or T2 changes in such cases.

Presented results give evidence, that MRI is of little value in patients with Parkinson disease.

3.5. Amyotrophic lateral sclerosis/spinocerebellar degenerative syndromes

No specific finding could be visualized by MRI. Those atrophies, which were visible in CT scan, particularly in the pontocerebellar region, were to be seen equally in MRI.

3.6. Vascular disease

Cerebral infarction could be visualized equally in both CT scan and MRI. Because of less artefacts a brainstem infarction could be better seen and judged in its extent in MRI than in CT scan (22). In vascular disease a disadvantage of MRI is the inability to differentiate recent infarction from old lacunar ischemic lesions (23,24).

Four patients with arteric-venous malformations were examined. In both modalities, CT scan and MRI, these lesions could be seen equally. A typical example is shown in Fig. 4. Of two spinal angiomas only one was detected by CT scan. Multiple bone infarctions acquired during deep sea diving, were visible only in MRI.

3.7. Inflammatory lesions of the CNS

BRANT-ZAWADSKI et al (25) suggested from MR scans of an experimental brain abscess, that MR may be more sensitive and specific to the early stage of infections than the CT scan. WALL et al (26) described the MRI appearance of abscess and indicates a potential value of MRI to evaluate

abscess outside of CNS and spine. Another report (27) stress the importance of MRI in spinal abscess.

Recently different case reports were published dealing with MR imaging in Neuro-Behcet disease, cerebral toxoplasmosis etc. (28,29). The sensitivity of MRI in identifying infected lesions within the brainstem and temporal lobe became apparent. MR contrast agents that cross the blood meningeal barrier should yield images demonstrating abnormal enhancement of the subarachnoid spaces in chronic meningitis. MR may prove more sensitive to subdural empyema than x-ray CT, which is not easily be differentiated from chronic subdural hematoma by MRI. In conclusion, MRI of infections within the CNS seems to be become one of the most promising capability of this technique in the future (30).

3.8. Space occupying spinal lesions

Through the three-dimensional imaging of MR tomography the cranio-caudal extention of the spinal lesions in all 19 examined patients could be defined more exactly than be the other neuroradiological methods. This applies particularly to intramedullar lesions, respectively tumors. The spinal gliomas are visualized by T2 weighted sequence with high signal intensity (Fig.5); additionally cystic parts can be differentiated easily and exactly from solid intramedullar lesions. In 5 out of 8 patients suffering from intramedullar tumor only MRI enabled a definite differentiation from syringomyelia. In those cases suffering from extramedullar

tumors (4 meningeomas, 3 neurofibromas, 2 metastasis, 1 lymphogranulomatosis and 1 lipoma) no additional information could be gained by MRI when compared to CT scan.

3.9. Brain and spinal cord injuries

Out of 10 examined patients of this group in three a posttraumatic syringomyelia could be proven only by MRI, as it was the case in two with a brainstem contusion and in one with a temporal lesion. In the remaining twelve patients no additional aspect could be elicited, but, at this place, the extremely high sensitivity in visualizing chronic subdural hematoma should be stressed (31).

3.10. Development disturbances

All nine cases with syringomyelia were proven by means of MRI. Three of them were associated with Arnold Chiari malformation. Three intramedullar cysts without significant distention of the cord were undetectable by CT scan and myelogram, but could be clearly visualized by MRI. Tumors associated with syringomyelia can be distinguished easily because of the different signal behaviour in T1 and T2 weighted sequences.

3.11. Intervertebral disc disease

Intervertebral disc degeneration is characterized by decrease of signal intensity in the T2 weighted image. The observed change in T1 and T2 values of the nucleus is in agreement with the reduction of water content known to ocurr with age. Intervertebral disc disease with herniation is

demonstrated by MR-high resolution surface coil imaging providing information comparable to CT or myelography in a completely noninvasive manner. The advantage of MRI is the simultaneous, sagittal sectioning not only of the affected disk but also the visualization of the upper and lower disks.

With advances in MR-technology that provide thinner sections and improved S/N ratio, the problems involving specifity and accurate localization of disk herniation may overcome. MRI may then dispeace CT as the preferred primary noninvasive diagnostic technique for evaluation of lumbar spine intervertebral disk disease.

4.DISCUSSION

The most important domaine of MR-tomography are diseases of the CNS. The high sensitivity but also specifity in detecting pathological lesions is described by many authors (5,6,32,33). In visualizing demyelinating lesions, particularly the plaques of multiple sclerosis MR tomography is the method of choice (8,12,13). It is the first time that the natural course of this disease can be documented and followed up closely. Although neuropathological correlates lack so far one of the most promising perspectives might be the possibility to differentiate old from recent foci. Furthermore, the early diagnosis might lead to a new impact on therapy.

Brain tumors are also visualized by MR tomography with a highest sensitivity. An enormous advantages is the fact that there are no artefacts in temporobasal lesions and processes located in the posterior fossa (34,35,36). The size and extension of the tumors can be depicted precisely through the threedimensional imaging, its relation to healthy brain structures can be judged, in particular in view of surgical intervention or radiation therapy (37). A further promising perspective seems to become the possibility to differentiate between tumor recurrency and radiation necrosis (38). In our cases the specifity - as to histological prediction - was somehow less by MRI than by CT scan. In using multiecho sequences a impact on differentiation of various tissue structures should be achieved. Beside hydrogen-spectrum other spectra will be utilized in future time. Finally the superior differentiation of tumor tissue from perifocal edema by using paramagnetic contrast material should be mentioned (39).

In epileptic patients MR tomography might display a higher sensitivity, in particular, with regard to lesions of the temporal lobe (40). A minor disadvantage of MRI - versus CT scan - is the invisibility of calcifications by MRI. We have pointed already to the possibility to use MRI tomography as imaging method for stereotactic procedures in parkinson syndrome, epileptic seizures and even biopsy of suspected tumors (14).

According to DAVIDSON et al (30) inflammatory lesions can be visualized by MRI at the very early stage. This applies particularly to temporal lesions in herpes simplex - encephalitis and brainstem encephalitis which we fail very often to detect early be CT scan.

In spinal cord lesions the sensitivity of MR tomography exceeds by far that of CT scan and myelography, the most important advantages being the fact that contrast material needs not to be instilled intrathecally anymore. The high discrimination allows to differentiate extra- from intramedullar lesions, furthermore cystic from solid intramedullar lesions. It is for the first time that syringomyelia can be visualized directly. Intervertebral disc-degenerations are characterized by decrease of signal intensity in the T2 weighted image. However, in lumbar disc prolaps disease, CT scan display so far, still a higher specifity, although the introduction of surface coils will render the MR tomography to an equal or even superior imaging method (41,42).

Summarizing it should be stated that, according to our experience and that of various authors, CT scan will not be replaced in total by MR tomography but for certain indications. The noninvasiveness and lack of radiation dangers underscore the superiority of MRI. Furthermore, no biological damage have been observed so far in patients

examined by MR tomography with magnetic field strength of 2,0 T and used radiofrequency.

Summary

200 patients with a wide spectrum of CNS disorders were evaluated by magnetic resonance imaging (MRI); the results were compared with conventional neuroradiological techniques, including computerized tomography (CT). MRI proved to be superior,, showing the highest sensitivity, particularly in white matter diseases and lesions located within the temporal lobe and posterior fossa. Some disadvantages for MRI have to be conceded in respect to specificity. The use of modified sequences and paramagnetic contrast material will improve this in future. Spinal lesions can be visualized in their craniocaudal extension and localization. Cystic and solid intramedullary lesions can be differentiated with high accuracy. Finally, the non-invasiveness of this neuroimaging method should be mentioned particularly. Thus, for a variety of CNS-lesions, MR tomography is already the most important neuroradiological method.

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Legends

Figure 1: Characteristic changes of MS-plaques: multiple abnormal areas with increased signal intensity in periventricular regions and within the white matter (SE, TE 2400 msec., TE 120 msec.)

Figure 2: Median-sagittal MR-image of a patient with occlusive hydrocephalus: in T2 weighted image a lesion with high signal intensity can be seen within the upper brainstem corresponding to a glioma, CT scan being negative.

Figure 3: Axial T2 calculated image of a metastasis of a hypernephroma, located within the posterior part of the corpus callosum: fingerlike edema (➡) solid part of tumor (▽) and central necrosis (➡) can be easily distinguished.

Figure 4: Axial T1 weigthed image (TR 500 msec., TE 40 msec.) shows precise location of arteriovenous malformation within the right parietal lobe: typical serpiginous region of absent signal.

Figure 5: Midline sagittal SE scan of the spinal cord (TR 1500 msec., TE 80 msec.): intramedullar area of increased spinal intensity corresponding to a glioma of the medulla.

Table 1 a

MRI IN 200 PATIENTS WITH VARIOUS DISEASE OF CNS

DIAGNOSIS	N	ADDITIONAL INFORMATION THROUGH MRI
MULTIPLE SCLEROSIS	35	9
BRAIN TUMORS	32	2 (BRAINSTEM GLIOMA, ASTROCYTOMA)
EPILEPSY	14	4 (TEMPORAL LOBE LESION, ATROPHY)
PARKINSON SYNDROME		
S.p. STEREOTACTIC OPERATION	6	5 (IN CT SCAN ONLY 1 LESION VISUALIZED
HEMIPARKINSON	4	NONE
AMYOTROPHIC LATERAL SCLEROSIS		NONE
SPINOCEREBELLAR DEGENERATION	8	NONE
CEREBROVASCULAR DISEASE	14	2 (ARTERIOVENOUS MALFORMATION, BONE INFARCTION
INFECTIONS DISEASE	7	2 (BRAINSTEMENCEPHALITIS, EPIDURAL ABSCESS)

Table 1 b

MRI IN 200 PATIENTS WITH VARIOUS DISEASE OF CNS

DIAGNOSIS	N	ADDITIONAL INFORMATION THROUGH MRI
SPINAL SPACE OCCUPYING LESION	19	5 (INTRAMEDULLAR LESION)
INJURY (BRAIN, SPINAL CORD)	18	5 (3 SYRINGOMYELIA, 1 TEMPORAL LOBE LESION, 1 BRAINSTEM)
DEVELOPMENT DISTURBANCE (SYRINGOMYELIA) ARNOLD CHIARI MALFORMATIONS	9	3 (SYRINGOMYELIA)
CERVICAL MYELOPATHY DISCOPATHY	15	CT SCAN STILL SUPERIOR
OTHERS	19	

Table 2

MULTIPLE SCLEROSIS: CT AND MRI FINDINGS

(N = 35)

DIAGNOSIS		MR POS.	CT POS.
DEFINITE	18	18	6
PROBABLE	8	6	2
SUSPECTED	9	3	-

Table 3

DIFFERENTIAL DIAGNOSIS OF PLAQUES WITH HIGH SIGNAL INTENSITY IN MR TOMOGRAPHY

- MULTIPLE SCLEROSIS
- BINSWANGER DISEASE
- ACTIVE HYDROCEPHALUS
- LEUCODYSTROPHIA
- LACUNAR INFARCTION WITHIN THE WHITE MATTER

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MRI of the central nervous system: diagnostic and therapeutic implications.

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