Fast Magnetic Resonance Imaging and Three Dimensional Volumetric Calculations in Degenerative Central Nervous System Diseases

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Introduction

Diagnosis of degenerative central nervous system (CNS) disorders with and without dementia is primarily based on neurological and neuropsychological examination (Gerstenbrand et al. 1990; Marsden 1985). In order to differentiate between treatable and nontreatable pathologies that cause dementia, neuroradiological examination has proven to be helpful (Le May 1986). In particular, magnetic resonance imaging (MRI), based on high tissue contrast and multiplanarity, has become a valuable tool in the detection and delineation of intracerebral pathologies (Aichner et al. 1988; Perovitch et al. 1990).

However, differentiation between senile dementia of the Alzheimer's type (SDAT) and multi-infarct dementia (MID) remains difficult, since the ischemic-like white matter lesions are detected in both types of degenerative diseases (Felber et al. 1990). To improve the capability of MRI, new gradient echo (GE) sequences have been introduced in addition to conventional spin echo (SE) sequences.

Strong, T1-weighted, GE sequences with a slice thickness of about 1 mm allow detection of even small parenchymal lesions as well as optimal differentiation between gray and white matter. Furthermore, nearly isotropic resolution allows in vivo, volumetric, computerized postprocessing.

The aim of this study was to investigate the impact of fast three-dimensional (3-D) imaging and volumetric calculation on the differentiation of degenerative disorders of various types.

Methods

All examinations were performed on a 1.5 T Magnetom using a circular polarized head coil with a field of view of 25 cm. The parameters of the 3-D

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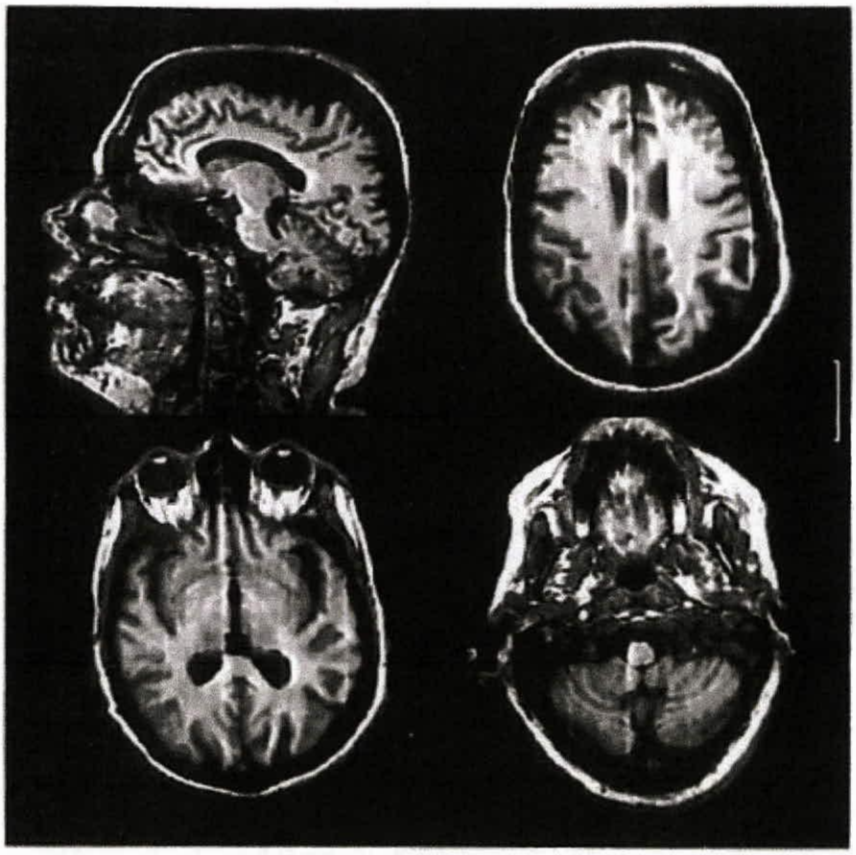

Fig. 1. A 61 year old patient with senile dementia of the Alzheimer's type. Sagittal 3-D FLASH GE sequence (see text) with axial reformations shows predominant atrophy of the temporooccipital cortex

FLASH sequence had been optimized for T1 contrast: TR, 40 ms; TE, 5–8 ms; α, 40° (Fig. 1).

Minimal pixel size and short TE times compensate for intravoxel-phased dispersion due to susceptibility effects at bony areas to soft tissue interfaces. By excitation of a 13–16 cm 3-D volume, 128 contiguous slices of the entire brain, 1–1.3 mm thick, were acquired within 21 min. The acquired data were postprocessed on a MR system computer. Brain parenchyma was isolated from the surrounding tissue using a "region-growing" segmentation algorithm. The volume of each segmentation was automatically calculated.

Patients

Between January 1989 and January 1990, 40 patients with diffuse or regional parenchymal loss were investigated. In 14 patients, additional postprocessing volumetric assessments were performed (SDAT $n = 2$, MID $n = 5$,

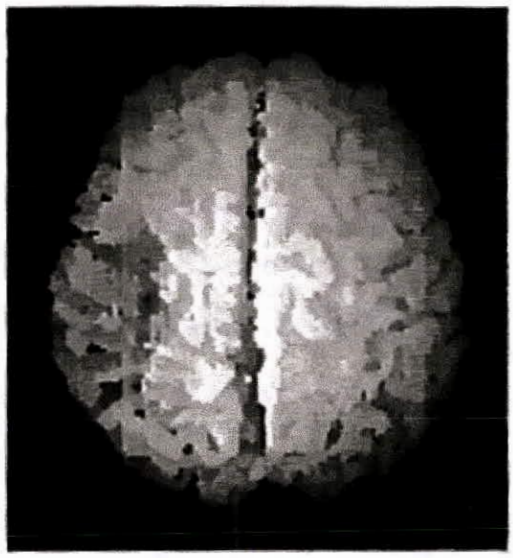

Fig. 2. A 49 year old patient with multiinfarct dementia. Surface reconstruction shows a huge postischemic defect on the right parietal lobe

spinocerebellar degeneration $n = 7$, control volunteers $n = 2$). To prove the accuracy of the volumetric values, a formalin-fixed brain was examined and the anatomical data were compared to the volumetric MR results. Surface reconstruction of the brain was done in an additional four patients (Fig. 2).

Results

A total of 14 patients, 2 volunteers, and 1 formalin-fixed specimen were scanned with a 1.5T MR system using a relatively T1-weighted GE sequence. The 3-D data were automatically segmentated and volumetrically postprocessed. In all cases the examinations were of diagnostic quality; the measurement time of 21 min for the 3D data was well tolerated by all patients. Relatively T1-weighted sequences allowed excellent delineation of gray and white matter. The contrast between cerebrospinal fluid (CSF) and cortex was sufficient for volumetric computerized postprocessing. A pixel size of $1-1.3 \times 0.9 \times 0.9$ was calculated in milliliters and was automatically processed for volumetric assessment. To evaluate the quality of this method, the anatomical volume and the 3-D volumetric data of the specimen were compared; a difference of only 4% was found (total brain volume: anatomical, 1098.1 ml; 3-D volumetric data, 1046.4 ml). The calculated brain volume of a normal female volunteer, age 45 years, was 1193.6 ml, that of a male volunteer, age 26, was 1304 ml. The two patients with SDAT, 61 and 57 years of age and both female, had a brain volume of 903.27 ml and 824 ml, respectively (Fig. 3). The five male patients with MID had a reduction of the total brain volume ranging from 1226.2 ml to 1093 ml.

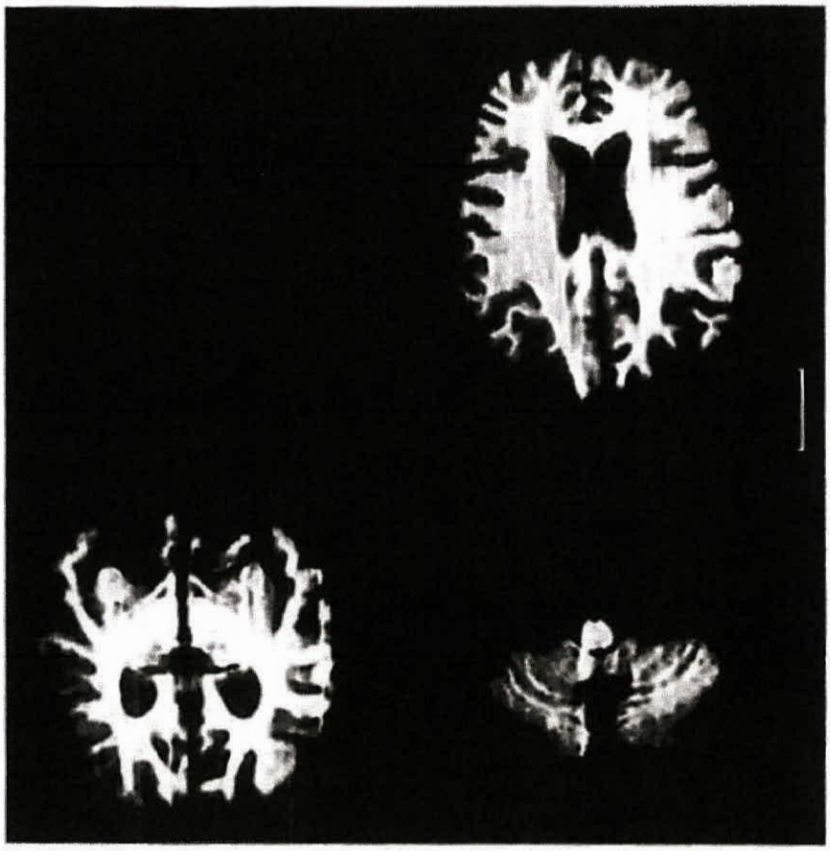

Fig. 3. Axial reformations of sagittal 3D FLASH examination in a patient with senile dementia of the Alzheimer's type postprocessed to isolate the brain from surrounding tissue. Volumetric data are: total volume, 824 ml; cortex, 705 ml; cerebellum, 118 ml

Discussion

In this preliminary study, 14 patients with different pathological conditions resulting in reduction of brain volume were volumetrically assessed. We used 1 mm thick slices and a relatively T1-weighted FLASH sequence with a nearly isotropic high resolution of less than 1 mm. With this technique, even the smallest lacunar lesions, related to vascular etiologies, can be detected. Therefore, approach may be a further step in the differentiation between MID mixed type and primary degenerative CNS disorders. In addition, this method has proven to be sufficient for volumetric postprocessing. In all patients volumetric calculation revealed a decrease in brain volume compared to nonage-matched volunteers. In SDAT and spinocerebellar atrophy, this method allows volumetric follow-up investigations which may be helpful in further understanding the course of these primary degenerative diseases.

It was found that, in patients with MID, the gray/white matter ratio in nonischemic areas was normal, whereas in patients with SDAT a thinning of

the cortical gray matter was present. The excellent cortical and medullary contrast, based on the strongly T1-weighted FLASH sequences, may further allow separate volumetric calculation of gray and white matter.

In addition, surface reconstruction revealed topographic information about cortical brain structures. In order to achieve a better correlation between neurological, neuropsychological, and electrophysiological findings, this method may be helpful for future investigations of degenerative CNS diseases.

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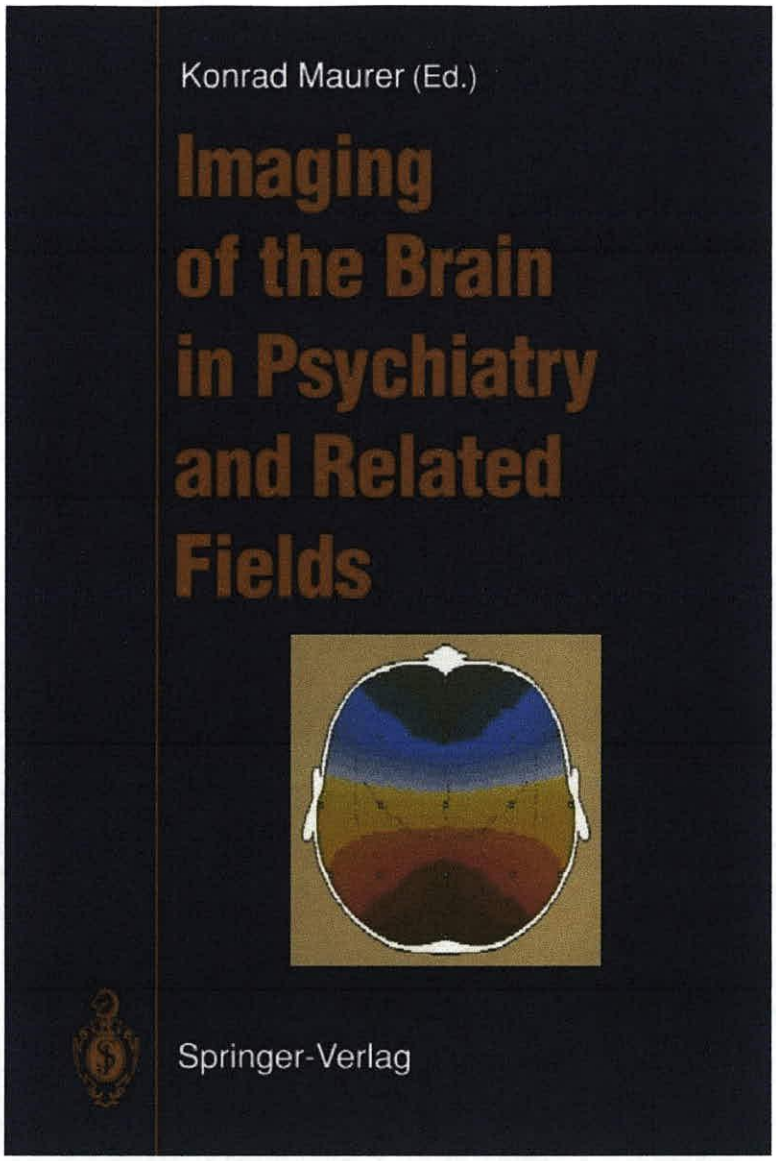

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