Case Study: Magnetic Resonance Fingerprinting (MRF) Imaging of the Brain

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Introduction

Because of its ability to probe numerous tissue properties, including those reflective of many common disease states, Magnetic Resonance Imaging (MRI) is widely used as a diagnostic tool in medicine. Whenever a patient is referred to MRI, for example due to neurological disorders of unknown origin, a (more or less standardized) set of qualitative images with different contrast is acquired. Each contrast reflects a different 'weighting' of tissues. The radiologist is trained to identify and describe areas which are 'hyperintense' or 'hypointense' compared to surrounding, normal-appearing areas. Reading all contrasts in conjunction and mentally comparing them to typical disease patterns, the radiologist will come to a diagnosis which is potentially accompanied by one or more differential diagnoses. Although successfully practiced around the world every day in thousands of cases, this approach has various disadvantages. Conventional MR imaging does not provide a quantitative indication of the contrast differences which are described, and the absolute signal intensity in the images has no direct meaning or implication for diagnosis. Furthermore, some diseases and early disease states may cause very subtle changes of tissue parameters which may not be reflected in visibly discernable contrast differences.

MR Fingerprinting (MRF)[1] is a new approach for MR data acquisition, post-processing and visualization [1]. Instead of acquiring images with different contrast, signals from different body locations are acquired using a pseudo-randomized acquisition scheme. As a result, each voxel appears to have a unique signal evolution or 'fingerprint' which reflects the multiple tissues and tissue properties present in the respective location. During post-processing, a pattern recognition algorithm matches the fingerprints to a previously acquired dictionary of signal evolutions, providing knowledge about the materials, their properties and concentration.

Finally, the information can be translated into quantitative maps of the magnetic parameters of interest but also into synthetic, 'classically weighted' images.

Theoretically, MRF could be applied in almost all cases where conventional, qualitative MRI is used today, including the imaging of the body stem [2]. In this case study we present two cases of frequent neurologic disorders and their representation in MRF images and maps.

Imaging details

Conventional MR imaging and MRF of the neurocranium was performed using a 1.5T MR scanner (MAGNETOM Aera, Siemens Healthcare, Erlangen, Germany). The MRF sequence prototype was based on a FISP (fast imaging with steady-state precession) acquisition scheme as described in Jiang *et al.* [3], consisting of an initial inversion pulse followed by a rapidly acquired series of 3000 undersampled spiral images with varying TR (14-17 ms) and flip angle (0-75°). Slices with 20% slice gap and 5 mm slice thickness covered the pathological region of interest. The spatial resolution of the acquired images was a 256 x 256 matrix with <1.2 mm isotropic resolution. The scan time requirements for MRF was ~48 sec per acquired slice.

Based on the MRF data, different conventional contrasts were generated. Images were processed by manually placing regions-of-interest (ROIs) in different locations and plotting the derived T1 and T2 values against each other.

Conclusion

As the cases presented here demonstrate, MRF is able to characterize tissues in terms of their quantitative instead of qualitative attributes.

With the prospect of acquiring tissue fingerprints with music-like gradient schemes [4] in the future, MRF may eventually overcome the common patient impression of MRI being a loud and frightening technology.

Acknowledgement

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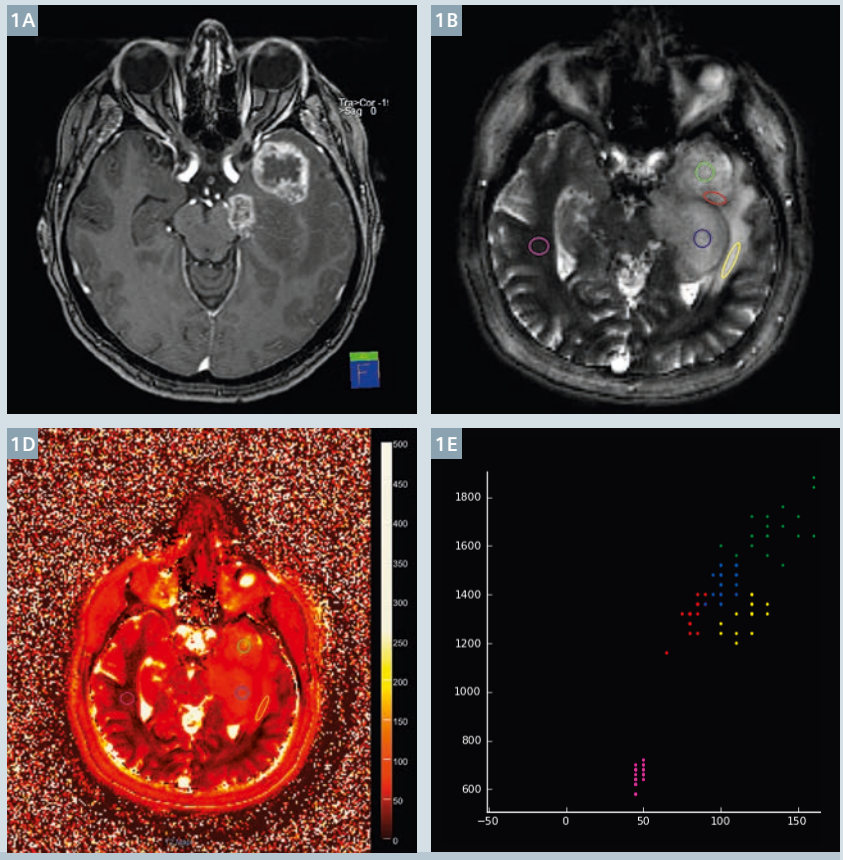
[1] WIP, MR Fingerprinting is currently under development and is not for sale in the US and in other countries. Its future availability cannot be ensured.

Case 1

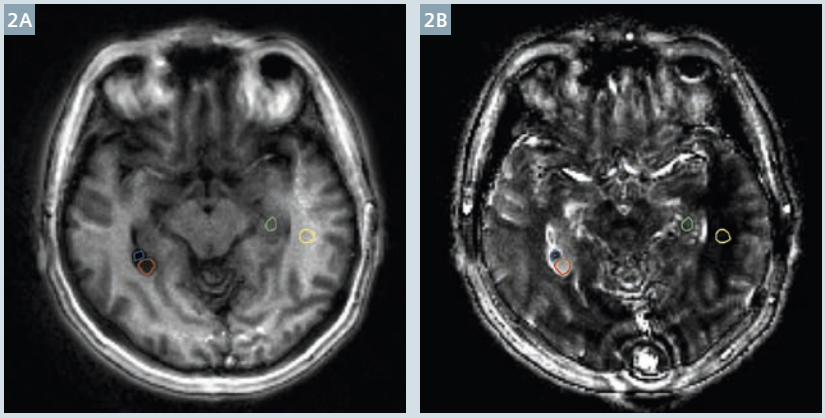
Patient with a Glioblastoma multiforme, WHO grade IV. The patient presented with subjective visual deterioration persisting for one week. The neurologic and ophthalmologic examination showed a complete postchiasmal left hemispheric lesion of the visual pathway.



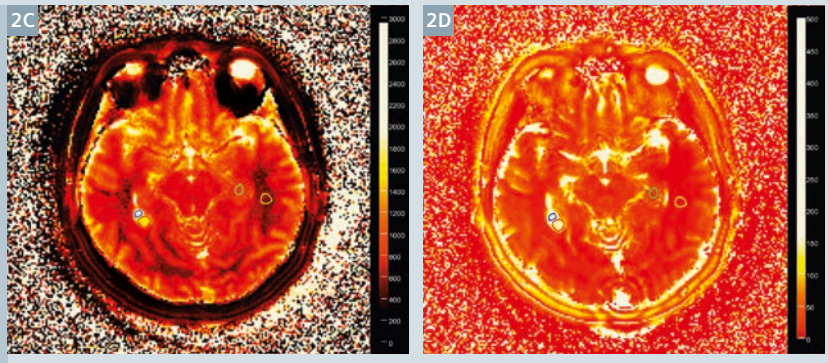
1 **(1A)** Contrast-enhanced T1-weighted MPRAGE images show one central necrotic lesion in the left temporal lobe, with contrast media uptake at its margin. A solid part of the lesion is visible at its dorsal margin. Another equally appearing lesion is located in the left cerebral peduncle. Dorso-laterally adjacent, this part of the tumor migrates into another solid part of the tumor that ranges along the hippocampus towards dorsal. This part shows little contrast media uptake, only in the lateral portion, and no central necrosis. Spectroscopic assessment of the central necrotic lesion (not shown here) revealed Choline / NAA disproportion and a lipid peak, while the more dorso-laterally located lesion also showed Choline / NAA disproportion, but to a lesser extent and no lipid peak. Consequently, in comparison to the central necrotic and strongly enhancing high grade part (Glioblastoma WHO IV) of the tumor, a lower grade part of the tumor has to be considered here. **(1B-D)** Corresponding calculated T2 image, T1 map and T2 map, derived from MRF data. ROIs were placed in the solid part of the tumor (red), the central necrosis (green), the lower grade part of tumor (blue), and in the surrounding edema respectively area of suspected tumor infiltration (yellow), as well as in normal appearing, contralateral white matter (pink). **(1E)** The scatterplot of T1 over T2 shows visible differences between the solid part of the centrally necrotic lesion (red), the central necrosis (green), the lower grade part of the tumor (blue), the surrounding edema / potential infiltration (yellow) and a clear distinction from normal appearing white matter (pink).

Case 2

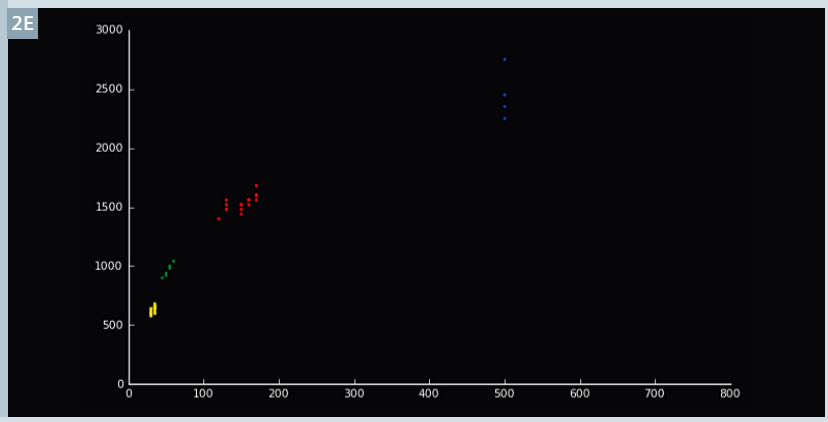
Patient with low grade glioma (WHO grade I), histologically differential diagnosis included pilocytic astrocytoma (WHO grade I) and ganglioglioma (WHO grade I). The patient presented with a history of repeated headaches and dizziness over the course of the last year and had one singular seizure about six months ago, manifesting with clonic muscle spasms of the left upper extremity spreading to the right upper extremity.



T1-FLAIR (calculated) T2-FLAIR (calculated)



T1 Map T2 Map



2 **(2A, B)** Calculated T1w and T2w FLAIR images. A lesion in the right temporal lobe located beneath the lateral ventricle is visible. It consists of a dorsal solid part and a rostral cystic part. In contrast-enhanced imaging (not shown here) the solid part showed uptake of contrast media, the cystic part did not. In spectroscopy (not shown here), the solid part of the tumor showed a mildly abnormal choline / NAA concentration and minimal expression of lactate.
(2C-E) ROI placement revealed different characteristics in the scatterplot representation, with the following assignments: solid part of the tumor (red), cystic part of the tumor (blue), normal appearing white matter (yellow) and gray matter (green).

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