

Assessment of Vascularity in Malignant Glioma: Development of an Imaging Protocol at 7 T

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Introduction

Malignant gliomas are histologically characterized by an abnormally high degree of microvascular proliferation. Tumor angiogenesis is therefore an important target in therapy, leading to the development of numerous anti-angiogenic agents and, recently, to the approval of Bevacizumab for therapy of recurrent glioma [1-4]. MRI therapy monitoring of brain tumors still heavily relies on determining the extent of contrast extravasation, but since anti-angiogenic substances can suppress contrast extravasation, this method is no longer suitable [5]. Measurements of perfusion parameters are an appealing solution, but even after many years of research perfusion quantification is not well established in clinical settings because of standardization and reliability issues [6]. Therefore, our goal was to image the tumor vasculature directly using the advantage of high-resolution 7T MRI.

Methods

Fourteen patients with astrocytic tumors including 10 patients with glioblastoma multiforme (GBM) were examined on a 7 T whole body MR system (Siemens, Erlangen, Germany), using a 24-channel Tx/Rx head coil (Nova Medical, Wilmington, VA). For each patient, a B1 calibration was initially performed with a fast turboFLASH technique at a reference point (iso-center of the coil). This 1 min B1 mapping was necessary to guarantee correct flip angle values for the coil iso-center.

To establish a clinical imaging protocol, the following imaging pulse sequences were used: 2D T2 turbo Spin Echo (TR 12000, TE 57 ms, 0.3×0.3×2.0 mm voxel size), T1w 3D FLASH (TR 6.6, TE 2.38 ms, 0.5×0.5×0.7 mm), T2 FLAIR (TR 12000, TE 94 ms, 0.6×0.4×2.5 mm), susceptibility weighted imaging (SWI, TR 23, TE 15 ms, 0.5×0.4×0.4 mm) and time of flight angiography (TOF, TR 15, TE 4.76 ms, 0.3×0.3×0.4 mm). All individual protocols were designed so that the imaging time per protocol did not exceed 10 min. T1 sequences were acquired unenhanced, after administration of Gd-BOPTA (MultiHance, Bracco, Milan, Italy) or both. For localization of the vessels in the tumor, a targeted maximum intensity projection (MIP) of the TOF angiography with a slice thickness of 15 mm was anatomically co-registered to the T1- and susceptibility weighted images using manufacturer-provided software (Syngo Image Fusion).

Results

In all patients 7 T images of the brain could be successfully acquired. At present, 7 T brain MRI is confined to the neurocranium as the current coil design reaches down only to the skull base. Signal inhomogeneities due to the B1 inhomogeneities were most pronounced with the spin echo techniques. However, even with a variation of B1 by a factor of 2 between the center of the head and the skull excellent spin echo images could be acquired.

The TOF technique proved to be superior to the T1- and T2-weighted sequences in visualizing the arterial intratumoral vessels (Fig. 1). After registration of a thin slice MIP to the morphological images, the vessels could be clearly identified as tumor vessels (Fig. 2C). SWI showed the venous part of the intratumoral vasculature, but also susceptibility artifacts caused by microhemorrhage or previous surgery (Fig. 2D). An image fusion of SWI with the TOF angiography depicted arterial and venous vessels simultaneously. The fusion tool provided reliable image registration in very short processing times, even if the automatic algorithm for registration was used. The high-resolution T1- and T2-weighted morphological images at 7T can be used for determining the dimensions as well as the internal morphology of the tumor and surrounding changes like edema and bleedings.

Conclusions

Given the excellent ability of TOF MRA and SWI at 7T to depict the arterial and venous intratumoral vasculature, we highly recommend to include these sequences into MRI protocols for malignant gliomas at 7T. These sequences are especially recommended for patients under antiangiogenic therapy, which can suppress the extravasation of contrast media, simulating a therapy response on contrast enhanced T1-weighted images. Unlike with all kinds of perfusion imaging, post-processing is very simple to perform, fast and reliable, making it ideal for clinical settings. Since these techniques directly image the vasculature, they seem to be ideally suited for monitoring new therapeutic substances with unpredictable effects on the blood-brain-barrier. As a feasible protocol for imaging glioma at 7T, we recommend a combination of T2 TSE, T2 FLAIR, T1 GRE and TOF angiography before and T1 GRE and SWI after application of contrast media.

References

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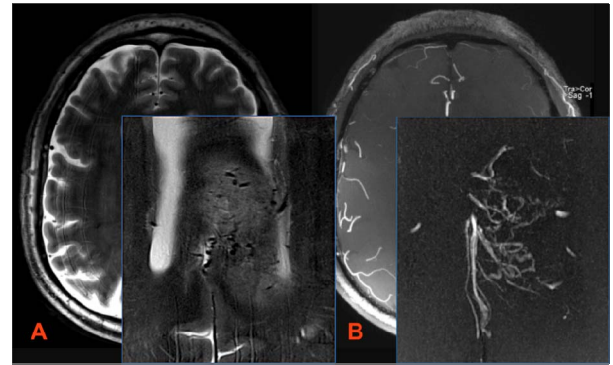


Fig. 1: Vascular imaging of a GBM. A) High-resolution T2w with 0.3 mm voxel size shows fine details of the internal morphology. B) TOF angiography shows the increased vascularization of the tumor.

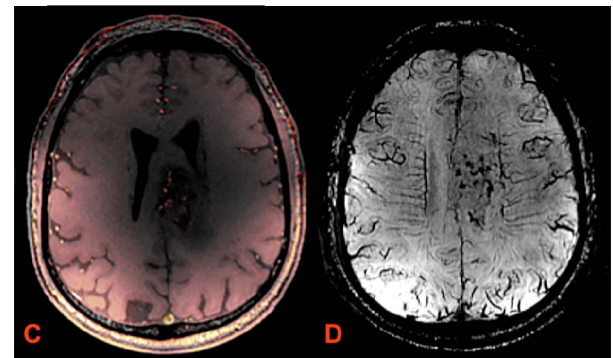


Fig. 2: C) Image fusion of TOF with T1w clearly localizes the arterial vessels inside the tumor. D) SWI shows venous vessels and susceptibility artifacts caused by microbleeds.