

Analysis of brain tumors and metastases by quantitative MT imaging with bSSFP: Initial experiences

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Introduction. MRI is sensitive for detecting CNS abnormalities, but lacks some specificity for their pathological substrates. In contrast, magnetization transfer ratio (MTR) analyses have been reported to show increased pathologic specificity for the characterization of brain tissue (1), e.g. for the differentiation of low-grade from high-grade gliomas and benign from malignant tumors. In this study, the efficacy of quantitative MT (qMT) imaging for characterization of benign and malignant brain tumors and metastases is analyzed with balanced steady-state free precession (bSSFP) (2). MT effects are described in terms of MTR, relaxation times (T1, T2), MT exchange rate (kf) and the macromolecular content (F).

Methods. Eleven patients (mean age: 60, (7f, 4m)) with 3 different brain lesions (4 glioblastoma multiforme (GBM), 4 meningiomas and 3 metastases) were investigated on a clinical 1.5T MR scanner (Avanto, Siemens, Erlangen, Germany). The MR examination consisted of a complete conventional MRI imaging protocol including DWI, T2w, FLAIR and T1w-/+ contrast enhancing (CE) sequences (Fig. 1). Quantitative MT-imaging included a B1 map, two RF spoiled gradient echo sequences with variable flip angles for T1 determination (3), 2 bSSFP sequences with variable flip angles for T2 determination (3) and 7 bSSFP sequences using different RF pulse durations ($T_{RF} = 230\mu s - 2100\mu s$) to yield F and kf (4). The qMT protocol was completed within 10 minutes, providing whole brain images with 1.3 mm isotropic resolution. Evaluation of qMT data sets (MTR, T1, T2, F, kf) and histogram analysis with ROIs placed within the CE portion of the lesions (Fig. 2), the surrounding edema and the non-affected brain tissue was performed using MATLAB (The MathWorks, Inc., Natick, MA, USA).

		T1 [ms]	T2 [ms]	MTR [%]	kf [1/s]	F [%]
CE-portion	GBM	1736±87	141±14	22.4±2.4	0.6±0.1	2.7±1.2
	Meningiomas	1228±55	109.5±9	23.5±1.1	1.2±0.6	2.6±0.7
	Metastases	1613±56	135±7	27.2±1.9	0.8±0.1	3.1±0.9
Edema	GBM	1312±94	157±14	31.2±1.9	1±0.4	4.8±1
	Meningiomas	1642±149	206±18	26.9±2.3	0.8±0.3	4.±1.3
	Metastases	1351±46	123±7	34.8±1.8	1.3±0.2	5.9±1.1
Healthy tissue	GBM	768±50	63±6	42.3±2.8	3.5±0.4	13.2±2.8
	Meningiomas	889±122	67±7	41.3±3.5	3.1±0.8	11.7±3.3
	Metastases	886±97	66±8	40.1±4.9	3±0.8	11±3.3

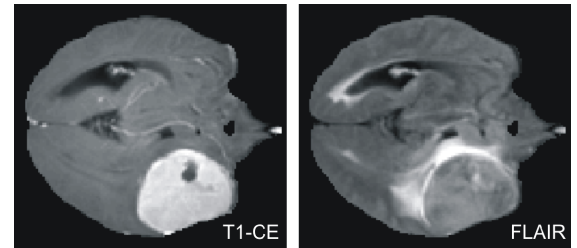


Fig 1. Axial T1-CE and FLAIR images of a patient with a meningioma.

Table 1. MTR and quantitative MT parameter estimates for the contrast-enhancing area, the surrounding edema and the healthy appearing tissue for the different brain lesion investigated. Given are the mean and standard deviation (±SD).

Results. Mean values for the ROIs within the different lesions and the non-affected brain tissue are summarized in Table 1. As expected, MTR was higher in the normal appearing than in the damaged brain tissue. For quantitative estimates, F and kf were found to be significantly lower and relaxation times significantly higher in tumors and metastases than in normal appearing tissue.

Within the lesioned tissue, F- and in general MTR-values were higher for the perifocal edema than for the CE-areas, despite similar kf. Also between the different pathologies several divergences were found. For the CE-areas, highest F was observed in metastases, whereas kf was highest in meningiomas, and relaxation times were markedly shorter for meningiomas than for GBMs and metastases. For edema, kf and F tended to be higher in metastases than in the other lesions investigated, whereas T1 and T2 were markedly higher for meningiomas than for GBM and metastases. Despite similar MTR for the CE-areas in GBM and meningiomas, kf tended to result in higher and relaxation times in significantly lower values compared to GBM, despite similar F.

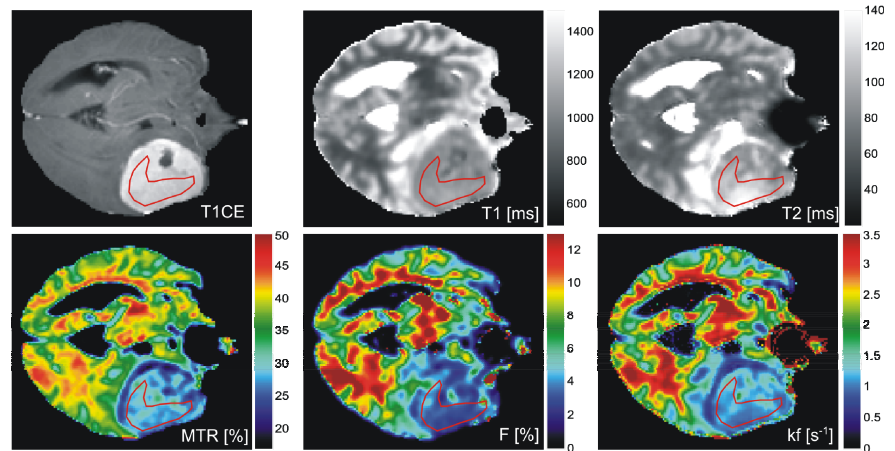


Fig 2. Exemplary ROI placed in the CE-part of the meningioma shown in Fig. 1. Mean values for the ROI were calculated based on maps of T1, T2, MTR, F and kf.

Discussion. Differences in MT-values for the CE-regions and the surrounding edema in different brain pathologies might be attributed to differences in edema characteristics (e.g. edema intensity), in cell infiltration and density as well as in myelin properties. Differences in relaxation times despite similar MTR-values between GBM and meningiomas indicate a higher diagnostic potential for qMT in comparison to the semiquantitative analysis obtained with MTR.

Conclusion. In different pathologies, contrast enhancing tissue and surrounding edema, which appear similar in signal intensity on conventional MRI, show differences in F, kf and relaxation times. Thus, qMT imaging might play a major role in adding information for diagnostic tumor characterization. However, more data have to be collected to confirm the value of complementary qMT imaging in the clinical setting.

References. (1) Pui MH et al., *J Clin Imaging* 29 (2005). (2) Gloor et al., *Magn Reson Med* 60 (2008). (3) Deoni et al., *Magn Reson Med* 53 (2005). (4) Gloor et al., *Proc. ESMRMB* (2008).