Correlation and fusion of perfusion and spectroscopic MR imaging for the characterisation of brain tumors

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Objectives:

For biopsy as well as for radiation therapy planning preoperative classification and detection of the most aggressive area of brain tumors are essential. We investigated whether a combination of spectroscopic and perfusion imaging is useful to preoperatively characterize intracranial tumors and if the regions of highest values correspond.

Materials and Methods:

Until now we investigated 12 patients with brain tumors (Fig. 1).
Besides T2- and T1-weighted morphologic images T2* weighted MR perfusion in the same slice position and 2D-proton MR spectroscopic imaging was performed (Fig. 2). For calculating the blood volume maps, the data were loaded into the programme DPTools© by Denis Ducreux, which in addition allows for transferring regions of interest (ROI) from morphologic images onto the perfusion maps (Fig. 5). For evaluation of the spectroscopic data we used the software Syngo® implemented on our MR-scanner (Fig. 6).
As ROI we defined the macroscopic apparent part of the tumor e.g. the enhancing area (ROI 1) (Fig. 3) and the surrounding area hyperintense on T2 images (ROI 2) (Fig. 4) and compared it to normal appearing white matter (ROI 3). Spectroscopic voxels with artifacts from bone or necrosis were excluded.
For lack of absolute concentrations relative regional Cho/NAA ratios (rrCho/NAA ratio) and relative regional cerebral blood volume (rrCBV) were used.
We also assessed match or mismatch of the areas of highest perfusion and Cho/NAA ratio.

Results:

Perfusion imaging was evaluable in all cases. In 2 glioblastoma some spectra in the tumor were disturbed due to intratumoral bleeding and necrosis. As these spectra were ignored for evaluation, all patients showed raised Cho/NAA ratio in ROI1.
RrCBV in the glioma III°, in 3 glioblastomas and in the meningeoma was highly elevated.
In the meningioma in both parameters increase was strictly limited to ROI 1, whereas in ROI 2 of the maligne gliomas Cho/NAA ratio was elevated.
Lymphomas showed no or only slight elevation of rrCBV in ROI 1 and non in ROI 2. Low grade astrocytomas neither had increase of rrCBV in ROI 1 nor in ROI 2, however as they do in Lymphomas spectra revealed raised Cho/NAA ratio in ROI 1 and in 1 case again in ROI 2.
Gliomatosis cerebri didn't show hyperperfusion but increased Cho/NAA ratio in either of the ROIs.
In 6 of 9 tumors, in which areas of highest rrCBV and Cho/NAA within the lesion were definable, perfusion and spectroscopy displayed the same location.

Conclusion:

Perfusion and 2D proton MR spectroscopic imaging are able to visualize characteristics of tumors such as vascular proliferation and infiltration
Not all of our patients demonstrate good local correlation of regions with highest values:
CBV helps to reveal areas with high density of vessels defining vital parts of tumors. That in gliomas represents a higher malignancy (e.g. Fig. 8). But CBV fails to detect poorly vascularized lesions (Fig. 7).
Cho/NAA ratio is a reliable instrument for locating neoplastic lesions (Fig. 11). But in some cases elevation of Cho/NAA ratio persists in necrotic regions (Fig. 10).
For that we suggest to combine conventional MR-imaging with MR-perfusion and -spectroscopy as a useful tool for preoperative characterisation of brain tumors as well as for biopsy and radiation therapy planning.
Results have to be confirmed with larger numbers of patients which is in progress.

Patients and MR-Imaging (Fig. 1 and 2):

tumor	patients
glioma II°	2
glioma III°	1
glioblastoma	5
gliomatosis	1
lymphoma	2
meningioma	1

Fig. 1: Patient classification depending on the tumor type (histological classified following the WHO grading system).

Fig. 2: MR-parameters of the T2* weighted perfusion, the chemical shift and the morphologic imaging.

sequence	T2-TSE	2D multivoxel spectroscopy	T1-SE	T2* perfusion (gre-EPI)
TE /TR	131 ms / 4850 ms	1500 ms / 135 ms	17 ms / 665 ms	2000 ms / 60 ms
matrix	256 x 256, FOV 256	160 × 160, FOV 160 mm	256 x 256, FOV 256	128 × 128, FOV 256 mm
measurement	20 slices	1 slice	20 slices	25 repetetive scans a 20 slices
slice thickness	3 mm without gap	10 mm	3 mm without gap	3 mm without gap
gadolinium	-	-	0,1 mmol/kg; 1,5 ml/s	2. Bolus: 0,1 mmol/kg; 5 ml/s
scanner	1,5 T whole body MR-scanner (Siemens Magnetom Symphony, Erlangen, Germany)			

Analysis (Fig. 3 - 6):

Fig. 6: By overlaying spectroscopic data onto T1, T2 and CBV maps mean Cho/NAA ratio for each ROI was defined.
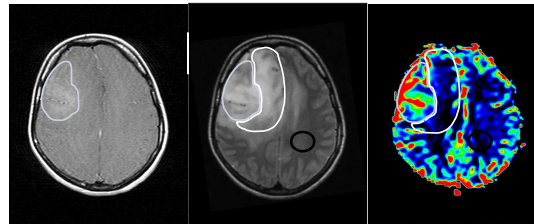
Fig. 3: Based on the postcontrast T1 image the enhancing area of the tumor was chosen as ROI 1 (light blue edge).
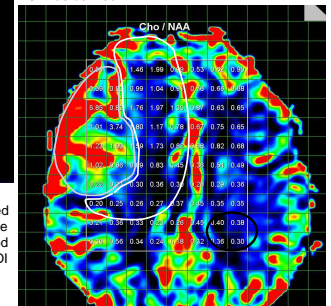
Fig. 4: The area hyperintense on T2 weighted images was taken as ROI 2 (white edge) and ROI 3 was positioned in normal appearing white matter (black edge).

Fig. 5: The ROIs were transferred onto the CBV-maps and the regional cerebral blood volume (rCBV) for each ROI was calculated.

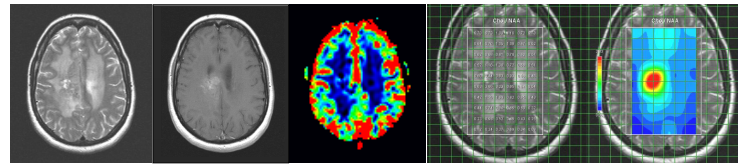## Results (Fig.7 - 11):

Fig. 7: Perfusion and spectroscopy of a low grade glioma (from left to right: T2, T1 post CM, CBV, Cho/NAA ratios and map superimposed on T2).
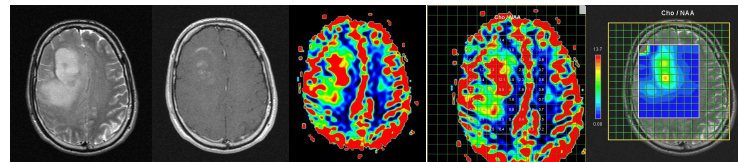
Fig. 8: Perfusion and spectroscopy of a glioma III° (from left to right: T2, T1 post CM, CBV, Cho/NAA ratios superimposed on CBV and Cho/NAA map on T2).
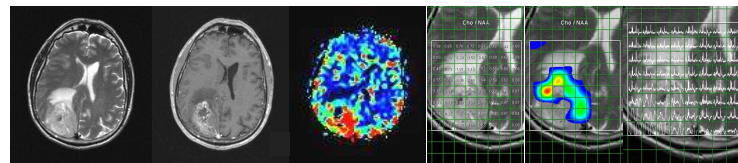
Fig. 9: Spectroscopy and perfusion of a glioblastoma (from left to right: T2, T1 post CM, CBV, overlay of T2 with Cho/NAA ratios, Cho/NAA map and spectra).
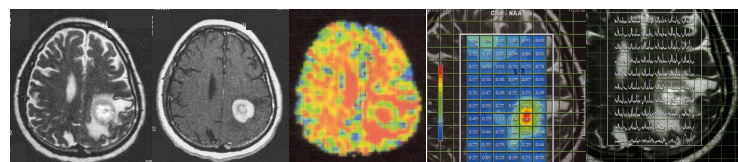
Fig. 10: Spectroscopy and perfusion of a lymphoma (from left to right: T2, T1 post CM, CBV, Cho/NAA map with ratios and spectra superimposed on T2).

Fig. 11: Regional values of cerebral blood volume and Cho/NAA ratio relative to normal appearing white matter.
In addition match or mismatch of the areas of highest values of both parameters are on display. Tumors, in which no region of highest CBV was evaluable, were marked with „-".

	matching of the areas of highest CBV and Cho/NAA	tumor (ROI 1)		surrounding tissue (ROI 2)	
		rrCBV	rrCho/NAA ratio	rrCBV	rrCho/NAA ratio
glioma II°	no	0,71	2,84	0,90	1,29
	-	0,87	7,96	0,90	1,90
glioma III°	yes	2,13	17,14	1,46	6,57
glioblastoma	no	8,15	4,47	2,57	2,17
	yes	5,31	8,72	1,33	1,72
	no	3,88	21,14	2,12	2,29
	yes	1,25	3,91	0,73	1,49
	-	0,75	19,13	1,01	7,63
gliomatosis cerebri	yes	0,63	4,93	1,40	3,41
lymphoma	-	0,78	5,91	0,64	2,25
	yes	1,48	2,91	0,98	0,90
meningioma	yes	12,26	5,60	0,52	1,08