Brain tumor perfusion intercomparison: Dynamic contrast enhanced magnetic resonance imaging exploiting T1, T2, and T2* contrast, pulsed arterial spin labeling, and $H_2{}^{15}O$-PET

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Introduction

Perfusion is increasingly becoming a useful tool in clinical practice of tumor diagnostics and could be especially used as functional parameter for treatment control. Various techniques for assessment of tumor perfusion are in clinical use after being properly investigated in healthy brain tissue. Methodical limitations of most of these techniques are evident in tumorous tissue, where the blood brain barrier is disrupted. We investigated the uncertainties of common measurement techniques for perfusion by applying it in the same patient in tumor and in healthy brain tissue.

Material and Methods

12 Patients with brain tumors (9 high grade gliomas, 2 meningiomas, 1 cerebral metastasis) were investigated. Perfusion was investigated with O-15-H20-PET (1 GBq bolus, 2D-scan, 47 slices, 128x128 matrix, FOV=659 mm) and calculated with the technique proposed by Watabe at al. [1] implemented into the PMOD-software. The MR investigations were performed subsequently as follows. All patients were investigated with a quantitative pulsed arterial spin labeling sequence FAIR/QUIPPS (3 slices, 8 mm, TI=1300, 1430, 1560 ms, TE=29 ms, 128x128 matrix, FOV=230 mm, inversion slab 35 mm, saturation slab 40 mm) [2]. Also all patients were investigated with the T1-weighted dynamic contrast enhanced imaging using an inversion prepared TurboFlASH sequence with 1 sec framing (1 slice, 5 mm, TI=300 ms, TE=4,2 ms, α=25°, 128x128 matrix, FOV=230 mm). The evaluation is described in detail in [3]. A second dynamic contrast enhanced perfusion measurement was performed with a double echo spin echo / gradient echo EPI-sequence with 1 sec framing (3 slices, 8 mm, TE(GE)=35 ms, TE(SE)=105 ms, TR=1000ms, 256x256 matrix, FOV=350 mm). The perfusion calculation is described in detail in [4]. The extravascular extracellular space was presaturated with contrast media while applying the T2/T2*-technique. For both contrast enhanced perfusion measurements, 0,1 mMol/kg Gd-DTPA was applied with a power injector within 4 seconds. All images were coregisterd with the T1-weighted post contrast images by an automatic software [5] using the anatomical images of the perfusion investigations. The images were resampled to a final resolution of 128x128 Matrix with 230 mm FOV. For intermodality comparison the MR images were smoothed with FWHM of 7 pixels to PET resolution.

The linearity of all methods was investigated separately for brain and tumor tissue. The pixels were extracted from the coregistered images and correlated in a scatter plot. An average curve was calculated separately for brain and tumor tissue (see Fig.) except PET (only brain). The correlation coefficients between all techniques were determined.

Additionally the mean tumor perfusion and reference brain perfusion were extracted from identical ROIs of each image. The ratio mean tumor perfusion versus reference brain ROI perfusion was calculated, normalized for all methods of a single patient evaluation to one, and subsequently averaged for all patients (see Tab.).

Results

A linear correlation was found between all methods (see Fig) except ASL and T1-DCE, where saturation was reached at highly perfused. The curve gradients differ between brain and tumor tissue for the most techniques. The correlation coefficients between MR-techniques and H20-PET are significant lower than between the different MR-techniques. The ROI evaluation (Tab.) shows that the ratios of perfusion tumor versus brain differ maximally up to a factor of 2.8. PET and T2 show relative small tumor perfusion ratios, whereas the T1-technique tends to overestimate the tumor perfusion. The ASL and T2* tumor perfusion ratios are in between. ASL provides the largest uncertainty of all MR-techniques.

Conclusions

The techniques exhibit significant methodical differences especially beween H20-PET and MRI because the MRI-techniques present venous outflow as perfusion and different image resolution. The tumor perfusion with respect to brain perfusion differs significantly whereas the linearity of all techniques is sufficient. The relative tumor perfusion of different techniques cannot be compared directly and thus under- or overestimated.

References

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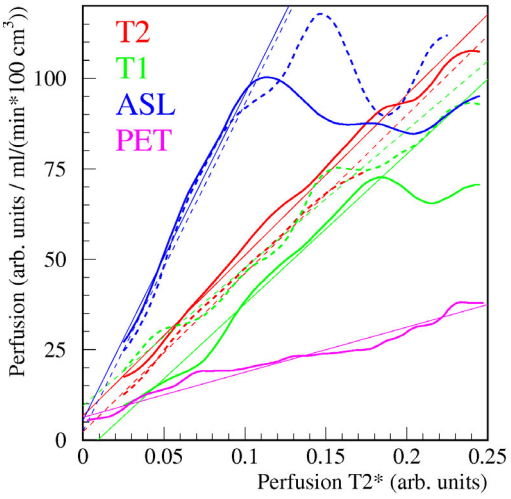

	ASL	PET	T1	T2	T2*
Mean Perfusion	0,83	0,62	1,73	0,69	0,89
Standarddev.	0,33	0,26	0,60	0,21	0,23
Minimum	0,37	0,16	0,82	0,33	0,41
Maximum	1,29	1,05	2,83	0,89	1,26
Rel. standarddev.	0,39	0,42	0,35	0,31	0,26

Tab.: Evaluation of the ratio mean tumor perfusion versus mean reference ROI perfusion. The ratios were normalized and averaged for all evaluations.

Fig.: The averaged correlation curves of extracted brain pixels (filled line) and tumor pixels (interrupted line) are plotted for different perfusion techniques. The T2* technique was used as reference method for all techniques. Each correlation curve was linearly fitted to guide the eye. The perfusion values for PET and ASL are quantitative, for the T2, T2* and T1-method are given in arbitrary units. For the later methods the curve gradient is arbitrary and cannot be quantitatively compared.