Quantitative MRI Estimates of Microvascular Permeability in Human Brain Tumors: Detection of Regional Heterogeneity and Correlation with Histological Grade

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Abstract Quantitative measurement of microvascular permeability in human brain tumors achieved using dynamic contrast-enhanced MR imaging should be correlated with histologic tumor grade in stereotactic guided biopsy samples. Dynamic contrast-enhanced MR imaging allows noninvasive determination of fPV and microvascular permeability in human brain tumors, with the permeability being predictive of pathologic tumor grade. MRI grading of tumors as defined by their microvascular permeability may provide a new and clinically useful method to determine the intratumoral heterogeneity. MRI assessed data can be used to guide stereotactic biopsies to the most aggressive area within an individual tumor mass.

Introduction The histologic tumor grade is the most accurate predictor of prognosis for patients with malignant brain tumors and influences strongly patient management and outcome. Stereotactic and image-guided biopsy and surgery, respectively, is becoming increasingly important in the management of brain tumors. Biopsies, however, only acquire small samples from the tumors and, therefore, fail to reproduce the heterogeneity inherent to tumors. Recently, Roberts et al. have shown that a relatively simple analysis of magnetic resonance (MR) imaging assessed data allows the determination of tumor fractional plasma volume (fPV) and microvascular permeability (Kp) in human brain tumors, with the permeability being predictive of pathologic grade (1). The aim of this study was to define whether a three-dimensional MR imaging technique with assessment of fPV and microvascular permeability can define regional heterogeneity in human brain tumors.

Methods In 25 patients with brain tumors, MR imaging was performed one day before stereotactic guided biopsies were taken. All patients underwent MR imaging with a 1.5-T whole body unit (ACS-NT Gyroscan, Philips Medical Systems, Best, The Netherlands) by using a standard quadrature head coil. The protocol included transverse T2-weighted turbo-spin-echo images (TE 110 ms, TR 1800 ms, 1 NSA, matrix 256 x 512, section thickness 2 mm, FOV 256 mm) and T1-weighted spin-echo postcontrast (0.1 mmol Gd-DTPA/kg bodyweight, Magnevist®, Schering AG, Berlin, Germany) images (TE 9.2 ms, TR 18 ms, 1 NSA, matrix 256 x 512, section thickness 2 mm, FOV 256 mm). Pre- and dynamic postcontrast 3D-SPGR imaging was performed over a course of approximately 10 minutes with the following parameters: TE 2.1 ms, TR 5.2 ms, 1 NSA, flip angle 10°, matrix 256 x 256, section thickness 2 mm, FOV 250 mm, acquisition time 11 sec per volume of 25 slices. All MR image data were transferred to an EasyVision workstation (Philips Medical Systems, Best, The Netherlands) and color coded maps of the relative enhancement and the maximum relative enhancement of the tumors were generated.

Regions of interest were defined for the sagittal sinus superior and for all areas within the tumors were stereotactic guided biopsies were taken. Serial biopsies (median 5 samples) were done with small forceps (diameter 1 mm). Tumor enhancement data were analyzed using a multi-compartment kinetic model to determine tumor permeability, as estimated by the endothelial transfer coefficient (Kp), and fractional plasma volume (fPV) as described (2).

Results Especially high grade tumors showed a marked intratumoral heterogeneity (Fig. 1), as reflected in the histologic samples and the corresponding permeability values. Kp values ranged from 0.3 to 25.3 ml min⁻¹ 100 cc⁻¹, with a strong correlation (r²=0.75) to tumor grade. In all patients, permeability values depicted the most aggressive area within the tumor mass. fPV values ranged from 0.02 to 0.18 ml cc⁻¹ and showed no correlation to tumor grade.

Conclusion Dynamic contrast-enhanced MR imaging allows noninvasive determination of fPV and microvascular permeability in human brain tumors, with the permeability being predictive of pathologic tumor grade. MRI grading of tumors as defined by their microvascular permeability may provide a new and clinically useful method to determine the intratumoral heterogeneity. MRI assessed data can be used to guide stereotactic biopsies to the most aggressive area within an individual tumor mass.

References