Differentiation of Glioblastoma Multiforme, Metastases and Primary Central Nervous System Lymphomas using Multiparametric Perfusion and Diffusion MR Imaging of a Tumor Core and a Peritumoral Zone – Searching for a Practical Approach.

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Abstract

Introduction

In conventional MR examination glioblastomas multiforme (GBM), metastases and primary CNS lymphomas (PCNSLs) may show very similar appearance. The aim of the study was to evaluate usefulness of multiparametric DSC perfusion and diffusion MR imaging in the preoperative differentiation of these tumors.

Material and Methods

Fifty three solitary enhancing tumors (20 GBMs, 20 metastases, 13 PCNSLs) were enrolled in the study. Parameters of cerebral blood volume (rCBV), peak height (rPH), percentage of signal recovery (rPSR) and apparent diffusion coefficient (ADC) were assessed from the tumor core and peritumoral non-enhancing T2-hyperintense zone.

Results

Within the tumor core there were no differences in perfusion and diffusion parameters between GBMs and metastases. Compared to GBMs and metastases, PCNSLs showed significantly lower rCBV and rPH, ADC as well as higher rPSR values. Max rCBV with a cut-off value of 2.18 showed the highest accurracy of 0.98 in differentating PCNSLs from other tumors. To distinguish GBMs from metastases analysis of the peritumoral zone was performed showing significantly higher rCBV, rPH and lower ADC values in GBMs with the highest accuracy of 0.94 found for max rCBV at a cut-off value of 0.98.

Conclusions

Max rCBV seems to be the most important parameter to differentiate GBMs, metastases and PSCNSLs. Analysis of max rCBV within a tumor core enables to distinguish hypoperfused (PCNSLs) from hyperperfused (GBMs and metastases) tumors while evaluation of max rCBV within the peritumoral zone is helpful to distinguish GBMs showing peritumoral infiltration from metastases surrounded by pure edema.

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Protocol

Data acquisition

Step 1.

All examinations were performed on a 1.5 T MR scanner (Signa Hdx, GE Medical Systems) using a 16-channel HNS (head-neck-spine) coil. Before contrast administration a standard MR examination was carried out including axial T1-weighted images, axial, coronal and sagittal T2-weighted images as well as axial FLAIR images followed by DWI and post contrast DSC perfusion and 3D T1-weighted imaging.

During the whole MR examination the patients were instructed to keep their eyes closed. No sedation or anesthesia were used in any of the patients.

Diffusion weighted imaging (DWI)

Step 2.

DWI was performed using a transverse single-shot echoplanar diffusion-weighted sequence with the following parameters: TE 89.9 ms, TR 8000 ms, slice thickness – 5 mm, FOV 26 cm, matrix size 128 x 128, NEX - 1, diffusion sensitive gradient b = 1000 s/mm^2 in the three orthogonal directions, scanning time: 42 seconds.

Perfusion weighted imaging (PWI)

Step 3.

Perfusion examination was performed with a dynamic susceptibility contrast (DSC) method using fast echoplanar T2*-weighted gradient echo sequence with the following parameters: TR = 1.900 ms, TE = 80 ms, FOV = 30 cm, matrix = 192 x 128, slice thickness = 8 mm without spacing, NEX - 1.0. Ten seconds after the start of the image acquisition a bolus of a 1.0 mol/l gadobutrol formula (Gadovist, Bayer Health Care, Germany) in a dose of 0.1 ml/kg of a body weight was injected via a 20-gauge catheter placed in the antecubital vein. Contrast was administered with an automatic injector (Medrad) at a rate of 5 ml/s and was followed by a saline bolus (20 ml at 5 ml/s). The whole perfusion imaging lasted 1 min 26 s in which sets of images from 13 axial slices were obtained before, during and after contrast injection. After PWI a post-contrast T1-weighted 3D sequence was performed using contrast bolus administered earlier for the perfusion examination. No contrast agent was administered before DSC perfusion MR imaging.

Image postprocessing

Step 4.

The PWI and DWI images were postprocessed using Functool software (ADW 4.4, GE Medical Systems).

Perfusion weighted imaging

Step 5.

The analysis was based on the evaluation of CBV parameters from the CBV maps as well as values of peak height (PH) and percentage of signal recovery (PSR) derived from perfusion curves.
Measurements of CBV were performed by placing ROIs on the CBV maps fused either with post-

contrast T1-weighted images or T2-weighted images. PSR and PH values were calculated from the perfusion curves based on formulas: PSR = (S1-Smin)/PH, PH = S0-Smin, where: S0 - start of a contrast passage, Smin - maximal drop of magnetic susceptibility, S1 - measurement after 24 seconds from Smin. All CBV, PH and PSR values were normalized to the values from the normal appearing white matter of the contralateral hemisphere in order to obtain relative values of all parameters (rCBV, rPH, rPSR).

Measurements of perfusion parameters were processed within a tumor core and a peritumoral zone. The tumor core was defined as an enhancing part of the tumor on the CBV map fused with the post-contrast T1-weighted image while the peritumoral zone was defined as a T2-hyperintense non-enhancing zone surrounding the tumor core on the CBV map fused with a T2-weighted image.

Measurements of perfusion parameters were obtained for the entire tumor (mean rCBV, mean rPH, mean rPSR) using large irregular freehand ROIs outlining the enhancing tumor core on each slice on the CBV map and subsequently calculating the arithmetical averages from all measured values. Maximal values of these parameters (max rCBV, max rPH, max rPSR) were obtained by placing small ROIs (40-60 mm^2) over several hot spots within large ROIs on each slice. The highest value from all ROIs was chosen as the tumoral maximal value. T1- and T2-weighted as well as post-contrast T1-weighted images were used to avoid inclusion of any hemorrhage, necrosis or big vessels within the ROIs.

Diffusion weighted imaging

Step 6.

Measurements of ADC for the entire tumor (mean ADC) and measurements of minimum ADC (min ADC) were assessed. Mean ADC values were obtained by manual outlining of the entire enhancing tumor core on each slice avoiding foci of hemorrhage or necrosis and then by calculating the arithmetical averages from all measured ADC values. Min ADC values were measured using small ROIs (40-60 mm2) located within the large freehand ROIs.The lowest value from all ROIs was chosen as the tumoral minimum ADC value.

Step 7.

In the hyperperfused tumors such as GBMs and metastases DWI and PWI analysis was also performed in the peritumoral non-enhancing area of T2-hyperintensity by obtaining mean ADC and min ADC values as well as mean rCBV, max rCBV, mean rPH, max rPH, mean rPSR, max rPSR in the manner similar to the measurements within the tumor core. Mean values of diffusion and perfusion parameters were obtained using large irregular freehand ROIs outlining the non-enhancing T2-hyperintense peritumoral zone while max rCBV and min ADC values were calculated using a small ROI method.