Early detection of response to radiotherapy in brain metastases using dynamic contrast-enhanced magnetic resonance imaging

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Introduction Cerebral metastases are the second most common cerebral tumors in adults and occur in about 15%–25% of all cancer patients [1]. However, if the lesions are close to or within functionally important brain regions, resection is not possible and patients are referred for radiation therapy. Magnetic resonance (MR) imaging has proven to be the most sensitive diagnostic modality in the assessment of patients with cerebral metastases [2]. Previous studies suggested that dynamic susceptibility weighted contrast-enhanced (DSC) MR imaging is a method for the assessment of radiosurgically treated brain metastases [3]. However, it is not suitable for the measurement when the blood–brain-barrier (BBB) is broken. This raises the question whether Dynamic Contrast-Enhanced MRI (DCE-MRI) [4], which uses a *T1-weighted* sequence to measure the bolus passage, is a more suitable approach when absolute quantification is required [5,6]. As yet no data are available about the role of dynamic contrast-enhanced MR imaging in patients with cerebral metastases. The purpose of our study was to assess if early follow-up K^{trans} measurements can help predict treatment outcome in patients with cerebral metastases.

Materials and Methods An intraindividual follow-up study in 7 lesions of solitary brain metastases after a single high-dose radiation therapy was performed. A total of three DCE MRI sessions were performed for all patients after radiation therapy. Following conventional MR imaging, all the patients underwent DCE-MR imaging, using a bird-cage quadrature head coil on a 1.5T (Sonata, Siemens Medical Systems, Germany). DCE imaging was performed using a 3D spoiled gradient recalled echo (3D-SPGR) sequence (TR/TE 3.0/1.1 msec, flip angle, 15°, slice thickness 6 mm, matrix size 128x88). At the contrast enhanced acquisition, 1.0M gadobutrol (Gadovist, BayerHealthCare, Berlin, Germany) at a dose of 0.1 mmol/kg of body weight was administered intravenously with the help of a power injector (Optistar MR, Mallinckrodt, Liebel-Flarsheim, OH) at a rate of 3 mL/sec, followed by a bolus injection of 20 mL saline flush. A series 60 time points for 22 slices were acquired with a temporal resolution of 4.6 seconds for each time point. The 22 slices were sufficient to completely cover the entire brain including the normal brain parenchyma in all the cases studied. All steps of the data analysis have been automated using the software of MIStar (Apollo Medical Imaging Technology). Perfusion indices transfer coefficient [K^{trans}] and leakage [Ve] maps were generated for the quantitative analysis. In each patient, the regions of interest (ROIs) defined by the Ve were the basis for the ROI of K^{trans} (Fig.1).

Results A decrease in tumor size on Ve maps was demonstrated in the lesions with stable condition after radiotherapy, but an increase in tumor size was demonstrated in tumor recurrence (Fig.2). In the regional K^{trans} difference between follow up images, the lesions with stable condition showed significant decrease but the tumor recurrence showed significant increase (Fig. 3).

Discussion DCE-MRI parameters have been shown to correlate with vascular permeability. Measurement of the K^{trans} reliably correlates with the increased tumor vascularity, particularly in brain tumors. In conclusion, the implemented technique enables an absolute quantification of the K^{trans}, which permits prediction of tumor response. A post therapeutic decrease of K^{trans} values indicated tumor response to therapy, whereas increase of K^{trans} values indicated tumor recurrence.

References [1] Nussbaum ES, Cancer 1996; 78: 1781–1788. [2] Yuh et al., Am J Neuroradiol 1995; 16: 373–380. [3] Essig et al., Radiology 2003; 228: 193-9. [4] Tofts et al., JMRI 1999; 10: 223–232. [5] Ferl et al., Magn ResonMed 2010;63:1366–1375. [6] O'Connor et al., Br J Cancer 2007;96:189–195.

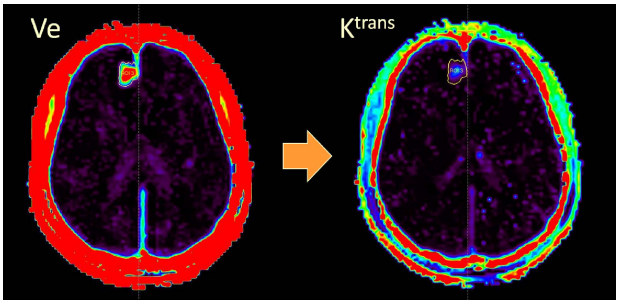

Figure 1. The placement of a region of interest (ROI) on the brain metastasis lesion. The ROI is selected on the Ve map then copy to the K^{trans} map.

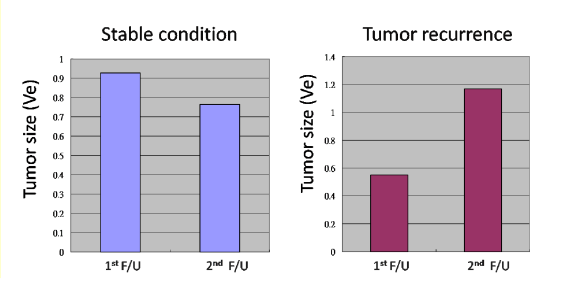

Figure 2. Tumor size selected from Ve maps of stable condition versus tumor recurrence following radiotherapy.

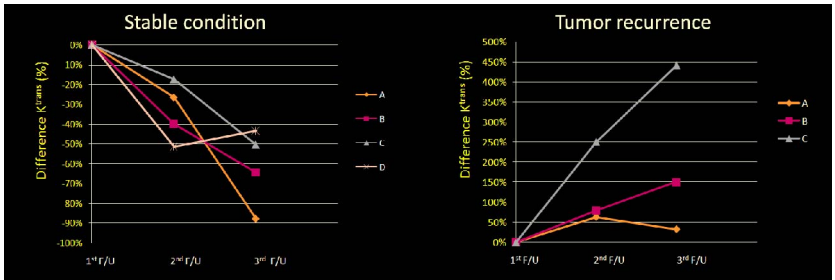

Figure 3. Graph depicts changes in the K^{trans} in patient with stable condition and tumor recurrence.