Dynamic contrast-enhanced quantitative simultaneous permeability and perfusion imaging of human brain tumours with one-second temporal resolution

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INTRODUCTION: The aim of this research was to investigate the feasibility of dynamic contrast-enhanced (DCE) MRI to simultaneously quantify the perfusion, blood volume and vessel permeability in high grade malignant brain tumour patients using an advanced k-space sharing technique [1]. Newly formed tumour vessels are highly permeable and often characterized by hyperperfusion. Several separate studies have shown that quantitative measurements of hemodynamic properties (permeability (k-trans)), cerebral blood flow (CBF), and cerebral blood volume (CBV) in tumours could serve as biomarkers of tumour grade and patient outcome. The hypothesis of this study is that 3D maps of these biomarkers can be feasibly acquired by using a high temporal and spatial resolution DCE protocol. Our objective was to acquire such data in brain tumour patients by combining k-space sharing and parallel imaging technology to reduce the acquisition time of a 3D FLASH sequence to approximately second [2]. Both these techniques are now commercially available on most modern MRI systems.

METHODS: Eight of 20 high grade (WHO III and IV) brain tumour patients have so far been recruited into a prospective observational imaging trial (RMH HREC 2008.193). DCE and DSC perfusion was performed during two successive bolus injections of Magnavist (0.05 mmol/kg @ 5 ml/s). DCE data was acquired with a 3D FLASH, k-space sharing, and GRAPPA-accelerated pulse sequence to achieve a temporal resolution of 1.1 second (1.7x1.7x3 mm resolution, 32 slices, 30° flip angle). CBV, CBF, and k-trans were calculated using previously reported methods [3]. DSC data was acquired with a single shot GRE EPI with a 1.5 sec temporal resolution (2.5x2.5x3 mm, 21 slices, 90° flip angle). CBV and CBF maps were calculated using a cSVD post-processing algorithm [4]. Statistical comparisons of CBV and CBF data for the two perfusion protocols were evaluated in 9 ROIs (3 in gray matter, 3 in white matter, and 3 in tumour tissue) per patient using linear regression.

RESULTS: As seen in figure 1 excellent quality time-concentration data was obtained from arteries, veins, normal and tumoural brain tissue using the DCE protocol. This resulted in CBV and CBF maps (figure 2) of improved quality compared to DSC maps. Namely increased brain-coverge and decreased susceptibility artefacts were noticeable. In addition DCE data allowed permeability maps (k-trans) to be calculated from the same dataset. Statistically significant intra-patient correlation (p < 0.05) was found between CBV and CBF for all patients included so far. These maps show the highly heterogeneous nature of perfusion resulting from the tumour neovasculature.

DISCUSSION: The use of DSC for imaging perfusion in brain tumour patients has several well-known drawbacks, including susceptibility induced signal drop-out and distortion, erroneous CBV quantification caused by vessel leakage, a lack of permeability quantification, and limited brain coverage. The mentioned artefacts are especially severe in proximity to sinus or post-surgical cavities, and/or surgical implants (clips or shunts). We have shown that whole brain coverage at a temporal resolution of 1.1 sec can be accomplished using commercially available k-space sharing 3D FLASH sequence. Thus, quantitative measurements of perfusion and permeability can be acquired with a single contrast injection from a single dataset (<2min total acquisition) without the drawbacks of DSC. If validated, this technique has tremendous potential for pheno-typing the neovasculature of brain tumours in a clinically relevant time frame. In conclusion, this DCE method has the potential to replace DSC for brain tumour perfusion imaging due to improved quality, better spatial coverage, increased temporal resolution, and permeability quantification.

REFERENCES: