Dynamic Contrast Enhanced Whole Brain Perfusion using a Rapid 3D T_1-weighted Sequence at 7T

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Introduction

7 T MRI has shown potential in imaging the human brain, in particular related to acquisitions with high spatial resolution. At lower field strengths, useful clinical information has also been obtained from perfusion scans following administration of a bolus of exogenous contrast agent. Here we present initial experience of obtaining quantified perfusion parameters from MR images acquired at 7 T using a dynamic whole-brain T_1-weighted acquisition during administration of a standard gadolinium contrast agent.

Various parameters of blood perfusion in the brain can be measured dynamically using MRI after administration of a bolus of paramagnetic contrast agent, such as cerebral blood volume (CBV) and cerebral blood flow (CBF). In order to quantify these parameters, a region representative of the time course of the arterial input function (AIF) needs to be defined [1]. Passage of a bolus of contrast agent results in changes in the T_1 and T_2* of the surrounding region. In order to characterise these changes, a rapid MRI acquisition must be employed. EPI is a fast acquisition with inherent T_2* weighting and has been frequently used for perfusion studies. However, it requires a relatively high dose of contrast agent, limiting further contrast enhanced studies that may be required in the same clinical examination, such as angiography, and the susceptibility induced spatial distortion in EP images causes problems in acquiring regions low enough down in the neck to obtain a realistic AIF [2]. Rapid FLASH acquisitions have also been used to acquire dynamic images, preceded by a saturation or inversion pulse to create T_1 weighting [3]. FLASH suffers less from spatial distortion than EPI and so better AIF's may be obtained. The acquisition is slower and yields less spatial and temporal resolution than EPI. However, a lower dose of contrast agent is required, allowing a tighter bolus to be injected and the possibility of further contrast enhanced examinations. Previously, we developed and implemented a rapid 3D T_1-weighted FLASH technique on both 1.5 T and 3 T MRI systems [5,6]. Whole brain volumes are acquired every 2 seconds providing high temporal resolution. As with other 3D acquisitions, the signal to noise ratio (SNR) per 'slice' is increased compared to a similar 2D acquisition, slice cross-talk effects are eliminated and all slices are effectively acquired at the same time point.

We have extended this technique to a 7 T MRI system and incorporated the perfusion protocol into a study involving multiple sclerosis patients who were receiving contrast, with approval from the local research ethics committee.

Method

The 3D FLASH sequence was implemented on a 7 T Philips Achieva system with a whole body gradient set and a head-only volume transmit coil and a sixteen channel receive RF coil (Nova Medical, Wilmington, MA, USA). A non-selective inversion pulse was transmitted with a TI of 600 ms to null the signal from blood both in and outside the imaging volume to limit inflow effects. Using parallel imaging, the entire volume could be acquired in a single readout block, every 2.0 s. A centre-out radial k-space ordering was utilised to fill a matrix of 80x80x10 with a left-right SENSE parallel imaging factor of 1.7, resulting in non-interpolated voxels with dimensions 2x2x10 mm. Other parameters were TE=3.1 ms, time per FLASH line =5.5 ms, flip angle=8°. 45 consecutive volumes were acquired, with a short bolus of 1.5 ml of Gd-DTPA (Gadovist, Bayer Schering Pharma) contrast agent hand-injected into the patient's antecubital vein at the fifth volume, followed by a saline flush at the same rate. A suitable AIF was found in the internal carotid artery in an inferior slice and quantitative maps of perfusion parameters were calculated using the Peter's method [3] modified for use with MRI [4].

Results

Perfusion acquisitions were undertaken on four MS patients at 7T. One patient moved considerably during the acquisition; the remaining three resulted in useable data. A representative example from one patient is shown below. CBF values (mean and standard deviation) from gray matter were 46 ± 8 ml/min/100g and from white matter 13 ± 3 ml/min/100g.

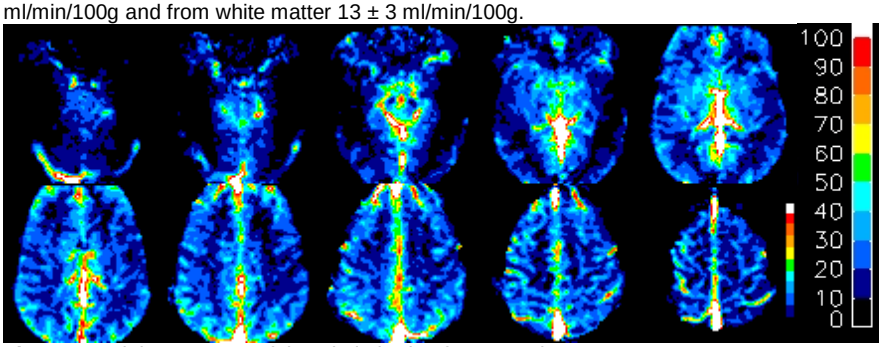

Figure 1. Axial CBF maps of the whole brain of a MS patient at 7 T. The colour bar scale is in units of ml/min/100g tissue.

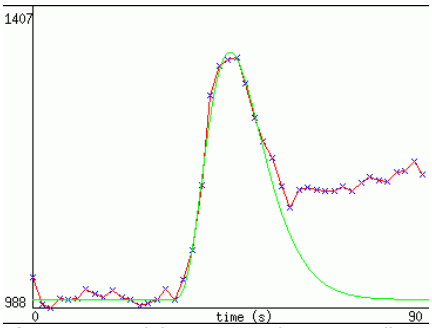

Figure 2. Arterial Input Function, manually defined in the carotid artery on the 2nd slice.

Discussion

Perfusion maps throughout the brain can be produced using the 3D T_1-weighted sequence at 7 T. The extra SNR and utilisation of parallel imaging at 7 T allow 10 non-interpolated slices to be acquired in a single-shot 3D FLASH acquisition. With further optimisation, the combined use of improved SNR with higher parallel imaging factors at 7T should result in improvements in the spatial resolution. Current 7 T MRI scanners have issues obtaining a uniform B_1 field throughout the head, resulting in a spatial variation in RF flip angles. This results in signal drop-out in the temporal lobes, as seen in Figure 1, as well as an imperfect non-selective inversion pulse used. The latter will result in a varying baseline intensity of nulled non-enhanced blood which will affect the quantification of perfusion values related to an AIF defined in a single location. In addition, the use of a head-only transmit coil (as opposed to the same technique using a body transmit coil at 1.5 T and 3 T) will result in limited range of the inversion pulse in the neck and below, resulting in a larger influence of inflowing non-inverted blood. However, despite these issues, the results obtained are in good agreement with accepted values[1]. The increased signal to noise at 7 T offers the potential of perfusion maps with high spatial resolution and excellent contrast to noise ratio. We therefore expect this technique to be important in future studies measuring perfusion in clinical studies at ultra high field.

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