INTRODUCTION

Parkinson’s disease (PD) is a chronic neurodegenerative disease that affects the motor region of the brain and causes uncontrollable movement, it is the second most common neurodegenerative disorder [Intro1] and approximately 9.4 million people suffer from PD worldwide [Intro2]. The disease’s pathophysiology is irreversible and currently has no cure. However, having effective biomarkers for PD will allow early detection and accurate progress tracking of the disease, which provide strong support for PD treatment and new solution development. One of the PD’s early signs is iron overloaded at the substantia nigra region in the brain stem [Intro4], which can be detected using Magnetic Resonance Imaging (MRI) [Intro3]. MRI is a non-invasive medical imaging technique, which constructs images based on proton’s different signal responses to a train of radiofrequency excitation (pulse sequence) under different chemical environments. The MRI signal decay exponentially with the time constant T2\*, which is tissue and magnetic field inhomogeneity dependent. As the overloaded iron caused by PD distorts the magnetic field, a more rapid decay of MRI signal and a smaller T2\* value will be observed at the substantia nigra, various studies have shown the latter quantitative property T2\* can be used as an effective biomarker for PD [Intro5] [Intro6]. A traditional way of generating quantitative T2\* images is to acquire MR images at different times and fit the signal’s exponential decay in each voxel to get the T2\*, this technique is known as T2\* mapping based on Multi-Echo Gradient Echo (GRE) sequence [Intro7].

However, the complex tissue movement at the brain stem (caused by blood flow, central cerebellum fluid, and the cardiac cycle etc.) causes tissue motion artefacts on MR images and makes high-quality brain stem MRI difficult to achieve [Intro8] [Intro11]. Additionally, it is even more difficult to get an accurate T2\* image of the brain because multiple high-quality MR images are required to obtain one T2\* image.

A simple way to reduce the effect of tissue motion is acquiring more MR images and averaging to reduce motion artefacts, but it will lengthen the acquisition time. Using a larger voxel size can also reduce the impact of the tissue movement, however, high-resolution MR images are essential to capture important tissue information in the tiny millimetre-size substantia nigra region [Intro8]. Other post-processing-based methods can perform motion correction on the acquired images, but these techniques mostly focused on the whole-body movement instead of the tissue motion [Intro9].

Based on all these limitations of previous methods, a new T2\* imaging technique is suggested [Intro10], which can reduce the impact of motion while maintaining short acquisition time and good resolution, using the pulse sequence named k-space-aliased Spoiled Gradient-Recalled (ka-SPGR). The images acquired with ka-SPGR are not simply related by decay time, instead, each image contains information coming from different times of the T2\* decay. By extracting useful information from each acquired image and summing them up, the T2\* related signal decay at specific times can be reconstructed and T2\* can then be calculated by fitting the exponential decay. Theoretically, even if the movement of the brain creates artefacts in some acquisition, it will not have a huge impact on the reconstructed T2\* decay signal, as the signal is obtained by averaging across multiple acquisitions. However, there was no quantitative analysis of the ka-SPGR T2\* measurement accuracy, and no suggested optimal MRI scanning parameters for the ka-SPGR sequence. Therefore, evaluation of the ka-SPGR’s T2\* accuracy and obtaining optimal parameters is desirable, before proving the motion robustness of the ka-SPGR method in vivo.

In this paper, the T2\* measurement using the ka-SPGR sequence is modelled using Bloch simulation, followed by Monte Carlo simulation to analyse the bias and variation of the measured T2\* when noise is added. Based on the simulation result and analysis, optimal scan parameters are selected. MRI data are then acquired from a phantom using the gold-standard method (multi-echo GRE) and ka-SPGR with optimised parameters, the quantitative T2\* images are reconstructed and compared. Furthermore, the T2\* percentage error and T2\* effective signal-to-noise ratio is used to evaluate the performance of ka-SPGR T2\* imaging relative to the gold-standard method.

References:

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