3D Quantitative Imaging of Relaxation Parameters of Whole Brain

Weitian Chen[1], Patrick D Koon[2], and Ajit Shankaranarayanan[1]
[1]*Global MR Applied Science Laboratory, GE Healthcare, Menlo Park, CA, United States,* [2]*GE Healthcare, San Francisco, CA, United States*

Introduction: Quantification of T2 or T1rho in brain can provide additional diagnostic information to anatomy images (1). A major challenge to such quantification methods is very long scan time in order to achieve high resolution with 3D coverage of the brain. In this work, we investigate fast 3D quantitative T1rho or T2 imaging of whole brain based on the method proposed in (2). This method is based on 3D Fast spin echo acquisition method Cube™ (GE Healthcare, Waukesha, WI), and we termed this method CubeQuant here. The eddy current effect from magnetization preparation in CubeQuant can cause adversary effect on image quality. We reported a simple method to address this problem. We also investigated CubeQuant for simultaneous 3D anatomical imaging of the brain and T1rho or T2 quantification within clinical feasible scan time.

Theory and Methods: The pulse sequence is shown in Figure 1. We first reset magnetization to zero by a few 90 degree RF pulses and crushers (3), which is followed by a time period for magnetization to experience T1recovery. Fat sat can be inserted during T1 recovery time. Prior to data acquisition, RF pulse clusters are used to impart T1rho or T2 contrast. The imaging data is then acquired using Cube™, which is a highly SNR efficient 3D FSE acquisition approach. The RF preparation length changes from TR to TR in order to acquire a set of 3D images with different level of contrast preparation. The 3D T1rho or T2 map is calculated by fitting the magnitude images to a mono-exponential relaxation model. The effectiveness of this method for T1rho or T2 quantification in cartilage has been demonstrated in (2).

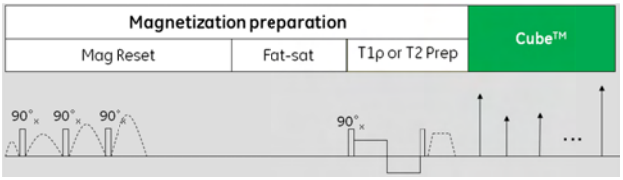

Figure 1: The pulse sequence.

The FSE acquisition approach used here is based on CPMG condition. Violation of CPMG condition can result in image artifacts (4). The eddy current from crusher gradient at the end of T1rho or T2 prep can lead to this undesired situation if the Cube™ acquisition is played out immediately after the crusher gradient. To address this problem, we put a 2 millisecond gap between the crusher and the beginning of data acquisition. An example of CubeQuant with and without this compensation is shown in Figure 2. The impact on quantification due to T1 relaxation during this gap is very small since T1 is usually much larger than 2ms.

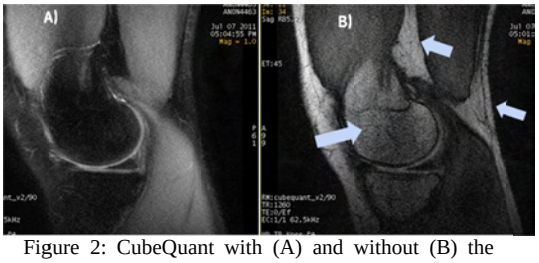

Figure 2: CubeQuant with (A) and without (B) the proposed eddy current compensation. Note failure of fat sat (arrows) and signal loss without the eddy current compensation.

Besides T1rho/T2 quantification, we can combine the source images to form a high SNR T2-weighted anatomy image. This has been demonstrated in (5) for knee imaging. In addition, we can also create fluid suppressed anatomy images by subtracting images with long T2/T1rho prep from those with short T2/T1rho prep.

The data sets were collected from a Discovery MR750 3T scanner (GE Healthcare, Waukesha, WI) using an 8 channel head coil (GE Healthcare, Waukesha, WI). Informed consent was obtained for in vivo scans. The scan parameters include: 0.9×0.9×1.6mm resolution, 24×18cm FOV, 120 slices, ETL 120, half NEX, 2X ARC parallel imaging (GE Healthcare) along phase encoding direction. Six acquisitions were acquired for either T1rho or T2 quantification. For T1rho, spin lock frequency is 500Hz, TSLs = 2, 10, 30, 50, 70, 100ms, with total scan time 6:20min. For T2, effective T2 prep lengths = 14, 28.4 42.9, 57.3, 71.7, 86.1ms, with total scan time 6:05min.

Results:

Figure 3 show the 3D brain anatomy images acquired using CubeQuant. The T2-weighted source images are summed together to form these anatomy images. The images were acquired in sagittal plane, and reformatted in coronal and axial plane. The subtraction of long T2-prep images from short T2-prep images show anatomy with fluid suppressed contrast. Figure 4a) and 4b) show T2 and T1rho map, respectively. Note elevated T1rho value compared to T2. Figure 5 shows the average signal intensity within a small ROI (5x5) decay as a function of TE/TSL and the corresponding exponential fitting. Note the data follows exponential decay fairly well.

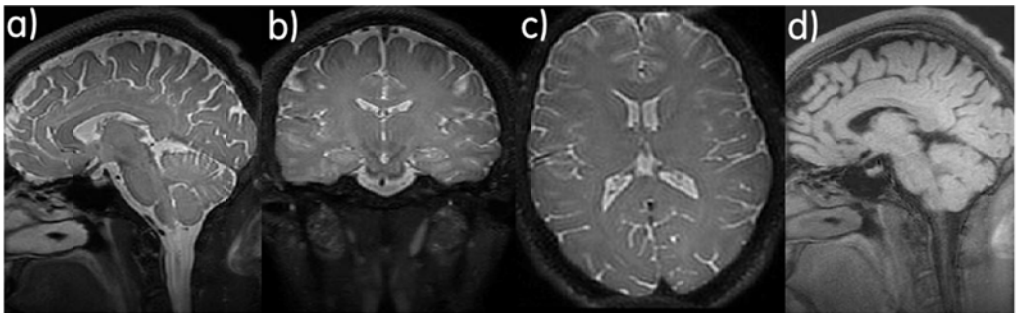

Figure 3: Anatomy images acquired in sagittal (a), and reformatted to coronal (b) and axial (c). The subtraction of source images created fluid suppressed contrast (d).

Discussion: The high SNR efficiency of Cube™ enables CubeQuant for high resolution 3D quantitative imaging within clinical feasible time. The Cube™ source images have T2-weighted contrast, and therefore can be used to create diagnostic anatomical images. T1rho imaging is SAR intensive. For the volunteer scan (180 pound) conducted at our 3T scanner, we observed during the scanning the SAR is well below the maximum allowed SAR when using body RF coil as transmitter with the given prescription of T1rho scan.

Conclusion: We investigated CubeQuant for 3D T1rho or T2 quantitative imaging of the brain. This sequence is highly SNR efficient and has potential to provide high resolution 3D T2-weighted anatomical image and T1rho or T2 map within one scan with clinical feasible time.

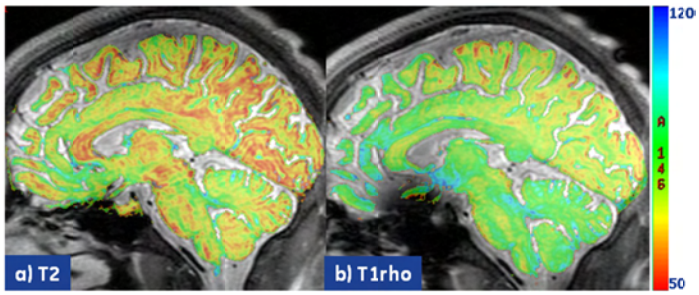

Figure 4: a) acquired T2 map, and b) acquired T1rho map.

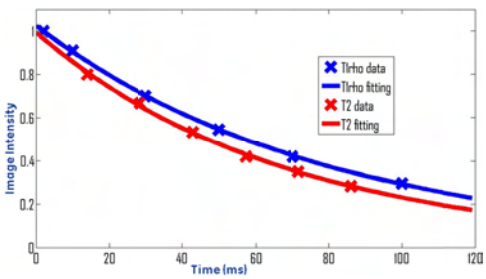

Figure 5: Image intensity within a 5x5 ROI follows exponential decay.

Reference: 1. Whittall et al, MRM 1997, p34 2. Chen et al ISMRM 2011, p231 3.Li et al, MRM 2008 p298 4. Rev Sci Inst 1958, 29:688 5. Chen et al, ISMRM 2011, p3249