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In vivo repeatability of Tailored MR Fingerprinting

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Synopsis

MR fingerprinting(MRF) has an advantage over quantitative MRI as it allows simultaneous acquisition of multi-parametric maps but does not generate multi-contrast images required for routine clinical studies. Tailored MRF(TMRF) allows simultaneous acquisition of two quantitative maps and six qualitative contrasts. A TMRF repeatability study was conducted for four days on one in vivo healthy human brain. Signal-to-noise ratio (SNR) and mean intensity values for grey matter(GM) and white matter(WM) were computed. Standard deviation of SNR for WM and GM were in the range of 0.1 to 0.75 and 0.2 to 1.1 respectively. This narrow range shows the repeatability of TMRF

INTRODUCTION

Magnetic resonance fingerprinting (MRF) reduces the long acquisition time of quantitative MRI by simultaneously acquiring multiple parametric maps such as T1, T2, etc. However, MRF does not provide multi-contrast images which are routinely utilized as a part of clinical studies. Though MRF reconstructed parametric maps can provide synthetic contrasts, it is challenging to estimate the phase terms from diffusion, flow, susceptibility, off-resonance, etc. Recently, a deep learning (DL) based MRF reconstruction approach directly reconstructing contrast images from MRF data has been reported[1]. For brain study, more than one contrast is required to make accurate decisions which leads to longer scan time. Some studies address these issues by acquiring multiple contrasts simultaneously such as EPIMix[2] and penta contrast[3], etc. Tailored MRF (TMRF) allows simultaneous acquisition of both multi-parametric quantitative (two maps) and qualitative (six contrasts) data[4]. The six contrasts are T_1 weighted, T_1 fluid-attenuated inversion recovery (FLAIR), T_2 weighted, short tau inversion recovery (STIR), water, and fat images. The quantitative imaging includes T_1 and T_2 maps. Previously, we demonstrated TMRF on in vivo healthy human brain. In this work, we focus on the repeatability of TMRF which was demonstrated on one in vivo healthy human brain over a period of four days on a 3T GE 750w scanner. The repeatability study was validated by comparing the signal-to-noise ratio (SNR) and grey matter (GM) and white matter (WM) mean intensity values over four days.

METHODS

The repeatability study protocol included a gold standard (GS) T_1 fast spin-echo sequence and TMRF. The acquisition parameters for the GS sequence were: field of view (FOV) - 22.4x22.4 cm^2, matrix size - 224x224, TR - 929 ms, TE - 7.6 ms, and flip angle - 111^0. The acquisition parameters for TMRF were: FOV - 22.5x22.5 cm^2, matrix size - 225x225, TRmin - 14.7 ms, and TE0 - 1.9 ms (TE_1 - 2.3 ms and TE_2 - 3.4 ms for Dixon imaging). The number of slices and slice thickness for GS and TMRF were 20 and 5 mm respectively. To calculate the SNR, TMRF was acquired twice with identical conditions on all four days. The acquisition time for TMRF was ~4 minutes and reconstruction time was ~3 minutes for all the six contrasts. The reconstructed images show low SNR due to undersampled k-space data and incoherent noise. This was removed by using a deep learning denoising model by learning the noise pattern from the same images. For quantitative maps, a modified version of the Deep RecOnstruction NEtwork (DRONE)[5] method was used to reconstruct T_1 and T_2 maps. WM and GM of all the contrasts and maps for all the four datasets (scanned for four days) were semi-automatically segmented using the threshold method with the help of 3D slicer software[7]. The threshold values were the same for all the datasets. The SNR was calculated for all the contrast images with the help of a 3D slicer which uses the “difference image method”. The measured SNR and mean intensity values of GM and WM for all the qualitative data and only mean intensity values of GM and WM for quantitative data were plotted.

RESULTS AND DISCUSSION

Figure 1 shows the six contrasts along with quantitative data (T1 and T2 maps) which were obtained simultaneously from TMRF. Figure 2 shows the representative gold standard (GS) T1 weighted and TMRF T1 weighted data (first column) and their corresponding segmented masks for one slice are shown in the second column. From figure 2, it can be observed that the TMRF T1 weighted contrast is comparable to GS data. This is representative data and is true for all other contrasts. The plot of SNR of WM and GM for all the four days shown in 3(a) and 3(b) respectively was computed using slicer 3D for four contrasts (T1 weighted, T_1 FLAIR, T_2 weighted, and STIR). From figure 3, it can be seen that the SNR range for white matter for T1 weighted is between 6 and 7, for T_1 FLAIR - 5 and 7, T_2 weighted - 9 to 9.5, and for STIR - 9.5 to 9.7. For GM, T_1 weighted is between 7.7 and 9, for T_1 FLAIR - 6.6 and 8.8, T2 weighted - 9.5 to 9.9, and for STIR - 9.5 to 10. Figure 4 shows the mean intensity values for WM and GM for four TMRF qualitative data (each color indicates one contrast) over four days. The range of mean intensity range for WM for T1w and T1 FLAIR is between 2300 and 2600 and for T_2w and STIR, the range is between 400 and 650. The range of mean intensity range for WM for T_1w and T_1 FLAIR is between 2300 and 2600 and for T2w and STIR, the range is between 400 and 650. Figure 5 shows the WM and GM mean intensity values for TMRF quantitative data (T_1 and T_2 map). From figures 4 and 5, it can be observed that the mean intensity values for GM and WM of qualitative and quantitative data are for all four days.

CONCLUSION

TMRF not only provides six contrasts and two maps simultaneously within 4 minutes but these outputs are also repeatable. Future work is to perform the repeatability study on multi-site MR scanners.

Acknowledgements

This work was supported, in part, by GE-Columbia research partnership grant and also performed at Zuckerman Mind Brain Behavior Institute MRI Platform, a shared resource, and Columbia MR Research Center site

References

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Figures

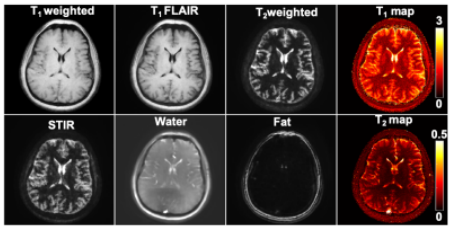

Figure 1: Representative images acquired using tailored magnetic resonance fingerprinting (TMRF) which provides qualitative and quantitative data simultaneously within ~4 minutes. This includes T1 weighted, T1 fluid attenuated inversion recovery (T1 FLAIR), T2 weighted, short tau inversion recovery (STIR), water and fat images. Quantitative data include T1 and T2 maps. All images were acquired on in vivo healthy human brain on a 3T GE 750w scanner. The reconstructed qualitative images were denoised using DL. The maps were generated using DRONE method.

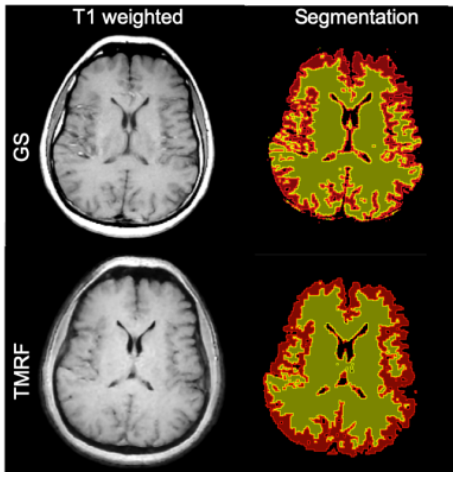

Figure 2: (a) Representative T1 weighted images obtained from GS and TMRF and corresponding grey matter (GM) and white matter (WM) segmented masks are shown in first and second columns respectively. The GM and WM segmentation was performed semi-automatically by threshold method using 3D slicer software. The skull stripping was performed manually using 3D slicer.

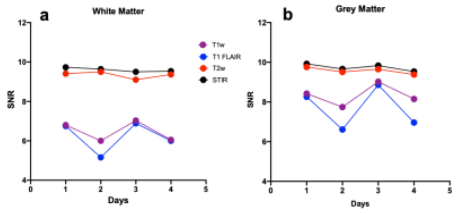

Figure 3: Signal to noise ratio (SNR) for the four contrasts (T1 weighted, T1 fluid attenuated inversion recovery (T1 FLAIR), T2 weighted, and short tau inversion recovery (STIR)) over a period of 4 days. All scans were performed on same in vivo healthy human subject on a 3T GE 750w scanner. The white matter (WM) and grey matter (GM) was segmented semi automatically using 3D slicer to get the (a) WM SNR and (b) GM SNR where different color represents different contrasts. The SNRs were similar for all the four days.

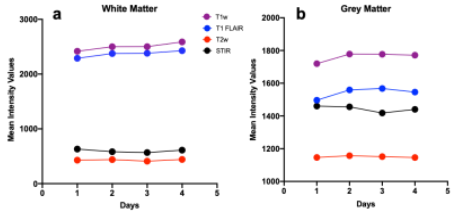

Figure 4: Mean intensity values of (a) white matter (WM) and (b) grey matter (GM) for four contrasts - T1 weighted, T1 fluid attenuated inversion recovery (T1 FLAIR), T2 weighted, and short tau inversion recovery (STIR) over the period of 4 days. The segmentation of WM and GM was performed using 3D slicer. The standard deviation of mean intensity value for all the contrasts over 4 days is small.

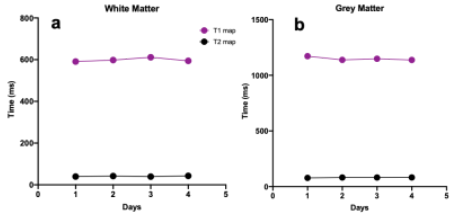

Figure 5: The white matter and grey matter of quantitative images (T1 map and T2 map) were segmented and mean value was calculated over a period of four days. The standard deviation is very small for both white and grey matter.

Proc. Intl. Soc. Mag. Reson. Med. 29 (2021)
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