MR Fingerprinting and B0 inhomogeneities

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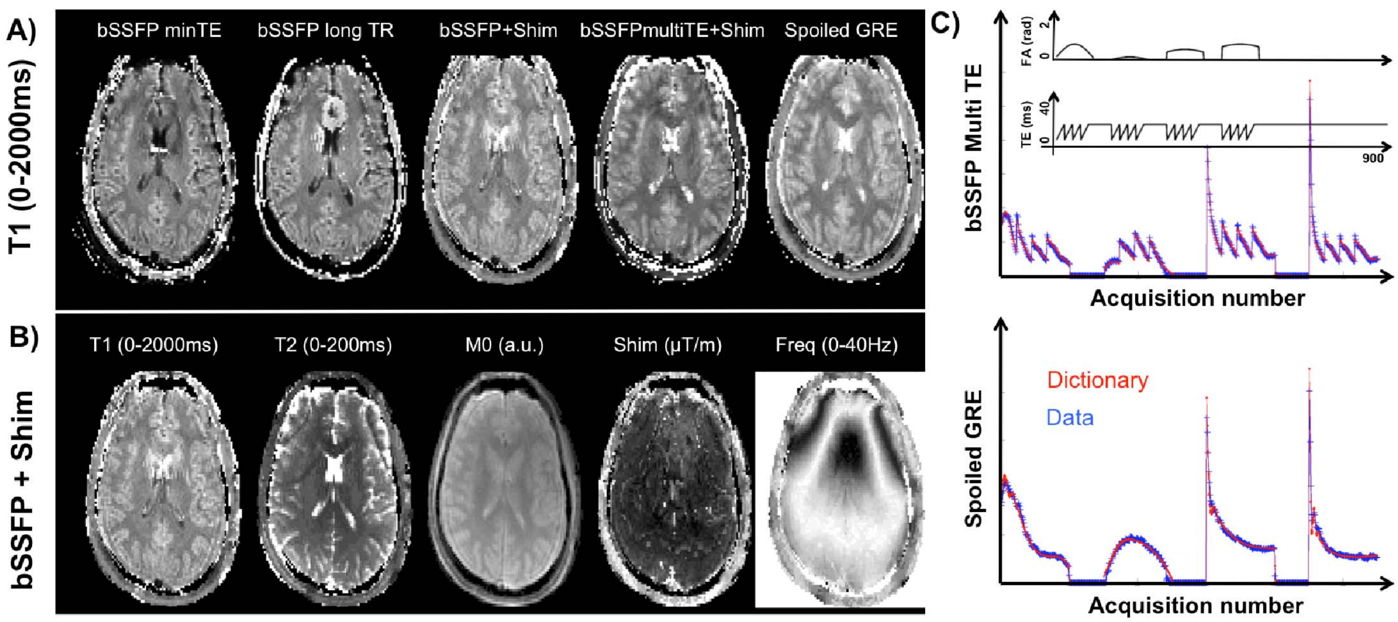
Introduction: In MR Fingerprinting (MRF), *in vivo* acquisitions of temporal signals are compared to dictionaries created from numerical simulations in order to derive multiple quantitative maps of tissue parameters. In the first implementation of the approach, a balanced SSFP sequence with variable TRs and flip angles was used to create maps of T1, T2, proton density (M0) and frequency shift [1]. This type of acquisition was chosen for its great sensitivity to relaxation times and because (unlike other fast GRE sequences), bSSFP is sensitive to T2 instead of T2* [2]. However, this last assumption is only true for short TRs (around 10ms) and a constant TE=TR/2. This can limit the possibilities offered by MRF, especially if one wants to increase the spatial resolution, change the magnetization behavior, or when one simply wants to use or obtain T2* information. In this work, we studied the behavior of MRF when short TEs, multiple TEs, long TRs, or gradient spoilers are used during an SSFP acquisition. We also studied the effect of adding virtual linear shim gradients into the dictionaries.

Materials and Methods: The local IRB committee approved the study. 1 volunteer (age 31yrs) was scanned at 3T (GE Healthcare Systems, Waukesha, WI) with an 8-channel head coil. The fingerprints were acquired using a fast GRE sequence with an 8 shot spiral readout. Acquisition parameters were (FOV=20x20 cm, ST=5mm, 128x128) with 900 time points. Bloch equations simulations were performed in Matlab (MathWorks Inc., Natick, MA, USA) for the creation of the dictionaries. The ranges used in simulation for T1, T2 and frequency shift were [50-5000ms], [20-2000ms], [0-40Hz] respectively. For all fingerprints, the flip angle (FA) scheme consisted of 4 sinusoidal functions separated by zeros to allow for longitudinal magnetization recovery (see FigC, black lines). Zero flip angles were also added at the end of the acquisition to allow for a complete T1 recovery between the different spiral shots. RF phase was alternated between 0 and 180 degrees. 5 different fingerprints were tested: **(1) bSSFP minTE:** a balanced SSFP acquisition with constant TR=17ms and TE=4ms. **(2) bSSFP long TR:** a balanced SSFP acquisition with constant TR=26ms and TE=13ms. **(3) bSSFP+Shim**: same as (1) except that a small and constant gradient was added in the numerical voxels to simulate the presence of a linear shim. Variations of the gradient amplitude created a new dimension in the dictionary. **(4) bSSFPmultiTE+Shim**: a balanced SSFP acquisition with constant TR=50ms and multiple TEs=4 to 30ms (the TE list is indicated in FigC). As for (3) a linear gradient was added in the dictionaries. **(5) Spoiled GRE**: a gradient spoiled GRE sequence with constant TR=17 and TE=4ms (no linear gradient added).



Results: Figure (A) shows T1 maps obtained using the 5 fingerprints. Artefacts are present on the maps when bSSFP is used with a short TE or a long TR. Simply introducing a linear shim gradient in the dictionary improves the results (the different maps obtained with bSSFP+Shim are shown in Fig B). Fingerprinting with different TEs (bSSFPmultiTE+Shim) can also reduce the dephasing artefacts. However, the quantitative T1 values appear lower than the ones found with the other approaches. Overall, spoiled GRE offered the best T1 results with a great WM/GM contrast. This can be explained by the small T2* influence on GRE acquisitions when using a short TE of 4ms. Yet, as expected from short TR/TE gradient echo sequences, T2 sensitivity was reduced (not shown). Example of signals (blue) obtained from a small ROI placed in white matter (10 voxels) are presented in Fig C. For both spoiled GRE and multiple echoes bSSFP one can observe a good match with one of the entries in the dictionary (red).

Conclusion: This study suggests that changing the TE or increasing TR in MRF can introduce B0 inhomogeneity artefacts in the relaxation maps. Several approaches can be used to reduce these effects, including multiple TE acquisition, gradient spoiling, and virtual shim gradients. One could also consider using a combination of these methods coupled with the incorporation of different frequency distributions in the virtual voxels to create T2* maps.

References: [1] Ma et al., Nature, 2013. [2] Scheffler et al, MRM, 2003. **Acknowledgements:** Supported in part by (NIH R01NS066506, RO1NS047607, R21NS087491, 1R01EB11654, 5R01EB2711, NCRR 5P41RR09784) and GE Healthcare.