A B_1-Insensitive qMT Protocol

Mathieu Boudreau[1], Nikola Stikov[1], G. Bruce Pike[2]

Hotchkiss Brain Institute

[1]McConnell Brain Imaging Center, Montreal Neurological Institute, McGill University, Montreal, Quebec, [2]Hotchkiss Brain Institute, Faculty of Medicine, University of Calgary, Calgary, Alberta

Introduction

- Quantitative magnetization transfer (qMT) imaging requires B_0 and B_1 measurements to correct for instrumental biases, and a T_1 measurement to constrain parameters in the fitting model.
- If using Variable Flip Angle (VFA) T_1 mapping[1], B_1 is used twice before fitting the qMT parameters: to correct the flip angles for T_1 mapping, and to scale the nominal MT saturation powers.
- **Inaccuracies in B_1** would **propagate** to the fitting of the qMT parameters through two pathways – through **errors induced in T_1**, and **errors in MT saturation powers**.
- This work demonstrates that for the Sled and Pike qMT model[2], certain qMT parameters are insensitive to a large range of B_1 inaccuracies when using VFA for T_1 mapping.

Methods

- Siemens 3T Tim Trio MRI system, 32-channel head coil
- 3 healthy adult volunteers
- Single slice, AC-PC orientation, slightly above the corpus callosum (2x2x5 mm^3)

Pulse Sequences

- B_0 → Two-point GRE phase-difference method
- B_1 → Double angle method (DAM) (α = 60°/120°)
- T_1 → Variable Flip Angle[3] (TR =15 ms, α = 3°/20°)
  → Inversion recovery[4,5] (TI = 30, 530, 1030, 1530 ms)
- qMT → Spoiled GRE optimal 10-point protocol[6], Gaussian-Hanning MT pulses, Sled and Pike qMT model[5]

Simulated B_1 Errors

- B_1 → Flat B_1 maps = 0.5, 0.75, 0.9, 1, 1.1, 1.25, 1.5, 2 n.u.

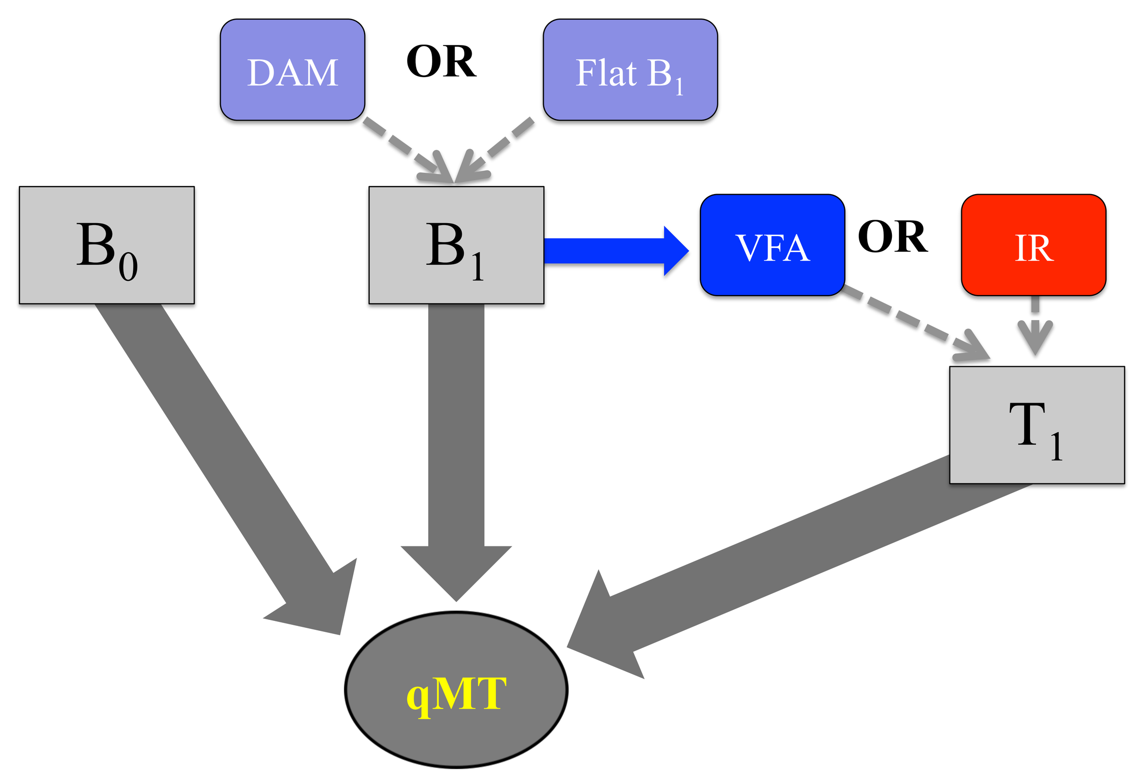


Figure 1. Quantitative MRI protocol processing hierarchy.

Results – Measured B_1 vs. Nominal FA

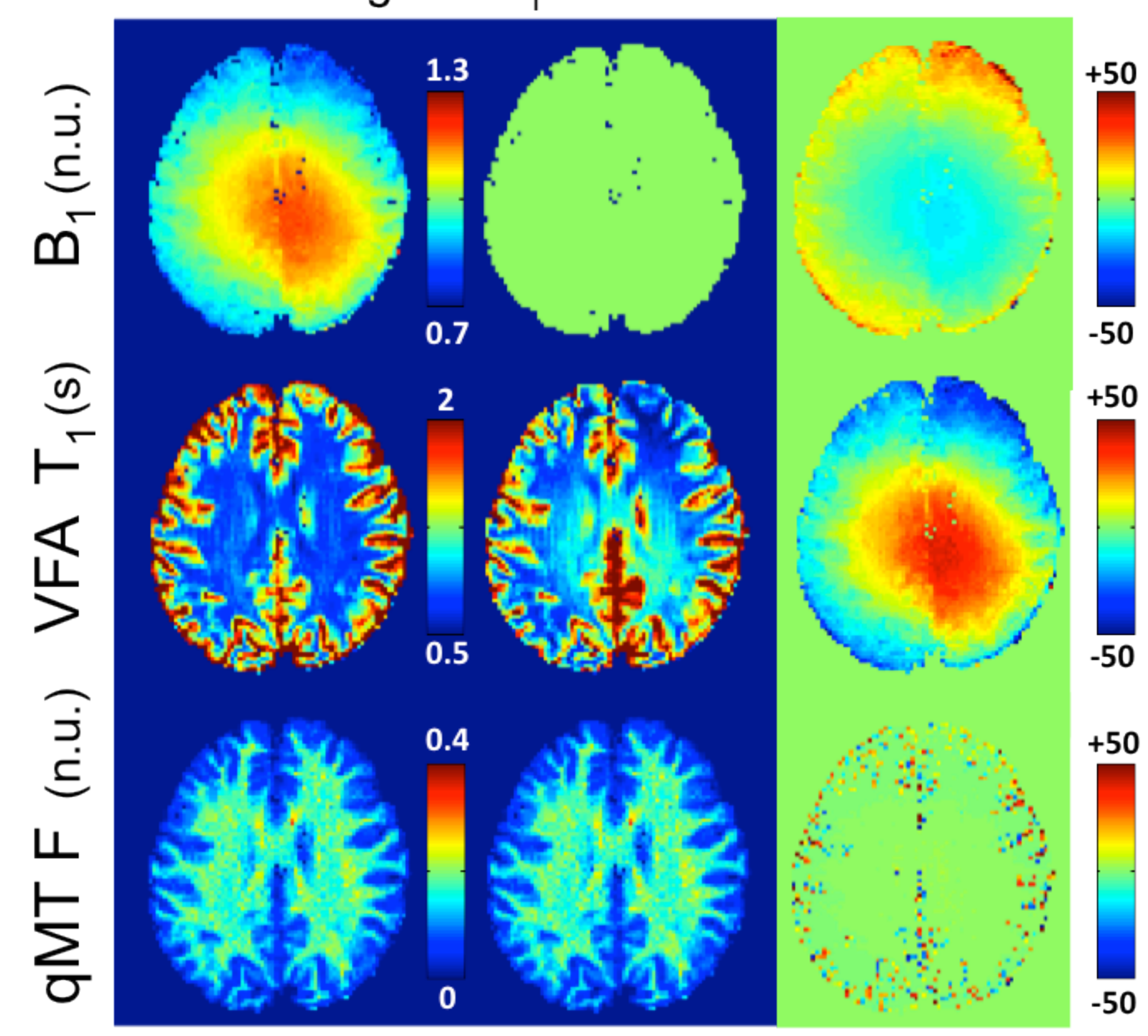


Figure 2. Comparison of VFA T_1 and qMT F maps using measured (DA) and nominal (B_1 flat = 1) B_1 maps.

Results – VFA vs. IR

Figure 3 shows the pooled whole brain Pearson correlation coefficients (a) and linear regression slopes (b) for qMT F values between the measured DA B_1 maps and simulated flat B_1 maps, for VFA (blue) and IR (red) T_1 maps.

High correlation (a) and linear regression slope values near 1 (b) for qMT F values are observed using VFA T_1 maps for a large range of flat B_1 maps (0.75 - 2 n.u.). qMT F maps fitted using IR T_1 are sensitive B_1 errors, as expected.

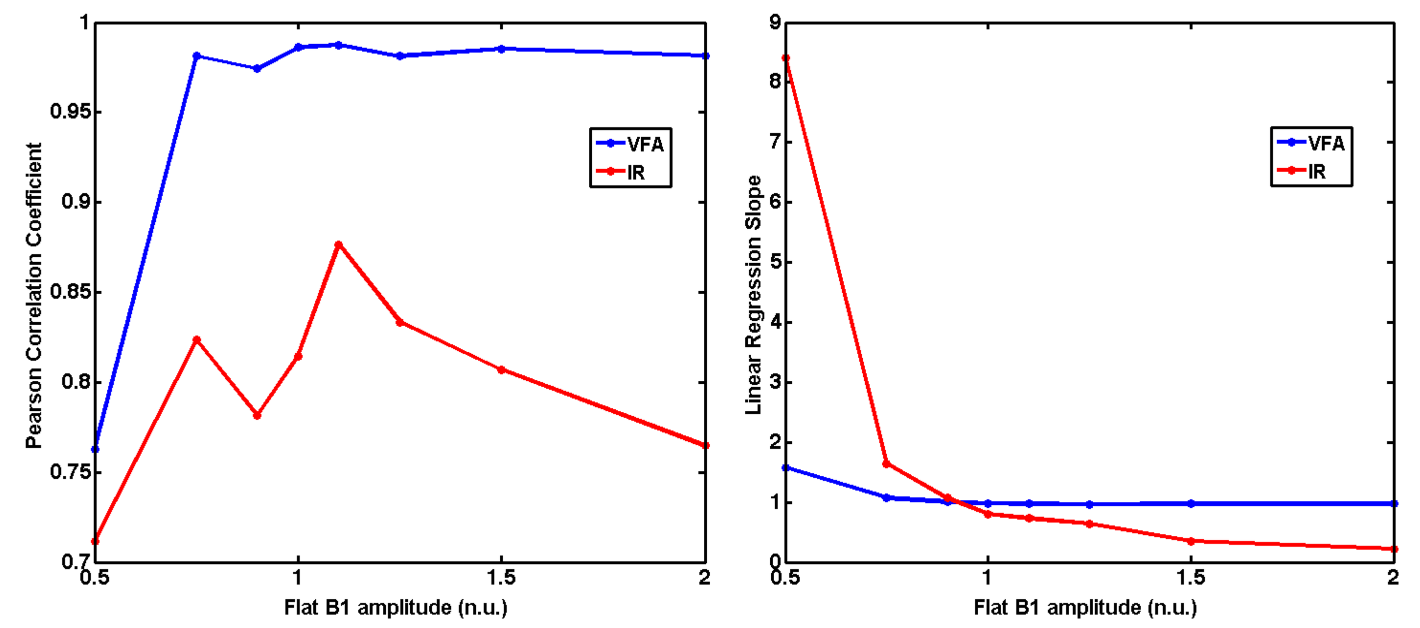
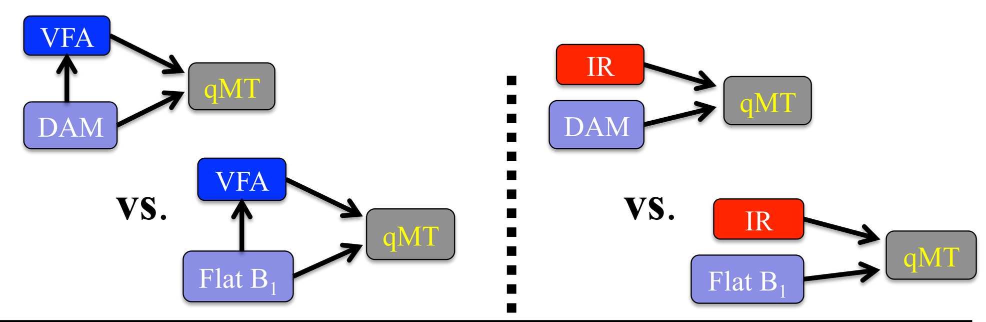


Figure 3. Linear regression analysis of the voxelwise qMT F parameter, comparing measured DA B_1 and a range of flat B_1 (VFA T_1, blue; IR T_1, red).

Results – qMT Parameters

Table 1. Voxelwise linear regression analysis of all fitted qMT parameters, using each T_1 method (VFA - left, IR-right), and a comparison of the measured (DA) and nominal FA (B_1 flat = 1) maps.



qMT	Pearson ρ	Slope	Pearson ρ	Slope
F	**0.99**	**0.98**	0.81	0.81
k_f	0.32	0.31	0.52	0.57
R_{1f}	0.81	0.98	0.78	0.71
T_{2f}	**0.99**	**0.95**	0.93	1.02
T_{2r}	0.92	0.90	0.87	0.91

Discussion

- VFA-based T_1 maps renders qMT F and $T_{2,f}$ insensitive to B_1 errors.
- Processing qMT F maps using VFA T_1 and a flat B_1 map (nominal flip angle assumption, large B_1 inaccuracies) results in nearly identical qMT F maps using DA B_1 maps, (Fig. 2), except where CSF partial volume effects are suspected.
- Severe overestimation of B_1 is better tolerated than severe underestimation for the qMT parameter F (Fig. 3).
- The exact origin of the erroneous B_1 and VFA T_1 nearly cancelling out in qMT F maps remains to be clarified.
- A possible explanation might be that errors in B1 propagate to F via counterbalancing effects on T1 estimation and MT saturation power

Summary

- This work demonstrated that qMT F maps fitted using VFA T_1 can be insensitive to B_1 inaccuracies.
- A strong correlation (0.99) between qMT F values fitted using measured and nominal B_1 maps was observed when using VFA T_1.
- More work in simulating the effects of B_1 and VFA T_1 inaccuracies on qMT parameter estimation is needed to have a clearer understanding of the limitations of this observation.

References: [1] Deoni S. et al, MRM 49:515-526 (2003) [2] Sled J. and Pike G. B., MRM 46:923-931 (2001) [3] Yarnykh V., MRM 63:1610-26 (2010) [4] Barral J. et al, MRM 64:1057-1067 (2010) [5] http://www-mrsrl.stanford.edu/~jbarral/t1map.html (Accessed: October 2012) [6] Levesque I. et al, MRM 66:635-643 (2011) [7] Schmierer K. et al, JMRI 26:41-51 (2007) [8] Yarnykh V., MRM 68:166-178 (2012)

Acknowledgments: This work was funded by the Natural Sciences and Engineering Research Council's Doctoral Alexander Graham Bell Canada Graduate Scholarship (M.B.), and grant funding was provided by the Canadian Institutes of Health Research.

Contact: mathieu.boudreau2@mail.mcgill.ca