A B_1-Insensitive qMT Protocol

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

[1]McConnell Brain Imaging Center, Montreal Neurological Institute, McGill University, Montreal, Quebec, [2]Hotchkiss Brain Institute and Department of Radiology, University of Calgary, Calgary, Alberta, Canada

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[2]

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.

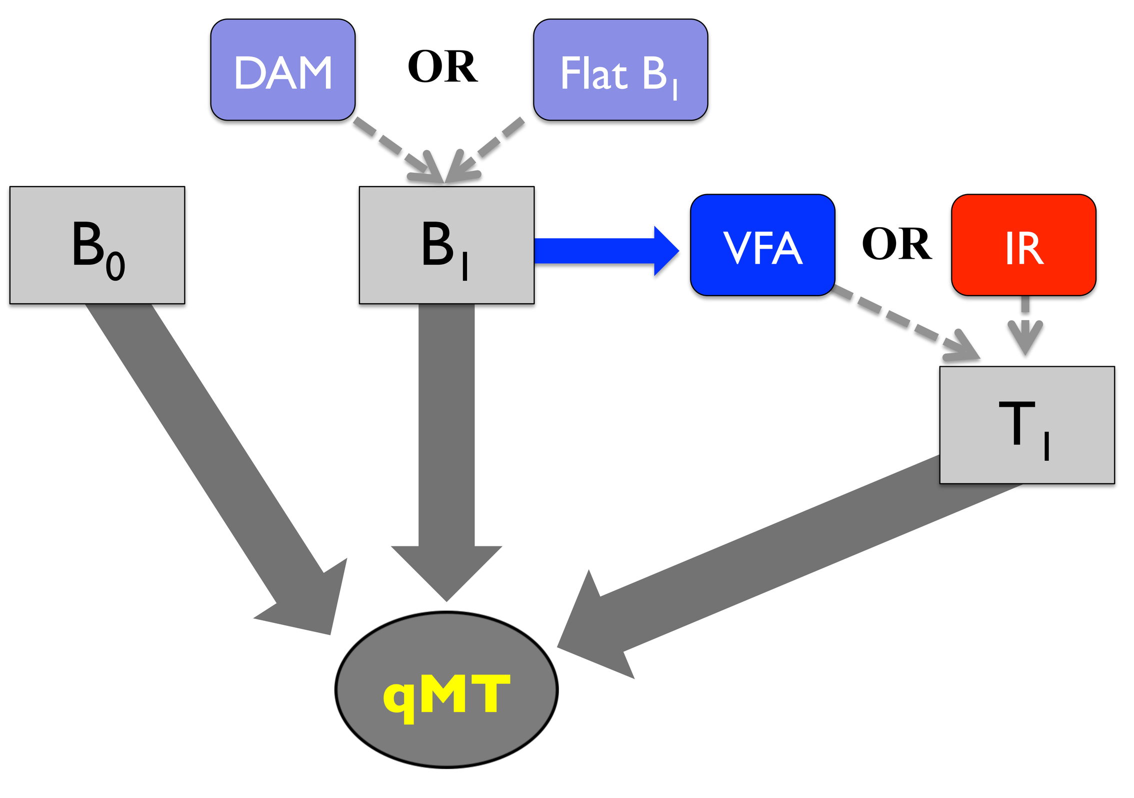


Figure 1. Quantitative MRI protocol processing hierarchy.

Results – Measured B_1 vs. Nominal FA

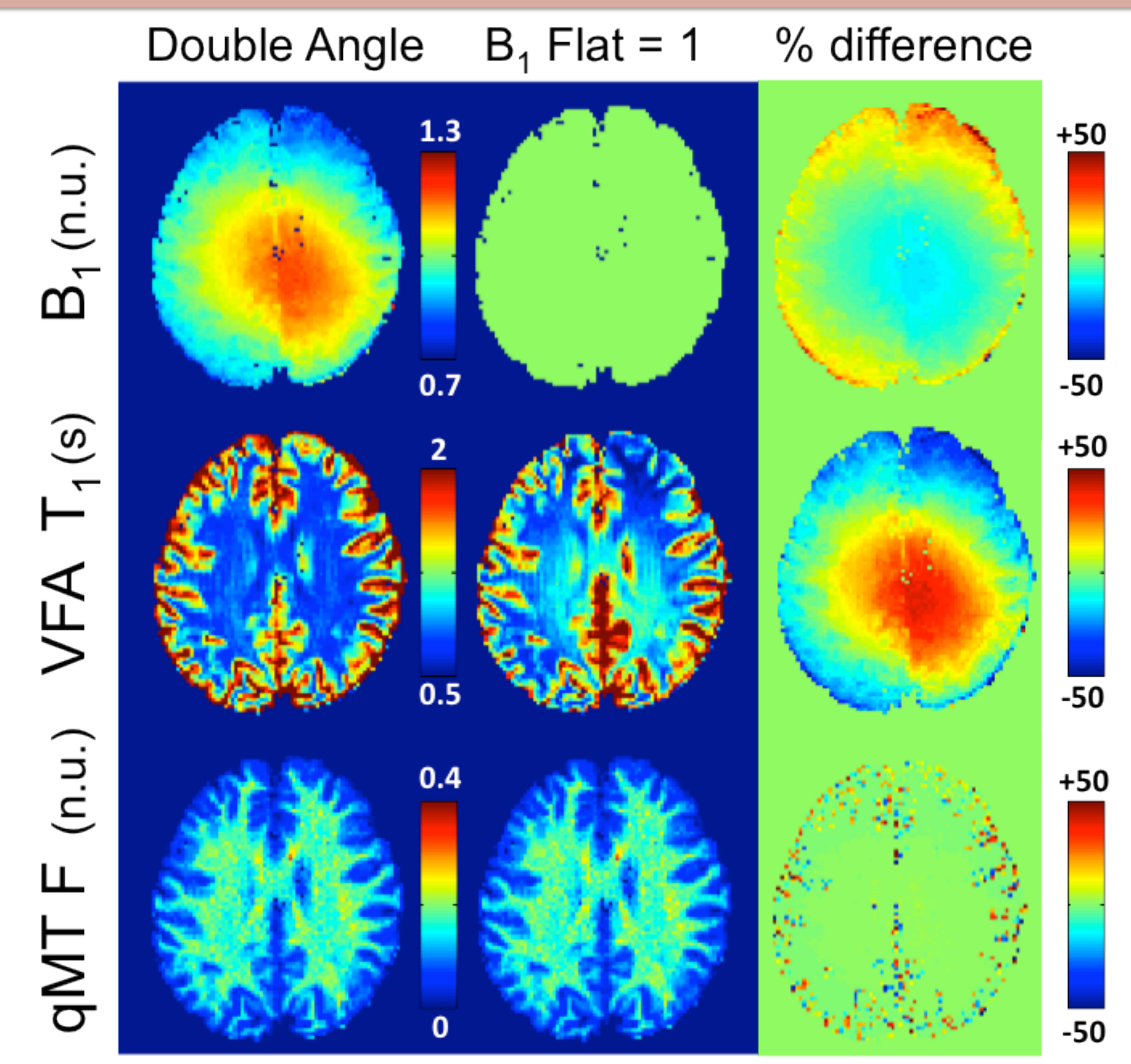


Figure 2. Comparison of VFA T_1 and qMT F maps using measured (DA) and nominal (B_1 flat = 1) B_1 maps.

Results – VFA vs. IR

Figure 3 shows the pooled whole brain Pearson correlation coefficients (a) and linear regression slopes (b) for qMT F parameter 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.

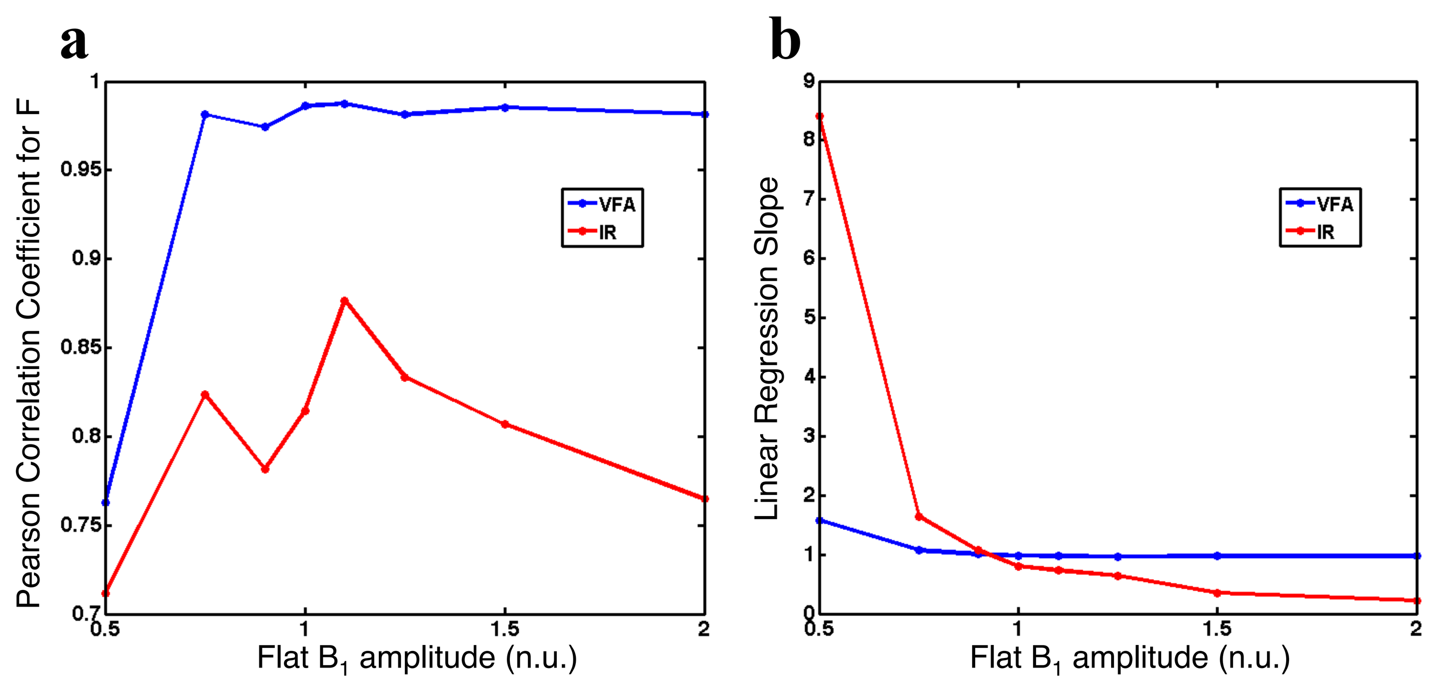
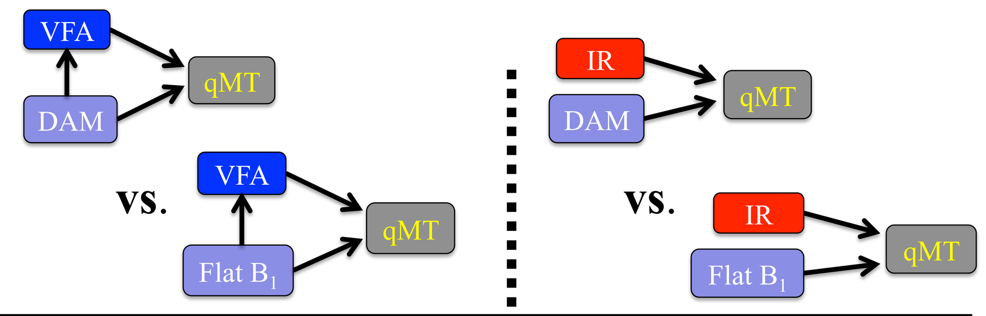


Figure 3. Linear regression analysis of the voxelwise qMT F parameter, comparing measured DA B_1 and a range of flat B_1 (VFA T_1, blue; IR T_1, red).

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 results in nearly identical qMT F maps to using measured 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 B_1 propagate to F via counterbalancing effects on T_1 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 (ρ = 0.99) between qMT F parameter 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)

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Contact: mathieu.boudreau2@mail.mcgill.ca