Optimizing Curve-Fitting Models for T1-Mapping via Inversion Recovery with 3 Tesla MRI

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Introduction

- Inversion recovery (IR) is a gold-standard method used for quantitative T1-mapping.
- There are multiple curve-fitting equations that describe the IR signal, each with underlying assumptions.
- This work sought to determine the optimal curve-fitting model when the number of data points is varied.

Methods

A NIST/ISMRM phantom was scanned on a 3T Siemens MRI scanner. This phantom contains 14 vials of $NiCl_2$ solutions with known T1 relaxation times. Three sets of scans were analyzed:

1. A high-resolution sequence with five inversion times (TIs) ranging from 500-1700 ms. (Resolution: 0.5 × 0.5 × 0.7 mm^3.)
2. The calibration sequence provided by the manufacturer with ten TIs ranging from 35-3000 ms. (Resolution: 1.0 × 1.0 × 6.0 mm^3.)
3. A subset of five TIs from the calibration sequence, chosen to best match the range used in the high-resolution set.

The magnitude data was manually converted into signed data and fit to two curve-fitting models:

$$S = S_0\left(1 + e^{-TR/T1} - 2e^{-TI/T1}\right), \ (1)$$

$$S = A - Be^{-TI/T1}. \ (2)$$

The two-parameter model given by eq. (1) assumes perfect inversion, whereas the three-parameter model, given by eq. (2), makes no assumption of the inversion pulse's flip angle and thus is more flexible.

The accuracy of the fits was assessed by considering the percent differences between fitted and reference T1 values. The precision was assessed by calculating the fitted uncertainty as a percentage of the fitted value.

Vials 9-14 were omitted from the analysis, as the minimum TI of the high-resolution sequence was too long to accurately map the low T1 range.

Results

Table 1. *Mean absolute percent differences in fitted T1.*

	High-Res	Full Calibration	Partial Calibration
Three-Parameter Model	16.4%	0.129%	7.78%
Two-Parameter Model	1.90%	2.94%	2.17%

Table 2. *Mean precision in fitted T1.*

	High-Res	Full Calibration	Partial Calibration
Three-Parameter Model	18.5%	2.09%	5.89%
Two-Parameter Model	1.85%	1.07%	1.63%

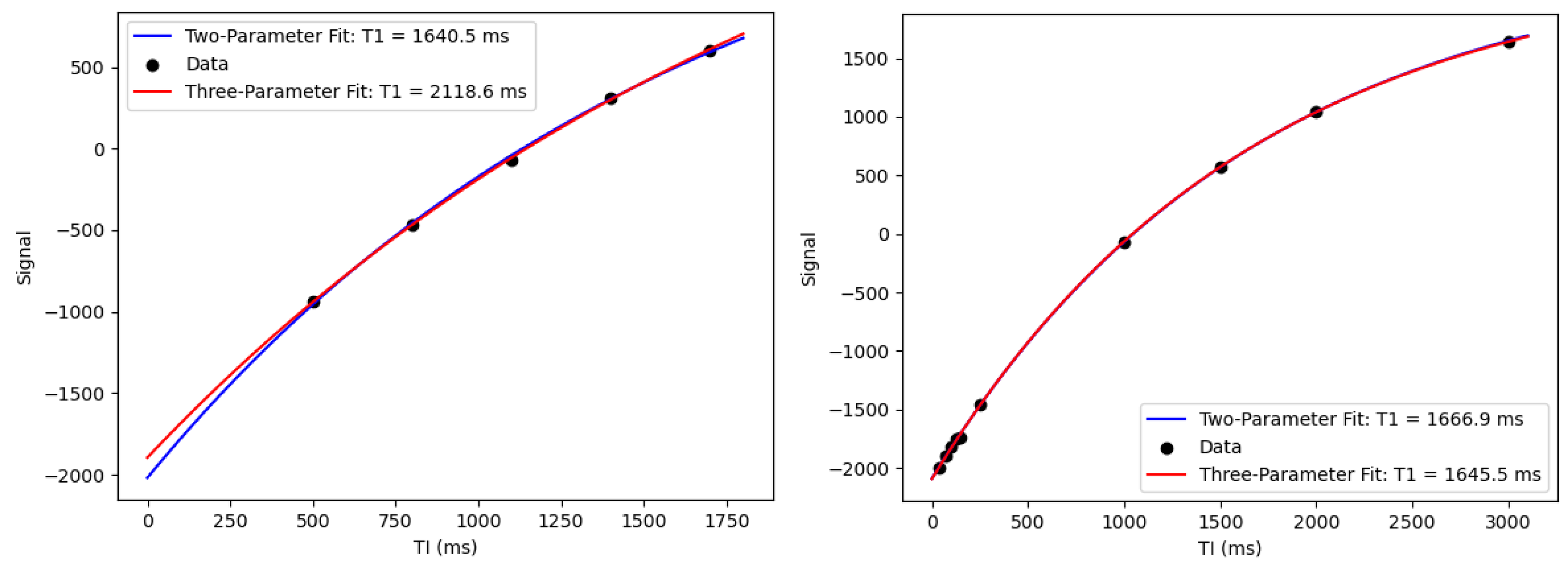

Figure 1. *Curve-fits using both models for vial 1 ($T1_{ref}$ = 1645 ms) for the high-resolution (left) and full calibration (right) datasets. The three-parameter model overfits the high-resolution data, yielding an inaccurate fit. Both models are accurate with the full calibration data.*

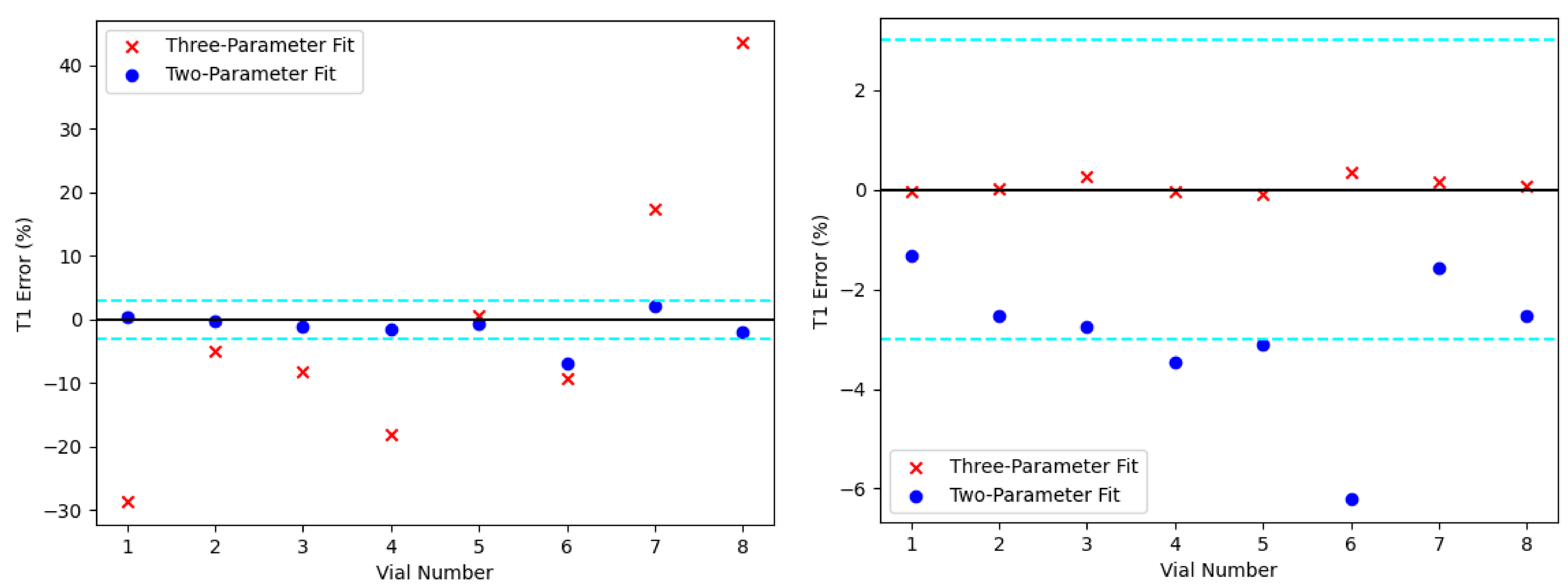

Figure 2. *Plots showing the percent differences between fitted and reference T1 relaxation times for both models for the high-resolution (left) and full calibration (right) datasets. The cyan lines are at ±3%.*

Discussion

- The two-parameter model performed reasonably well for all datasets and can be used even in cases where the number of data points (i.e., number of TIs obtained) is limited.
- The three-parameter model has excellent performance in the full calibration sequence but performs poorly with the limited datasets.
- The high-resolution and partial calibration datasets show similar patterns in the obtained mean absolute percent differences. This indicates that differences in the number of TIs used for T1 mapping is more impactful than possible resolution effects.
- The two-parameter model has better precision than the three-parameter model across all datasets.

Conclusion

- The three-parameter model is best-suited for very high-accuracy fitting when a longer series of scans is acquired.
- If the number of TIs used is reduced to improve the required scan time, the three-parameter model is prone to overfitting. In this case, the two-parameter model is most appropriate.
- T1 mapping via IR can be performed at high resolution with minimal impact on the accuracy of the obtained relaxation times.

This variability in accuracy highlights the importance of tailoring the curve-fitting workflow to the T1-mapping application.

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More Info

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References

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