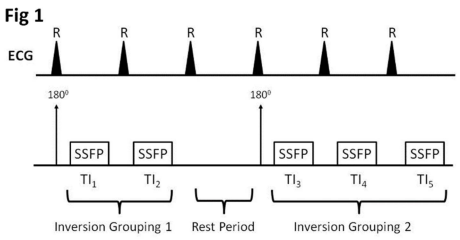
Inversion Group (IG) Fitting: A New Fitting Algorithm for Modified Look-Locker Inversion Recovery (MOLLI) that allows for Arbitrary Inversion Groupings

Issac Y Yang[1], Kai-Ho Fok[1], Bernd J Wintersperger[2,3], and Marshall S Sussman[2,3]

[1]*Faculty of Medicine, University of Toronto, Toronto, Ontario, Canada,* [2]*Department of Medical Imaging, University of Toronto, Toronto, Ontario, Canada,* [3]*Joint Department of Medican Imaging, University Health Network & Mt. Sinai Hospital, Toronto, Ontario, Canada*

Introduction: Modified Look-Locker Inversion Recovery (MOLLI)[1] is commonly applied for myocardial T_1 mapping. Following a 180^0 pulse, SSFP readouts are performed on consecutive cardiac cycles to acquire multiple TI's (inversion groups) (Fig1). To improve the quality of the subsequent T_1 fit, additional inversion group(s), separated by quiescent "rest periods" are typically acquired. Rest periods are needed for magnetization recovery to equilibrium, otherwise data combined from different inversion groups will not follow a MOLLI-like recovery curve. The requirement of rest periods can significantly reduce the scan efficiency and/or increase scan time (by up to ~30-40%)[2]. In this study, we present a new technique, Inversion Group (IG) fitting, which allows accurate T_1 fitting without requiring rest periods.

Fig 1



Theory: In conventional MOLLI, data is fitted with a three parameter model[3]: $S(TI) = A - Be^{-\frac{TI}{T_1^*}}$. In the proposed IG fitting technique, a more general model with a separate B_i parameter for each inversion group is used:

$$S(TI) = A - B_i e^{-\frac{TI}{T_1^*}} \qquad (1)$$

The additional B_i parameters account for incomplete magnetization recovery between groupings. As a result, Eq.1 may be used regardless of the presence or absence of rest periods. T_1 can be calculated from T_1^* as[4]:

$$T_1 = T_1^* \cdot (\frac{B_i}{A} - 1)/\delta_i \qquad (2)$$

δ_i denotes the fraction of magnetization inverted on inversion group *i*. For simplicity, we calculate T_1 from the first inversion group where it is known that δ_i=1.

Methods: Phantom and in vivo experiments were performed on a 1.5T scanner (Magnetom Avanto fit). T_1 maps were calculated with both 3-parameter and IG fits. Phantom experiments were performed on $MnCl_2$ doped water (T_1≈1000ms). *In vivo* experiments were performed on 5 patients. In all experiments, three different MOLLI inversion groupings were acquired: 5(3)3, 5(0)3, and 1(0)2(0)3(0)5 (non-bracketed numbers indicate number of readouts within inversion group and bracketed numbers denote number of heartbeats in rest period).

Results: The phantom results (Fig 2) demonstrate that T_1 values for the IG fits are consistent across all inversion groupings and not statistically different (P=0.25) from the 5(3)3 acquisition-the reference standard (arrows), while the 3-parameter 5(0)3 and 1(0)2(0)3(0)5 showed substantial deviations (p≈0). On the other hand, precision of the IG fits was found to be slightly poorer than the 3-parameter fits, likely due to the larger number of free parameters in the fit. Fig 3 shows T_1 maps from one patient. For 3-parameter fits, a dramatic decrease in T_1 value is observed across different inversion groupings while IG fits remained consistent. Quantitatively, the reduced χ^2 values were very similar across all IG fits and the 3-parameter 5(3)3, while the reduced χ^2 of other inversion groupings of the 3-parameter fit were much larger (Table 1). However, all IG cases aside from the 1(0)2(0)3(0)5 showed slightly poorer precision compared to the 3-parameter fits, as indicated by the coefficients of variation listed in Table 1.

Fig 2

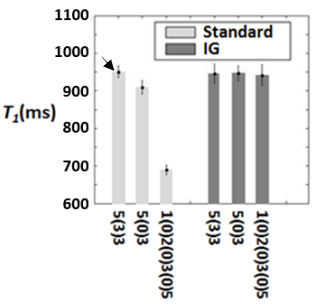
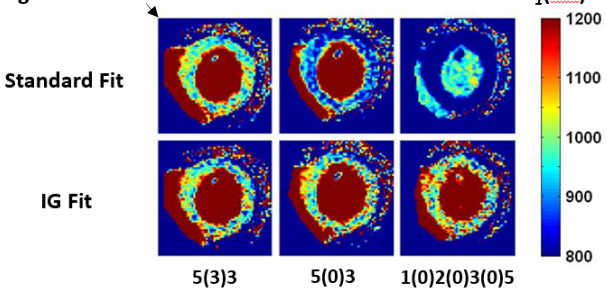


Fig 3



Conclusion: The IG fitting technique provides accurate T_1 fitting for any inversion grouping /rest period combination at the cost of a slight loss of precision relative to the conventional 3-parameter method. Further improvements will likely allow overcoming this current limitation.

References:

1. Messroghli et al. *Magn Reson Med* 2004. **52**(1)
2. Reiter et al. *Radiology* 2014. **271**(2)
3. Deichmann et al. *JMRI* 1992. **96**(3)
4. Kellman et al. *Magn Reson Med* 2014. **71**(4)

Table 1: Reduced χ^2 and coefficient of variation over all patients

	3-Parameter Fit			IG-Fit		
	5(3)3	**5(0)3**	**1(0)2(0)3(0)5**	**5(3)3**	**5(0)3**	**1(0)2(0)3(0)5**
Reduced χ^2	17 +/- 6	41 +/- 13	137 +/- 68	18 +/-7	16 +/-5	25 +/- 12
COV	0.06 +/- 0.005	0.07+/- 0.007	0.06 +/- 0.004	0.08 +/- 0.004	0.08 +/- 0.005	0.1 +/- 0.08