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Correction for T1-Nonlinearity in Myocardial Signal Intensity Improves First-Pass Perfusion Quantification

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Abstract:

Introduction:

The nonlinear T1 saturation recovery in first-pass contrast-enhanced MR myocardial perfusion imaging is an important issue which affects quantification of myocardial blood flow. Despite many efforts focused on improving the linearity of the LV blood pool signal intensity, relatively little work has been published with regard to nonlinearity in the myocardium.

Purpose:

We hypothesize that 1) T1-nonlinearity is significant in the myocardium and it will affect both semi and fully quantitative perfusion estimates, 2) this nonlinearity will affect a long saturation recovery delay more than a short one, 3) a nonlinear correction of the myocardial signal intensity will improve quantitative perfusion estimates, 4) semiquantitative perfusion indices underestimate perfusion independent of T1-nonlinearity.

Methods:

Ten normal volunteers went through 40 dual-bolus (Gd-DTPA 0.005 and 0.1 mmol/kg) perfusion studies on a 1.5T Siemens Espree scanner to cover the interplay of rest vs. stress states and short vs. long saturation recovery delays (TD 70 and TD150 ms) for quantitative perfusion estimates. Rest perfusion was performed 4 hours after the dipyridamole (0.56 mg/kg over 4 minutes) stress study. TD70 and TD150 studies were acquired on separate days. A look-up-table (LUT) for signal intensity versus T1 magnetization was calculated based on the following imaging parameters: 90° prep, 25° readout, TR 7.5ms, TE 1.48ms, 8mm slice, acquisition matrix 128x80, FOV 360x270. The T1 value was converted to the contrast concentration using the equation $1/T1 = 1/T1_{init} + \gamma \bullet [Gd]$ ($T1_{init}$: 850ms, γ: 4.5L/mmol). The time-signal intensity curves were analyzed on 6 sectors of a mid ventricular slice. Semiquantitative perfusion indices of intensity upslope (SLP) and contrast enhancement ratio (CER) were measured.

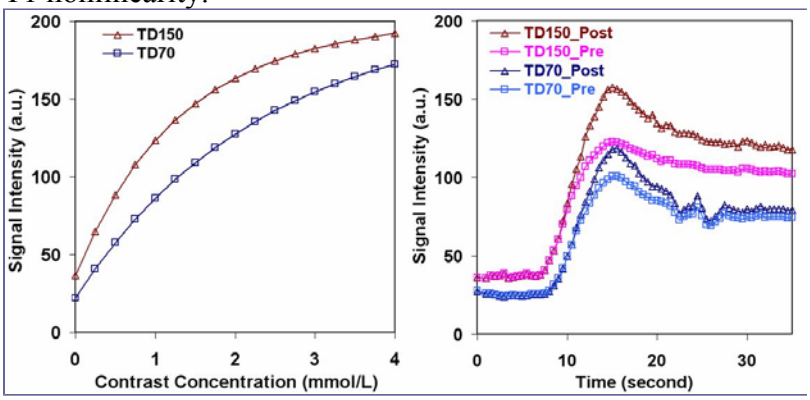
Fully quantitative myocardial blood flow (MBF) was estimated using a Fermi model constrained deconvolution. All perfusion estimates were compared before and after the LUT correction and correlated against the MBF of the LUT corrected TD70.

Results:

Figure-1 shows the relationship between myocardial signal intensity and contrast concentration for TD70 and TD150. Raw time-signal intensity plot shows the LUT correction has the largest effect near peak contrast enhancement. Table-1 summarizes the results of fully quantitative MBF and semiquantitative CER and SLP before and after the LUT correction. Both fully quantitative and semiquantitative measurements were significantly improved after the LUT correction for the stress perfusion but to a lesser extent for the rest study. The degree of correction required for TD150 was higher than TD70 due to more severe nonlinearity. Figure-2 shows semiquantitative SLP and CER still underestimated vasodilated MBF even after the LUT correction. The effects of underestimation were of similar magnitude for TD70 and TD150.

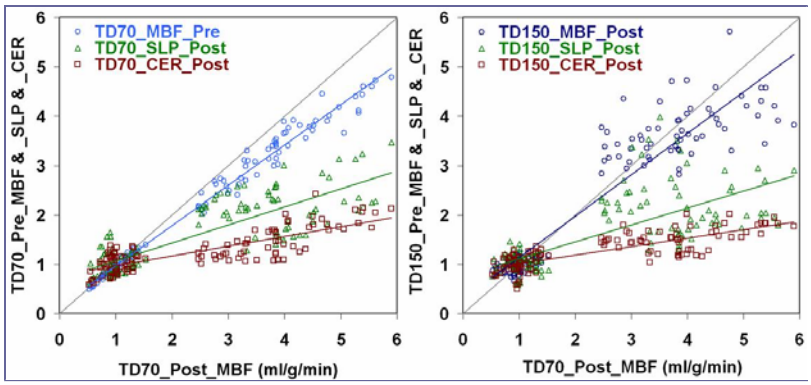
Conclusions:

The effect of T1-nonlinearity between myocardial signal intensity and contrast concentration significantly affects perfusion quantification. This nonlinearity leads to underestimation of all quantitative perfusion measures studied. The effects are more severe for TD150 than TD70. A LUT correction based on acquisition specific relaxivity models of signal intensity versus contrast concentration can correct the signal intensity curves for perfusion quantification. However, semiquantitative perfusion indices still underestimated vasodilated blood flow despite correction of the T1 nonlinearity.



MBF: ml/g/min, SLP and CER: a.u.

mean (n=10)	**Rest** PreLUT	**Rest** PostLUT	**Rest** % of correction	**Stress** PreLUT	**Stress** PostLUT	**Stress** % of correction
TD70_MBF	**0.95**	**1.00**	**4.8%**	**3.34**	**3.89**	**16.3**
TD70_SLP	0.36	0.38	6.1%	0.75	0.80	11.9%
TD70_CER	1.69	1.78	5.5%	2.43	2.70	11.2%
TD150_MBF	**0.91**	**0.97**	**6.8%**	**2.92**	**3.72**	**27.1%**
TD150_SLP	0.35	0.40	14.5%	0.71	0.88	24.1%
TD150_CER	1.51	1.71	13.2%	2.13	2.60	22.4%



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