T_1 Measurement of Flowing Blood and Arterial Input Function Determination for Quantitative 3D T_1 –weighted DCE-MRI

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INTRODUCTION

Accurate measurement of the arterial input function (AIF), or contrast concentration time-course in plasma, is necessary for reliable quantification of physiological properties such as blood volume (v_b) and endothelial transfer constant (K^{trans}) in dynamic contrast-enhanced MRI (DCE-MRI). However, AIF characterization, including measuring T_1 in flowing blood, is generally prone to errors such as partial volume or in-flow effects. Conventional means to circumvent these difficulties, such as adopting a standard AIF curve[1] or assuming a reference blood T_1 value[2], do not account for individual differences and are a major source of inaccuracy in DCE-MRI. In this study, we propose a method for accurate AIF extraction and T_1 measurement in flowing blood in the presence of B_1 field inhomogeneity. Rate kinetics of the measured AIF and blood volume measurements in rabbit muscle are presented to demonstrate the accuracy and reproducibility of the proposed method.

METHODS

Ten rabbits were imaged on a 1.5-Tesla MRI system (Signa EXCITE TwinSpeed, GE), using an 8-channel transmit/receive knee-array coil over the lower abdominal area. Pre-injection blood T_1 was measured using a 3D fast SPGR sequence (θ=2°,10°,20°) and segmented SE-EPI (60°/120°, 120°/240°) to correct for B_1 variation, as described in [3]. A bolus of Gadomer (0.033 mM/kg, Schering) was injected by hand and monitored over 5 minutes using 3D fast SPGR (TR/TE= 5.2/1.3 ms, θ=15°, BW=31 kHz, FOV=12 cm, matrix=256×224×16, SL=3 mm, 1 NEX, time resolution=14 s). Single time-point measurements using the same sequence (4 NEX) were taken up to 1 hour post-injection.

AIF determination began with manually drawing an ROI on a portion of the iliac artery sufficiently distal from the entry slices to eliminate in-flow effects. Partial volume errors were removed by retaining only voxels with a purely vascular contribution for blood T_1 measurement and AIF characterization. These voxels were identified based on concentration changes within the top 25% of the maximum change in the first 15 seconds post-arrival. Plasma concentration was calculated from the change in T_1 relaxation rate, assuming a relaxivity of 16 litre/mM/s [4] and a hematocrit of 0.2857[5]. The AIF was fitted to a bi-exponential decay model to obtain a smoothed curve for estimating the blood volume in muscle using compartmental analysis[6].

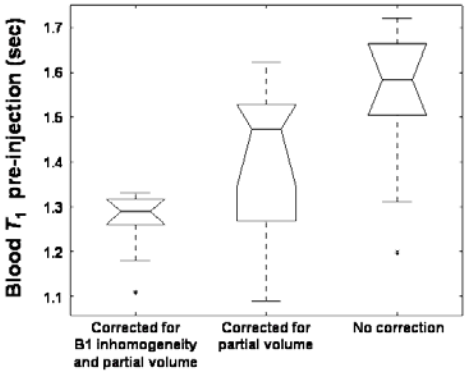

Fig.1. Blood T_1 measurements in 10 rabbits with and without correction of partial volume and B_1 errors.

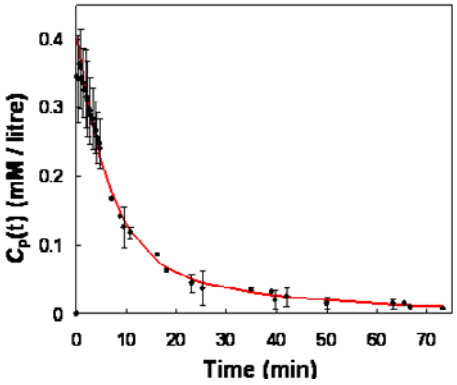

Fig.2. Mean AIF (dots) +/- 1 SD across 10 rabbits and model fit to the mean AIF (red line).

RESULTS

Figure 1 shows pre-injection T_1 measurements in flowing blood using the proposed method, in agreement with the literature (1260-1441 ms)[7,8]. Significantly larger values resulted when errors due to B_1 inhomogeneity and partial volume effects were not accounted for. AIF measurements based on individually measured blood T_1 were reproducible across the 10 rabbits (Fig.2). In four rabbits, both iliac arteries were available for AIF measurement; consistency between paired AIFs was evident in a small unsigned mean difference (1-12%) in concentration C_p. Fitting individual AIFs and the mean AIF to a bi-exponential decay model yielded rate constants in agreement with the literature, demonstrating accuracy of our AIF measurement technique (Table 1). Finally, to demonstrate the accuracy of DCE-MRI analysis based on AIFs measured using the proposed approach, blood volumes v_b obtained in rabbit skeletal muscle are compared to reference values (Table 2).

CONCLUSIONS

We have presented a method that allows accurate blood T_1 measurement and AIF extraction for reliable quantitative DCE-MRI analysis. Accurate blood T_1 measurement is necessary to account for individual differences, and it is the first step towards accurate AIF characterization. The AIFs obtained in all rabbits were reproducible and followed decay rate constants expected for this contrast agent, Gadomer. Blood volume measurements in rabbit skeletal muscle obtained via individually measured AIFs were reproducible and agreed with reported values.

Table 1. Biexponential decay model fit to mean AIF and individual AIFs (N=10 rabbits).

AIF	Amplitudes (kg/litre)		Decay rate constants (1/min)		Reference
	A_1	A_2	m_1	m_2	
Mean	9.94	2.19	0.153	0.026	This study
Individual	9.10 ± 2.46	2.57 ± 1.72	0.141 ± 0.038	0.034 ± 0.023	(rabbits)
	–	–	0.25 ± 0.08	0.031 ± 0.011	[9] (rabbits)
	6.43	2.39	0.227	0.0258	[10] (rats)

Table 2. Blood volume measurements in muscle based on individual AIFs (N=10 rabbits).

Resting muscle	Blood volume v_b (%)	Reference
Back	1.12 ± 0.41	This study
Leg	1.77 ± 0.76	(rabbits)
–	1.5 ± 1.0	[11] (rats)
Leg/Back	3.2 ± 1.3	[12] (mice)

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