Quantitative Analysis of DCE-MRI Kinetic Parameter Deviation Induced by Dual-flip-angle T1 Mapping in Head and Neck

Jing Yuan[1], Steven Kwok Keung Chow[1], David Ka Kwai Yeung[1], Anil T Ahuja[1], and Ann D King[1]

[1]*Imaging and Interventional Radiology, The Chinese University of Hong Kong, Shatin, NT, Hong Kong*

Introduction: T_1 mapping is essential for DCE-MRI kinetic model analysis. Multiple-flip-angle (MFA) method [1] is preferable for DCE T1 mapping due to its superior signal-to-noise ratio (SNR) and time efficiency. Dual-flip-angle (DFA) [2] reduces the FA numbers to 2 to maximize the time efficiency, however, potentially decreases the T1 measurement accuracy and leads to errors in kinetic model analysis. Although good T1 accuracy by DFA has been reported in brain with optimized flip angles, it may not be readily used for head and neck (HN) DCE-MRI where low SNR, low spatial resolution, tissue heterogeneity and susceptibility typically present. Therefore, we aimed to experimentally evaluate whether DFA could obtain accurate kinetic parameter estimation compared to MFA for DCE-MRI in HN in this study.

Methods: 23 patients with HN squamous cell carcinoma received DCE-MRI at 3T, with T1w spoiled gradient echo sequence. Informed consents were obtained. Gd-DOTA (0.1mmol/kg) was injected intravenously at 2.5mL/s using a power injector pump, followed by a 20-ml saline flush (2.5mL/s). TR/TE=3.9ms/0.9ms, FA=15º, FOV=230mm, matrix =128x128, thickness=4mm, SENSE factor =4, dynamics=185, and temporal resolution=2.59s/dynamic. Pre-contrast images were acquired with four FAs of 2º, 7º, 12º and 15º for T1 mapping based on the suggested values in literatures [3]. Other imaging parameters were identical to DCE acquisition. MFA and DFA T1 maps were calculated with all four FAs, and FA pairs of [2º, 7º], [2º, 12º], [2º, 15º], [7º, 12º] and [7º, 15º] by the least-square fitting of the theoretical equation for spoiled gradient echo signal intensity (Fig. 1). k_{ep}, K^{trans} and v_p maps for extended Tofts model were generated based on MFA and DFAs using an automated extracted arterial input function (AIF) [4]. A literature arterial blood T1 of 1550ms at 3T was used to compensate the reduced T1 measurement due to the in-flow effect. Hematocrit was set as 0.42. k_{ep}, K^{trans}, and v_p by MFA and DFAs were compared for primary tumors (PTs), salivary glands and muscles. A Kruskal-Wallis test was performed (significant p-value level 0.05).

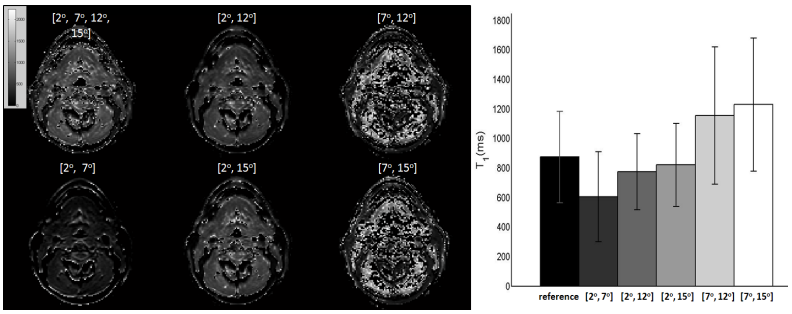

Fig.1. T1maps (R^2>0.8) and the bar plots generated by MFA and DFAs

Results: The DFAs of [2º, 7º], [2º, 12º], and [2º, 15º] overestimated, while [7º, 12º] and [7º, 15º] underestimated K^{trans} and v_p significantly in PTs, muscles and salivary glands (Fig. 2). [2º, 15º] obtained the smallest but still significant overestimation for K_{trans} and v_p in PTs, 32.1% and 16.2% respectively. K_{ep} estimates by DFAs were relatively closed to the MFA reference, without significant difference from the MFA reference except for k_{ep} estimate by [2º, 7º] in salivary glands. T1 mapping error induced by DFAs seemed to have the greatest influence on the estimate of K^{trans} in PTs and salivary glands, and v_p in muscles.

Discussion: Although T1 mapping accuracy could be improved by the optimized flip angles such as [2º, 15º], the T1 map difference could still be significant due to the limited SNR and susceptibilities for HN DCE-MRI images. Inaccuracy of T1 mapping could propagate through tracer concentration into kinetic model fitting and lead to significant errors in kinetic parameter estimates. k_{ep} is insensitive to T1 because it is only dependent on the time-intensity curve pattern instead of the absolute T1 values. If scan time permits, multiple flip angles rather than dual flip angles are suggested for T1 mapping in DCE-MRI studies to ensure accurate quantitative pharmacokinetic model analysis.

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References: [1] Fram EK et al, MRI 1987; 5:201-208; [2] Wang HZ et al, MRM 1987; 5:399-416; [3] Yu Y et al, Radiology 2010; 257:47-55; [4] Rijpkema M et al. JMRI 2001; 14:457-463.

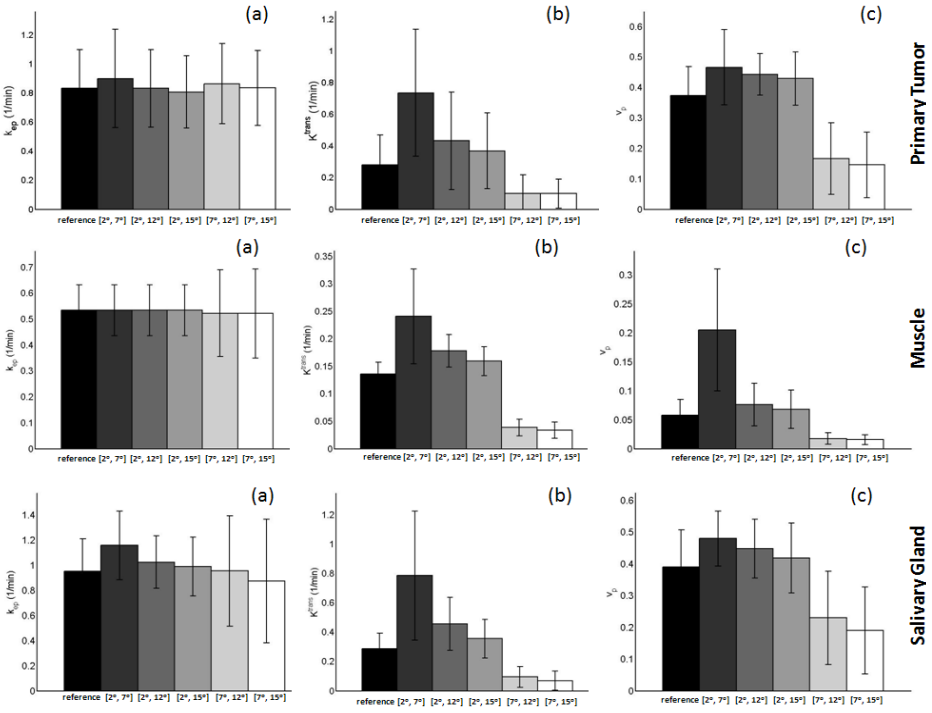

Fig.2. Kinetic parameters estimates in primary tumors, salivary glands and muscles based on the MFA and DFA T1 maps