Comparison of Look-Locker and Variable Flip Angle T1 Mapping for DCE-MRI in Prostate Patients at 3T

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INTRODUCTION

In DCE-MRI, the temporal behavior of the MR signal following contrast agent (CA) injection, provides insights into a wide range of physiological parameters, i.e. perfusion, permeability and angiogenesis, by means of dedicated pharmacokinetic modeling of the CA concentration over time. An intuitive T1 map obtained before CA administration is essential to convert the image intensities from a series of T1-weighted images into CA concentration. Due to the time and SNR efficiency, spoiled gradient recalled echo (SPGR) sequence with variable flip angle (VFA) has been widely used to construct the T1 map. Even though efforts have been made to improve the accuracy of VFA via actual flip angle imaging (AFI) (1-2), VFA has been reported to be less accurate in vivo than in phantom (3). Look-Locker sequence consists of an initial inversion pulse followed by a train of pulses with a constant flip angle. Compared to other T1 mapping techniques, Look-Locker is almost as efficient as the inversion recovery approach (4). This paper compared the T1 maps from the Look-locker and the VFA approaches, as well as the corresponding pharmacokinetic parameters based on T1 maps from both techniques for differentiation of prostate cancer, to investigate the accuracy of the VFA T1 mapping in prostate cancer patients.

METHODS

MRI: Diagnostic prostate MRI scans including T2-weighted, ADC map, 3D Spectroscopic Imaging, Look-Locker T1 mapping, AFI, DCE-MRI were performed on 16 patients using the 16-channel anterior half of a 32-channel SENSE cardiac array (Invivo, Orlando, FL) in combination with an endorectal coil (BPX 30, Medrad, Warrendale, PA) on a 3.0 T whole-body scanner (Philips Healthcare, Best, the Netherlands). Look-Locker T1 maps were acquired with M2D TFE sequence with FA = 12°, TR/TE = 5 ms / 1.89 ms, 35 Look-Locker phases. AFI was acquired with 3D FFE with two interleaved TRs: TR = 17ms and TR = 85ms. DCE-MRI used 3D T1FFE sequences with FA =5° for reference scan and FA=15° for 52 dynamic scans during a single-dose bolus injection of 0.1 mmole/kg dose of Magnevist (Berlex, Princeton, NJ) at a rate of 3.0cc/s after the third scan. DCE-MRI was performed with 4X slice oversampling to suppress inflow (5). Both Look-Locker and DCE-MRI were acquired with a resolution of 1.02 mm × 1.02 mm × 6 mm.

Data Analysis: All analyses were performed using an in-house built IDL (ITT, Boulder, CO) program along with Image J (http://rsbweb.nih.gov/jj). Look-Locker T1 maps were calculated by monoexponential curve fitting. VFA T1 maps were derived using the low flip angle scan and average of the four high flip angle scans before CA injection. Pharmacokinetic parameters were fitted with a two-compartment model. SPGR images were corrected with flip angle maps from the AFI approach. For comparison of T1 maps, ROIs covering the whole prostate were drawn on all relevant T1 maps. In patients demonstrating early enhancement on DCE-MRI, tumor ROIs were drawn where K_{trans} was elevated and the corresponding normal ROIs were drawn on the contralateral of the prostate.

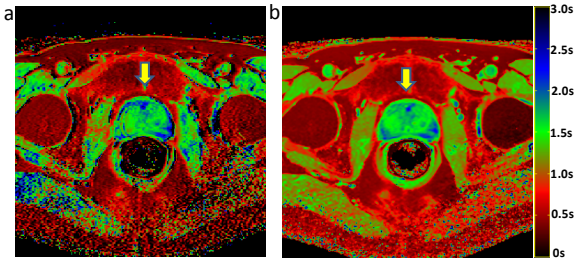

Figure 1. Representative T1 maps from VFA (a) and Look-Locker approach (b). Arrows indicate prostate.

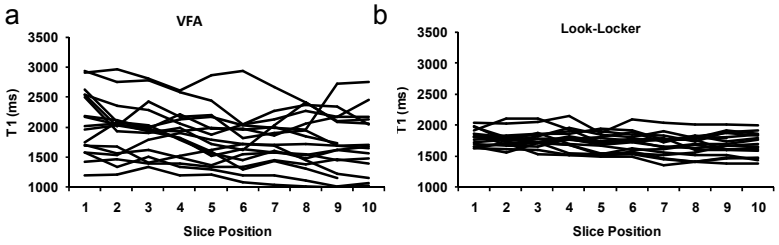

Figure 2. T1 of femoral artery from VFA (a) and Look-Locker (b) techniques. Each line represents one patient.

RESULTS

Figure 1 illustrates representative T1 maps from VFA and Look-Locker approaches. Obviously, T1 maps from Look-Locker showed better SNR at the expense of much longer scan times (5 min vs. 20 sec). Compared to the Look-Locker technique, the VFA approach generated larger variations as evidenced by the femoral arterial T1 in Figure 2. Nevertheless, prostate T1 values from VFA and Look-Locker demonstrated a good correlation as shown in Figure 3a. Bland-Altman plot indicates that VFA technique overestimated higher T1s but underestimated lower T1s (Figure 3b). Out of 16 patients, 5 patients demonstrated focal areas of early enhancement corresponding to adenocarcinoma with Gleason scores ranging from 6 (3+3) to 7 (4+3). K_{trans} of tumor tissues was significantly higher than the corresponding normal tissues from both VFA and Look-Locker techniques (Figure 4a). Tumors also tended to have increased K_{ep} from both approaches (Figure 4b). No statistical difference was observed in K_{trans} and K_{ep} derived from T1 maps by the two techniques.

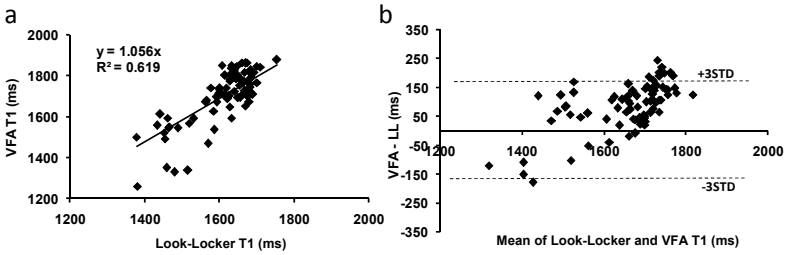

Figure 3. (a) VFA and Look-Locker T1 demonstrated a good correlation. (b) Bland-Altman plot indicates VFA overestimated higher T1s but underestimated lower T1s.

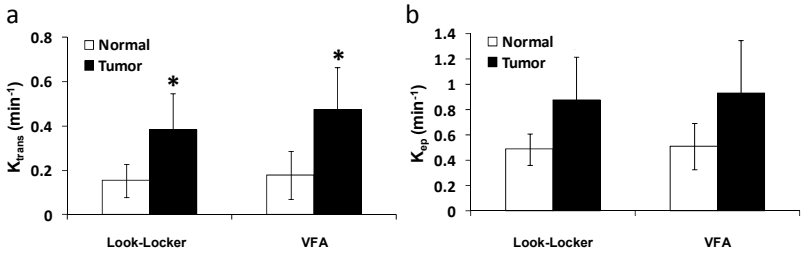

Figure 4. K_{trans} and K_{ep} based on T1 maps from both Look-Locker and VFA approaches were elevated in tumor areas (*p < 0.05).

CONCLUSION

Despite larger variations and lower SNR, VFA T1 mapping demonstrated a good correlation with the Look-Locker technique for prostate T1. Pharmacokinetic parameters derived from T1 maps by the two techniques demonstrated similar performance in differentiation of tumor tissues. Our results suggest that with flip angle correction and slice oversampling to suppress inflow, the VFA approach can generate satisfactory T1 maps for DCE MRI in patients undergoing MRI for prostate cancer.

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