

Asymmetry of Obturator Muscle Perfusion during Prostate MRI: Implications for the Reliability of Pharmacokinetic Analysis

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Introduction

In quantitative analysis of T₁-weighted (T1W) dynamic contrast-enhanced MRI (DCE-MRI) obtained during prostate MRI, accurate measurement of an arterial input function (AIF) from femoral arteries can be compromised by blood inflow effects, contrast uptake delays and B₁ field inhomogeneities, resulting in unreliable pharmacokinetic information. Recently, a reference region/tissue model^{1,2} (RRM) has been proposed, in which an AIF-substitute is derived from reference tissues with known kinetic parameters. This new approach is very attractive as it has the potential to derive a reliable “AIF” from obturator internus (OI) muscle which lies close to the prostate, and is free from above-mentioned artifacts; however, the pharmacokinetic characteristics of enhancement within these muscles is not available in the setting of prostate cancer. In this study, we have measured the kinetic parameters of the obturator muscles for 12 patients and found intra- and inter-subject variations in their pharmacokinetics.

Methods & Materials

All measurements were performed on a 3T Philips MRI scanner (Philips Healthcare, Best, NL) with combined a SENSE cardiac coil and an endorectal coil (Medrad, Indianola, PA). Pre-contrast T₁ mapping was based on a 3D T1W fast field echo (FFE) dual-flip-angle (5° and 15°) method. The relevant parameters in the protocol were TR/TE of 8.8/2.0 ms, FOV of 262, 262 and 60 mm and corresponding digital resolution of 1.02*1.02*6 mm³, and the number of scan averages was 10 and 2 for two flip angles while the latter was collected in dynamic mode with 100 dynamic scans. All patients had transrectal ultrasound (TRUS) guided biopsy-proven prostate cancer with the Gleason score (GS) ranging from 6 to 9. The biopsy samples taken from different locations (right/left apex/mid/base) within the prostate were also characterized using the percentage of cancer (%PC) within the needle biopsy core. A standard two-compartment pharmacokinetic model was used in the calculation of volume transfer constant (K^{trans}) for contrast agents and extravascular-extracellular space (V_e). Arterial input function was measured in the left femoral arteries at several levels. An efficient matrix-based computation method³ was implemented using in-house software based on IDL6.4 (ITT Visual Information Solutions, Boulder, CO). Within the selected slice, the pixel values (mean +/- std) of K^{trans} and V_e within region of interests (ROI) from left and right obturator muscles were calculated for 12 patients; also calculated was the prostate malignancy index (MI), defined as the product of GS and %PC.

Results & Discussion

Figure 1 shows an example of region of interests in both OI muscles indicated by yellow arrows. The mean and standard deviation of K^{trans} and V_e within right and left ROIs among all subjects were 0.069 +/- 0.044 (1/min), 0.103 +/- 0.031 (data not shown), respectively. The heterogeneous contrast uptakes among subjects are demonstrated especially by K^{trans} with its coefficient of variation (CV) as large as 64% (see Figure 2). The K^{trans} variations might have been compounded with an inaccurate AIF even though the blood inflow effects and B1 field inhomogeneities were minimized. To remove the systematic errors, we focused on K^{trans} measured from the contralateral OI muscle regions (right and left, see Figure 1) within an individual and correlated them with the available biopsy results. Figure 2 shows the discrepancies between K^{trans} (R) and K^{trans} (L) for most subjects, especially for subject 5, 7, 8 and 11; these differences are most likely due to the intrinsic pathophysiological conditions in the muscles in the presence of nearby tumor. For comparison, the prostate malignancy index (MI) derived from TRUS guided biopsies are shown in Figure 3 for the corresponding locations where K^{trans} were calculated; and most subjects had different “compounded grade” lesions found on either side except for subject 4 and 10. An interesting relationship was established between the difference of MI and the difference of K^{trans} from two contralateral sides; this correlation, shown in Figure 4, strongly demonstrates that the pharmacokinetics of OI muscles is affected by prostate malignancy, where high grade tumors in prostate likely reduce the perfusion of nearby obturator muscles. This finding is also aligned with the published kinetic parameters for normal subjects⁴ (K^{trans} of 0.156 +/- 0.095 (1/min); 0.245 +/- 0.206 (1/min) and V_e of 0.113 +/- 0.021; 0.125 +/- 0.027 in left and right OI muscles, respectively) and subjects with benign prostatic hyperplasia⁵ (K^{trans} of 0.045 +/- 0.025 (1/min) and V_e of 0.13 +/- 0.04). In summary, we have shown that both inter- and intra-subject contrast uptake variations were found in obturator muscles; therefore, these muscles should not be taken as reliable references for quantitative analysis of prostate DCE-MRI data.

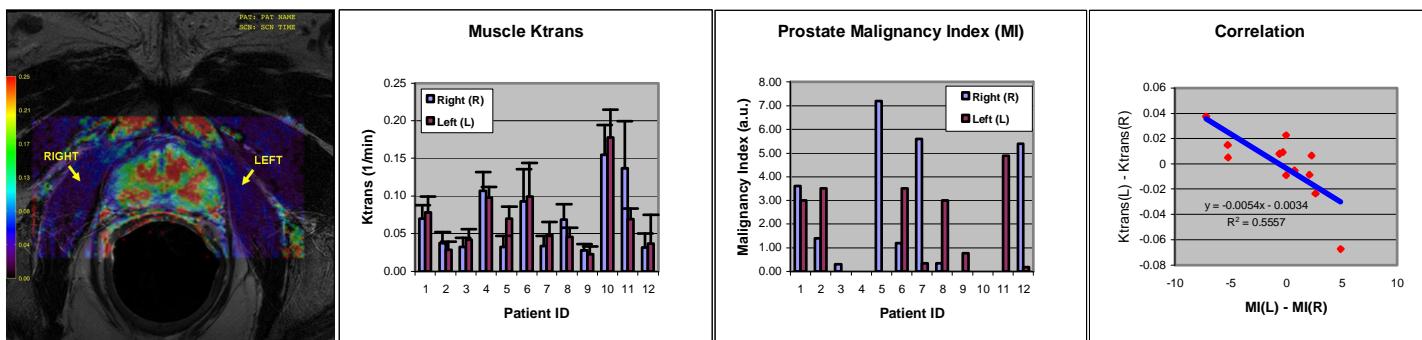


Figure 1 (left): K^{trans} map overlaid with T2W image; Figure 2 (mid left): Comparison of K^{trans} within intra and inter-subject; Figure 3 (mid right): Comparison of malignancy index (MI) taken from right and left side of prostate (apex or mid) among 12 subjects; and Figure 4 (right): Correlation between the difference of MI and the difference of K^{trans} between right and left muscles, showing reverse intra-subject relationship between MI and K^{trans}.

References

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