

High Spatio-temporal Resolution Dynamic Contrast Enhanced MRI of the Prostate Utilizing Differential Subsampling with Cartesian Ordering (DISCO)

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Introduction: Dynamic contrast enhanced (DCE) MR imaging is a critical component of multiparametric evaluation of the prostate, which in combination with T2 weighted imaging and diffusion imaging demonstrates excellent sensitivity and specificity for detection, localization, and even characterization of intermediate and high grade prostate cancer [1]. There is a common tradeoff between spatial resolution and temporal resolution in DCE-MRI sequences, with each having its merits. The evolving literature on the value of pharmacokinetic modeling in the evaluation of the prostate is very promising [2], particularly in the developing clinical application of monitoring response to therapy and detection of recurrence after non-surgical treatment [3]. Perfusion analysis and generation of semi-quantitative and quantitative parametric maps (*Ktrans*, *Kep*, *Ve*, *iAUGC*, among others) is dependent on high temporal resolution DCE-MRI. We investigated the performance of a new differential subsampling with Cartesian ordering (DISCO) sequence, a variable density pseudo-random k-space segmentation scheme with view sharing, which is capable of very high temporal resolution but also has excellent spatial resolution [4] for diagnosis of prostate cancer.

Methods: A T1-weighted 3D SPGR sequence utilizing DISCO was obtained on 3T Discovery MR750 and Optima MR750w (GE Healthcare, Waukesha, WI) with the parameters including: 12° flip angle; +/-62.5 kHz bandwidth; TR/TE=5.7ms/2.2ms; 256x192 matrix; 38 3mm thick slices; 1NEX, FOV of 20-22 cm with no phase wrap; ARC acceleration 2.5x1.5; acquisition time of 6.5 sec per phase; 55 multi-phases. A pelvic phased-array coil or GEM coil was used for dynamic imaging (endorectal coil only used for anatomic imaging). IV injection of gadodiamide (Omniscan, 0.08 mmol/kg) at 2 mL/sec initiated 20 sec after starting DISCO sequence.

Experiment 1: To demonstrate improved quality of parametric (*Ktrans*, *Kep*), color map images generated from the high temporal resolution sequence (6.5 sec/phase) were compared with those obtained from a simulated lower temporal resolution sequence (by averaging two phases; 13 sec/phase). Post processing was performed utilizing the GenIQ software (AW v4.6 GE Healthcare).

Experiment 2: DISCO DCE images were retrospectively reviewed in 31 consecutive patients who subsequently underwent radical prostatectomy. Two blinded reviewers (an experienced and an inexperienced reader) independently evaluated three separate image sets in terms of 1) diagnosis of prostate carcinoma utilizing ESUR grading scale [ranging from 1=clinically significant disease is highly unlikely to be present, to 5=clinically significant cancer is highly likely to be present] and 2) sextant location of the epicenter of the dominant lesion. The three image sets included 1) precontrast and subtraction DCE images at phase 8, 16 and 53 only, 2) precontrast and full DCE sequence images, and 3) the addition of postprocessed parametric color map images including *Ktrans*, *Kep*, *Ve*, *iAUGC*, and Primary. Images were reviewed on DynaCAD 3.0 (InVivo, Gainesville, FL) at each of the three separate image interpretation sessions.

Results: Experiment 1 demonstrates that higher temporal resolution data subjectively results in more robust pharmacokinetic modeling and resulting color maps (Figure 1), even when the slower temporal resolution comparison was still within the recommended ESUR guidelines. There is a trend toward correlation with tumor grade and quantitative perfusion parameters (Figure 2), but no relationships reached statistical significance. In Experiment 2, reader performance improved relative to reading session, from an average ESUR score of 3.52 and 4.08 for the inexperienced and experienced readers in Session 1 up to 4.35 and 4.60 respectively in Session 3 with the full DCE data set and color maps for review (Figure 3). Of the 5 cases that both readers failed to correctly identify, all were Gleason 7 tumors (four were 3+4). In 2 of those cases, readers did correctly identify a tumor but it was not considered the dominant lesion by pathology.

Conclusions: The very high temporal resolution of the DCE DISCO sequence allows more robust pharmacokinetic modeling, while maintaining the excellent spatial resolution, even without an endorectal coil, can help to clearly define pathology. One useful initial application of this combined high spatio-temporal resolution is where T2 weighted imaging is limited for anatomic definition, such as post-treatment monitoring (Figure 4) or evaluation for tumor recurrence.

References: [1]. Hegde et al. JMIR 37(5):1035-54. [2] Vos et al. Eur Urol 64(3):448-55. [3] Barrett et al. MRM 67(3):778-85. [4] Saranathan et al. JMRM 35:1484-92.

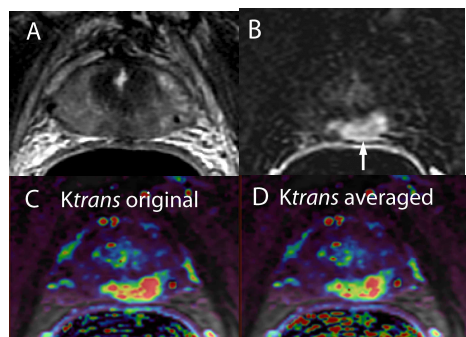


Figure 1. 85-year-old man with a history of Gleason 8 prostate cancer treated with primary external radiation therapy 9 years earlier now presented with PSA recurrence to 3.4 ng/mL. (A) T2 imaging is limited due to radiation changes. (B) Corresponding subtracted DCE DISCO image obtained at phase 8 sharply defines a hyper-enhancing intraprostatic lesion (arrow). (C) The lesion is more conspicuous on the corresponding *Ktrans* color map obtained from the high temporal resolution sequence (6.5 sec/phase) when compared with the simulated lower temporal resolution (13 sec/phase) sequence color maps (D). Subsequent targeted biopsy confirmed recurrent Gleason 4+5 tumor.

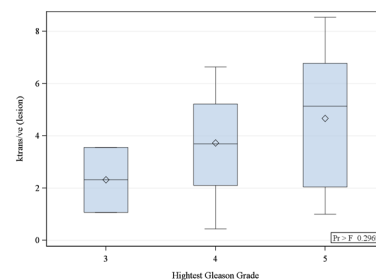


Figure 2. Relationship between the ratio of *Ktrans*/*Ve* and highest Gleason Grade tumor.

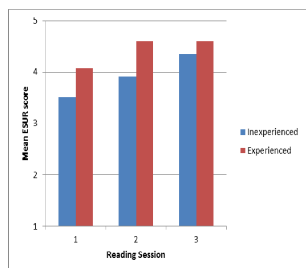


Figure 3. Average ESUR score [1-5 rating] for the inexperienced and experienced readers over the 3 separate reading sessions, for cancers correctly diagnosed compared to final pathology. Performance was highest (score 4.35 and 4.6 out of 5 respectively) for Session 3 with full pharmacokinetic analysis and color overlap maps.

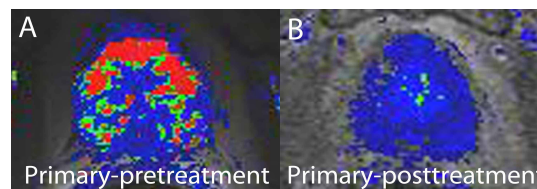


Figure 4. 60-year-old man with extensive Gleason 9 cancer. Primary pharmacokinetic map (DynaCAD) before (A) and response (B) after androgen deprivation therapy, with DISCO.