MULTIPARAMETRIC MRI (MpMRI) FOR PROSATE CANCER

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Key Learning Points:

1) Currently the most valuable and practical MpMRI protocol consists of T2WI, DWI and DCE.
2) Significant and additive improvement in the predictive values for prostate cancer detection, especially in the PZ, is achievable when combinations of the imaging strategies are combined.
3) Information from MpMRI can be used to direct and increase the yield from prostate biopsies.
4) Insights into the aggressiveness of a given prostate lesion can be obtained with one or several quantitative MRI parameters (ADC, in particular); such characterization may facilitate the selection of patients for enrollment and maintenance on active surveillance protocols.

Introduction

Prostate cancer presents a substantial challenge to the clinical practice for several reasons: 1) it is common (~240,000 new cases/yr); 2) the morbidity and prognosis from individual's cancers are difficult to predict; 3) treatment morbidities for inconsequential prostate cancers can be substantial; 4) standard clinical assessments (PSA, digital rectal examination and pathology Gleason score) have known and significant limitations.

Magnetic resonance (MR) imaging offers an alternative assessment that has shown continuous improvement for the detection of clinically significant prostate cancer, for staging of prostate cancer, for improved positive yields from TRUS-guided biopsies and for optimizing patient management.
The MR techniques that have emerged over time are largely complementary to one another and need to be understood in terms of their relative value and the acquisition strategies that offer maximum benefit to patients. The combined approach of multiple acquisition strategies is referred as multiparametric MRI.

T2-weighted imaging (T2WI)

Imaging of the prostate with magnetic resonance (MR) began in the mid-1980s and relied upon T2-weighted imaging to demonstrate anatomy and pathology that had not been previously visualized with imaging. These are most commonly accompanied by T1-weighted imaging to improve the specificity for cancer and avoid confusion with post-biopsy changes (presumed to be hemorrhage). T2WI effectively delineates the peripheral zone as relatively high signal intensity, where ~ 70% of cancers are discovered at pathology. Prostate cancer is seen on T2WI as having relatively low signal intensity when detected in the PZ, although such findings are not specific. The inherent high signal of fluid on T2WIs favors the detection of signal abnormalities in the fluid

filled seminal vesicles and has benefited the detection of cancer spread to these structures.

Because the T2-weighted approach excels in demonstrating anatomic detail, it is optimized by using high spatial resolution protocols. This, in turn, has been incrementally enabled through SNR improvements (endorectal coils, phased array coils, 3T instruments and various combinations) and faster imaging techniques (echo-train SE sequences and parallel imaging).

High-resolution T2W images are used for prostate cancer detection, localization, and staging.

MR spectroscopy (MRS)

The goal of MRS is to supplement the anatomic information available from T2WI with tissue signatures in an effort to improve diagnostic specificity. MRS has evolved from single voxel samplings with the water-suppressed, stimulated echo acquisition mode (STEAM) sequences or point-resolved echo spectroscopy (PRESS) sequences to 3D spectroscopic acquisitions using a water-suppressed PRESS box so that the acquired signal emanates from the gland. Since the metabolites of interest in MRSI are in far less abundance than the solvent water molecules, water suppression pulses must be applied which contributes to the long scan times characteristic of these acquisition.

In MRS, increases in Cho can be appreciated in comparison with the citrate signal along with the corresponding quantitative measure of the (Cho + Cr)/Cit ratio. This measurement can be limited in the setting of chronic prostatitis. As an inherently low spatial resolution technique with substantial technical demands and variability in execution, the promise of MRS has never been realized in broad clinical practice; it is perhaps best considered a research tool.

Dynamic Contrast Enhanced (DCE) Imaging

The emergence of DCE imaging has been supported by computerized analyses that are abundantly available for commercial purchase. Controversies surrounding DCE MRI for prostate cancer include whether to use a quantitative, semi-quantitative or qualitative assessment, the specific acquisition protocol to be applied, whether to use an arterial input function, and a lack of validation for derived quantitative parameters.

Pharmacokinetic modeling of dynamic tissue Gd concentrations are generally based on two-compartment assumptions and considerations focusing on the plasma compartment of the vasculature and the interstitial compartment between prostate cells, into and out of which the contrast agent can leak.

DCE imaging has allowed for incremental improvements in detection and prostate cancer staging. There is recent interest in its potential to demonstrate tumor heterogeneity.

Diffusion weighted imaging (DWI)

The emergence of DWI into prostate cancer evaluations has been one of the most important contributions to diagnosis and evaluation. Given the ease with which the study is performed and the ability to employ widely available vendor-supplied

software for analyses, meaningful qualitative and quantitative assessments are readily achievable. It is generally accepted that a long b value of at least 800 s/mm^2 should be employed in a contemporary protocol, while recent data suggest that even longer b values provide additional diagnostic value. Challenges for standardization include the lack of a uniform acquisition strategy (sequence nuances, b values employed, averaging strategies) and the lack of post-processing harmonization across vendors and institutions.

DWI and accompanying ADC values have been useful in improving prostate cancer detection and characterization. ADC values have been shown to inversely correlate with Gleason score.

Conclusions

Current MpMRI relies on combining the data generated from at least 3 of these acquisition strategies, and most commonly consists of T2WI, DCE imaging, and DWI. How these data are weighted when generating a final diagnosis or management directives remains undefined and represents an important opportunity for standardization towards uniform practice.

References:

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Table 1: General guidelines for acquisition parameters

	Slice Thickness		**In- plane spatial resolution**		**Comments**
Technique	1.5T	3.0T	1.5T	3.0T	
T2WI	4mm	≤3mm	0.7 x 0.7mm	0.5 x 0.5mm	
Kinetic DCE	4mm	4mm	1.0 x 1.0mm	0.7 x 0.7 mm	Temporal res ≤ 10s
DWI	5mm	4mm	2.0 x 2.0mm	1.5 x 1.5mm	b values: 0,100, 800

Table 2: High Spatial Resolution 3T Imaging Parameters					
Sequence	**T1w (SE or FSE)**	**T2w FSE**	**T2w FSE**	**DWI+**	**High Spatial Resolution 3D GRE**
Imaging plane	Axial	Axial	Coronal	Axial	Axial
Coils	TPA and ERC	TPA and ERC	TPA and ERC	TPA and ERC	TPA and ERC
Anatomic coverage	Aortic bifurcation to pubic symphysis	Prostate and seminal vesicles	Prostate and seminal vesicles	Prostate and seminal vesicles	Prostate and seminal vesicles
TE (msec)	12	165	165	80	2.1
TR (msec)	600 -700	6375	7600	7000	7.1
Excitation Flip angle	90o	90o	90o	90o	18 o
Slice thickness/spacing (mm)	5.0/1	1.5 -3.0/0	2/0	3/0.3	2-3.0mm/0; larger sections used for larger glands
FOV	28-22 cm	12 cm	14 cm	16 x 18 cm	12 cm
Matrix*	256 x 192	320 x 224 -192	320 x 224-192	140 x 128	256 x 224
NEX	2	4	4	(see b values)	2
Echo train length	NA or 3	22	22	Single shot	NA
Acquisition time	5 min	5 -7 min	5-6 min	4 min	1 min, 32 sec each x 7 ~ 11min total
Frequency direction	Transverse	AP	AP or SI	AP	AP
b values				0, 50, 1000 (2 NEX), 2000 (5 NEX)	
Receiver bandwidth	50 kHz	31.25 kHz	31.25 kHz	90 kHz	20.83 kHz

+ Uses SPAIR for fat suppression

* frequency x phase