MRI and MRSI of Prostate Cancer

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Disclosures

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Introduction

- The most commonly diagnosed visceral cancer
- The second most common cause of cancer death in American men
- Up to 15-30% of men over age 50: Indolent

Normal Anatomy

- Histology: glandular + non-glandular
- Model by McNeal: 4 zones
 Peripheral zone (PZ; 70-80%)
 - Central zone (CZ; 20%)
 - Transitional zone (TZ; 5%)
 - Anterior fibromuscular stroma (AFS)



Prostate Cancer

- Site : PZ 70%, TZ 20%, CZ 10%
- Histopathology 95% - Adenocarcinoma - acini of prostate duct
 - 5% small-cell carcinoma: most common mucinous adenocarcinoma squamous carcinoma sarcomatoid carcinoma TCC adenoid basal cell tumors malignant mesenchymal tumors etc.

Diagnosis of Prostate Carcinoma

- Digital rectal examination (DRE)
- PSA: <4ng/ml
- Trans-rectal ultrasound (TRUS): "Gleason score"

Clinical challenges in detection

- PSA
 - 70-80% of patients with PSA >4ng/ml DO NOT have prostate carcinoma
 - Normal PSA (<4ng/ml) in nearly 20% of biopsy proven prostate carcinoma
- DRE
 - Underestimate local extent up to 40-60%

Cancer Imaging 1;44,2000 Urol Clin North Am 24:299,1997













4





T Primary tumor

T1 Clinically inapparent tumor, not palpable, not visible on TRUS

T2 Clinically localized within the prostate

T3 Clinically locally invasive beyond the capsule

T3a Extracapsular extension T3b Tumor invades the SV

T4 Clinically locally invasive involving the adjacent organs (e.g. rectum, bladder, levator ani)







Treatment planning – Rad Onc



Treatment planning

Simulated IMRT planning with a boost





Challenges in Image interpretation



- Post-biopsy change
- Post-biopsy hemorrhage
- Prostatitis
- Hormone
- Radiation
- Atrophy
- etc.

Multiparametric MRI					
	Image	Technique	Pros	Cons	
eMRI	Anatomy	High resolution (e.g. 3mm) T1, T2	Universal Consistent	Limited sensitivity (SE), specificity (SP)	
DWI	Diffusion Cell density Cell membrane	ADC map	Short scan time	Limited SE and SP	
DCE-MRI	Perfusion Angiogenesis	Degree , Rate of enhancement	Specific in the setting of RP or post treatment	Variable techniques Limited SE and SP	
'H-MRSI	Prostate Metabolism	Cho, Po, Cr, Ci	Specific to the prostate cancer	Technically challenging	

eMRI – endorectal MRI, DWI – diffusion-weighted imaging, DCE – dynamic contrast enhanced, MRSI – magnetic resonance spectroscopic imaging, ADC – apparent diffusion efficiency, Cho – choline, Po – polyamine, Cr – creatine, Ci - citrate

MR Spectroscopy

- A technique to provide metabolic or biochemical information of tissue
- ¹H, ³¹P, ¹³C, ¹⁹F, ²³Na, ⁷Li, ³⁹K, ¹⁵N, ¹⁷O

Evolution of technology

Endorectal coil

m-t

Software, hardware

MRSI

Normal prostate

- Citrate: (substantially high)

 Essential end-product of epithelial cells
 24-130 mM = x 240-1300 of blood level
- Choline:

 - Essential nutrient for cell membrane synthesis
 Compounds involving the phospholipid synthesis and hydrolysis (e.g. choline, phosphocholine)
- Polyamine:

 Highly concentrated in epithelial cells
 Regulate epithelial cell proliferation, differentiation, and growth of epithelial cells

*No significant change in peripheral zone citrate and choline levels with age

Prostate ¹H-MR Spectroscopy



Prostate carcinoma

- Citrate: 👢
 - Change in epithelial cellular function and structure
 - Transformation of epithelial cells to citrate-oxidizing cells that may be essential in process of malignancy and metastasis
- Choline: 1
 - Inc. rate of cell proliferation
 - Inc. cell density
 - Change in cell membrane composition
- Polyamine:
 - Overexpression of ornithine decarboxylase, a polyamine biosynthesis enzyme









Interpretation of MRSI

• Primary score based on Ch+Cr/Ci ratio:

SDs from Normal	0-1	1-2	2-3	3-4	4+	
Score	1	2	3	4	5	
 Initial adjustment: Ch:Cr > 2:1 - 2 or 3 to 4 Ch:Cr < 2:1 or normal polyamines - 4 to 3, 5 to 4 						
 Final adjustment: – SNR < 8: 4 to 3, 5 to 4 						
				ι	JCSF	



Technical considerations for highquality prostate MRSI

- Technical overview of prostate MRSI
- Patient selection, preparation, and setup
- Prescribing prostate MRSI
- Automatic and manual prescan tuning
- Patient communication and cooperation

Basic building blocks of MRSI



- PRESS-CSI
- Outer volume signal suppression
- CHESS for water suppression



- Slice selective excitation and refocussing RF pulses in orthogonal directions → define inner volume
- CSI: phase encode each step in all directions → long acquisition time
- Dual-band spectral spatial refocusing pulses or BASING
 pulse used for water and lipid suppression

Outer volume signal suppression

- <u>Very selective spatial saturation</u> (VSS) RF pulses
 2ms 11kHz or 7kHz
- 6-12 repetitively applied pulses to help conform to a volume of interest (VOI)
- Progressive flip angles
 - B1 homogeneity
 - TG accuracy

CHESS for water suppression

- Repetitively applied to knock down water signal
 - Based on the same principle as FatSat pulses (excitation + spoiling)
 - Subject to the same pitfalls when Bo and B1 are inhomogeneous or inaccurate
 - Small residual water signal is used as reference

Patient selection

- Post biopsy
 Wait 4-6 weeks for blood clots to resolve
- Patients with brachytherapy seeds
- Patients with hip or other metal implants

IM/

Patient preparation and Setup

• Nurse and technologist's experience in placing endorectal coil



Prescribing prostate MRSI

• Recognizing anatomy in all three planes



Prescribing prostate MRSI



Automatic and Manual prescan

- After auto prescan (APS), look for:
 - FWHM (<15Hz at 1.5T)
 - Water suppression (>98%)
 - TG (with scanner limit)
- Repeat APS or Adjust graphic prescription and repeat APS
- Manual spectro prescan

 - Bo shimming
 TG may need adjust at 3T



Patient communication

Communicate to the patient that the next scan is about 15 minutes, and it is very important that he breathes nice and easy and try not to move during the scan.

JMA



Clinical Applications of MRSI

• Detection

- Staging
- Surveillance



• Tumor behavior



Post biopsy hemorrhage







Detection Accuracy

	Μ	IRI		MRL
	Reader 1	Reader 2	MRSI	MRSI
Sensitivity (%)	77	81	63	95
Specificity (%)	61	46	75	91

UCSF, Radiol 1999; 213:473-480



Detection: T2 vs. DCE, MRSI

Surveillance



T2a, G6, PSA 4.2 6-year post EBR, PSA 2.1

G8, G9, extensively on the right

Surveillance

H+EBR 10/03 T1c, G7, PSA 4.6 ng/ml → PSA 0.9 ng/ml





Bx 3/28/06 Rt. Ant horn \rightarrow G8

Monitoring: Hormone Treatment

(Cho+Cr)/Ci	Ci, detectable (Cho+Cr)	Metabolic atrophy
100%	0%	0%
94%	6%	0%
61%	33%	6%
31%	44%	25%
	(Cho+Cr)/Ci 100% 94% 61% 31%	(Cho+Cr)/Ci Ci, detectable (Cho+Cr) 100% 0% 94% 6% 61% 33% 31% 44%



Monitoring: Hormone Treatment

- Follow-up MRSI within 4 months following hormone deprivation therapy
- Similar accuracy in localizing prostate cancer using combined MRI/3D-MRSI

	М	RI		MRI+	
	Reader 1	Reader 2	MRSI	MRSI	
Sensitivity (%)	91	75	56	92	
Specificity (%)	48	60	80	92	

Radiol 2001, 221:380-390

Aggressiveness of tumors

• Tumor volume: MRSI

- > 4 voxels: 80% risk for extracapsular disease

- Radiology 1999, 213; 481-488
- Tumor metabolism: MRSI
 - Citrate
 - Choline









Significance of Ch+Cr/Ci ratio





Challenges in MRS Imaging

- Tumor detection sensitivity
 - Patient factors
 - Technical factors
 Spatial resolution
 Spectral resolution
 Field inhomogeneity
- Scan time

Perfluorocarbon (PFC) compound

- PFCs = (carbons + fluorine atoms) without hydrogen atoms.
- Physical Characteristics
 - Magnetic susceptibility matches with that of human tissue.
 - No signal on MRI
 - Chemically inert
 - Immiscible with water
 - Low surface tension, high specific gravity
 - Tasteless, odorless, virtually non-toxic



Linewidth with Air vs. PFC





To be further explored

- Spectral resolution
- Spatial resolution
- Scan time
- Use of endorectal coil

Summery

- MRSI evaluates the metabolic status, specifically Cho, Po, Cr, and Ci of prostate tissue at the cellular level.
- MRS improves the specificity in tumor detection but with limited sensitivity.
- Limited sensitivity are related to patient and technical factors.
- Technical challenges remain to be further improved.

Thank you.



Monitoring: Hormone Treatment

• Effect of hormone deprivation: MRI

- 42-224 days (mean 103 days)
- Results:
 - Detection accuracy: 74%
 - Staging accuracy: 68%
 - Overestimation of presence of tumor: 24%

AJR 1996, 166: 1157-1163





74Y, Hx of 3 negative biopsies, Rising PSA 13.8 ng/ml

Local Staging: MRSI

- Tumor volume = voxel count \propto ECD
- MRSI: strict criteria on MRI + voxel count

	MRI		MDC	MRSI	
	R 1	R 2	- MIKS	R 1	R 2
Sensitivity (%)	54	17	50	54	46
Specificity (%)	95	94	91	96	93

Radiol 1999; 213:481-488