CASE PRESENTATION AND MINI-REVIEW

MR Imaging of Prostate Cancer: Present Limitations and Future Directions

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Prostate: Function

largest accessory gland of male reproductive system

produces a thin, milky, slightly alkaline fluid that provides approximately 20% of the volume of semen

prostatic fluid aids in motility and fertility of sperm
Prostate: Relational Anatomy

from: http://www.types-of-incontinence.com

from: http://images.webmd.com
Prostate: Inherent Anatomy

two-thirds glandular, one-third fibromuscular

has a dense, fibrous capsule that is surrounded by a fibrous prostatic sheath, which is continuous with the puboprostatic ligaments

is divided by urologists and radiologists into zonal anatomy, although lobar anatomy is more commonly described.

Images from: http://medocs.ucdavis.edu
Prostate Cancer

190,000 new cases per year in the US

earlier identification may present an opportunity for more effective treatment, but...

huge range of biological malignancy

lack of accurate prognostics: current tools include DRE, serum PSA, histological grading (Gleason score), biopsy, staging schemata, and imaging techniques
Prostate Cancer

Grading:

performed at biopsy

the sum of dominant and secondary Gleason grade patterns

correlates loosely with clinical outcome

from: http://www.rmg.md
Prostate Cancer

Staging:

the TNM and the Whitmore-Jewett systems have been used widely

modified to incorporate results of imaging studies (US, MR)

many groups are now using multiplex staging models

the value to prognosis and treatment recommendations remains controversial.

<table>
<thead>
<tr>
<th>TNM</th>
<th>Whitmore-Jewett</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>A</td>
<td>Clinically inapparent tumor, not palpable, nor visible by imaging</td>
</tr>
<tr>
<td>T1a</td>
<td>A</td>
<td>Tumor incidental to histologic finding</td>
</tr>
<tr>
<td>T1b</td>
<td>A</td>
<td>&lt;5% of tissue resected</td>
</tr>
<tr>
<td>T1c</td>
<td>B</td>
<td>&gt;5% of tissue resected</td>
</tr>
<tr>
<td>A1</td>
<td>A</td>
<td>&lt;3 chips</td>
</tr>
<tr>
<td>A2</td>
<td>A</td>
<td>&gt;3 chips</td>
</tr>
<tr>
<td>T1c</td>
<td>B</td>
<td>Tumor identified by needle biopsy</td>
</tr>
<tr>
<td>T2</td>
<td>B</td>
<td>Tumor confined within the prostate*</td>
</tr>
<tr>
<td>T2a</td>
<td>B</td>
<td>Tumor involves half of a lobe or less</td>
</tr>
<tr>
<td>T2b</td>
<td>B</td>
<td>Palpable nodule &lt;2cm and confined to one lobe</td>
</tr>
<tr>
<td>T2c</td>
<td>B</td>
<td>Palpable nodule &gt;2cm and confined to one lobe</td>
</tr>
<tr>
<td>T2c</td>
<td>B</td>
<td>Tumor involves both lobes</td>
</tr>
<tr>
<td>T2c</td>
<td>B</td>
<td>Not both lobes</td>
</tr>
<tr>
<td>T3</td>
<td>C</td>
<td>Tumor involves both lobes</td>
</tr>
<tr>
<td>T3a</td>
<td>C</td>
<td>Tumor involves more than half of a lobe but not both lobes</td>
</tr>
<tr>
<td>T3b</td>
<td>C</td>
<td>Palpable nodule involves both lobes</td>
</tr>
<tr>
<td>T3c</td>
<td>C</td>
<td>Tumor involves both lobes</td>
</tr>
<tr>
<td>T4</td>
<td>C</td>
<td>Tumor extends through and beyond the prostatic capsule†</td>
</tr>
<tr>
<td>T4a</td>
<td>C</td>
<td>Unilateral extracapsular extension</td>
</tr>
<tr>
<td>T4b</td>
<td>C</td>
<td>Bilateral extracapsular extension</td>
</tr>
<tr>
<td>T4c</td>
<td>C</td>
<td>Tumor involves seminal vesicle(s)</td>
</tr>
<tr>
<td>T4d</td>
<td>C</td>
<td>&lt;6cm tumor beyond prostatic capsule</td>
</tr>
<tr>
<td>T4e</td>
<td>C</td>
<td>&gt;6cm tumor beyond prostatic capsule</td>
</tr>
</tbody>
</table>

* Tumor found in one or both lobes by needle biopsy but not palpable or visible by imaging is classified as T1c
† Invasion into the prostatic apex or into (but not beyond) the prostatic capsule is not classified as T3 but as T2.

The TNM classification serves both clinical and pathological staging. Although only DRE findings are taken into considerations in Whitmore-Jewett staging system DRE, PSA, and TRUS findings are also considered in TNM system.

Patient Presentation

49 y.o. Caucasian male in good health

PSA values at annual physical exam:

- Dec 2000: 2.1 μg/L
- Dec 2001: 2.3 μg/L
- July 2002: 1.8 μg/L
- July 2003: 5.4 μg/L

TRUS-guided biopsy in July 2003 revealed 1 of 12 cores positive at the left apex, and a Gleason Score of 3+3

now presents for staging evaluation
MRI in a 1.5T magnet was performed using endorectal and body coils. T1-weighted sequences in the axial plane, and T2-weighted sequences in the axial, coronal, and sagittal planes were acquired without Gadolinium contrast.
MRI Basics:

The MR scanner creates a magnetic field $B_0$

Hydrogen atoms in tissue, which themselves are small magnets (M), align themselves with the magnetic field and precess about it with frequency $\omega_0$, the Larmor frequency

from: Wolbarst AB. Physics of Radiology, 2nd ed. Fig 42-8.
MRI Basics (cont’d):

radiowaves from a transmission coil in the horizontal plane are pulsed with repetition time TR and cause nutation of the dipole.

from: Wolbarst AB. Physics of Radiology, 2nd ed. Fig 42.6.
nutation of (M) and subsequent relaxation induce voltage changes in a detection coil, which are recorded at echo time TE; these data produce the images:

T1: longitudinal relaxation time (z axis)

T2: transverse relaxation time (y axis)

from: Wolbarst AB. Physics of Radiology, 2nd ed. Fig 42-9.
MRI Basics (cont’d):

The data on which the images are based may be weighted toward either of the relaxation times (T1 or T2), by manipulating the repetition time (TR) and the echo time (TE)

Shorter TR and TE values produce data that depict T1-weighted images. Longer TR and TE values produce data that depict T2-weighted images.

Body tissues have characteristic signal strengths on T1 and T2-weighted images.
Patient Presentation

Technique

Endorectal coil:

intracavitary detection coil

permits 3-4 mm slices to be obtained at small fields of view, which therefore provides high spatial resolution and high signal-to-noise ratio

photos: courtesy R. Baroni
Patient Presentation

Images

T2-weighted axial
Patient Presentation

Images

T2-weighted axial

- bladder
- central zone
- peripheral zone
- endorectal coil

from: BIDMC Centricity
Patient Presentation

Images

T2-weighted axial

12x9 mm low signal focus

from: BIDMC Centricity
Patient Presentation

Images

T2-weighted axial

12x9 mm low signal focus

3x3 mm low signal focus

from: BIDMC Centricity
Patient Presentation

Images

T2-weighted axial

12x9 mm low signal focus

3x3 mm low signal focus

9x7 mm low signal focus

from: BIDMC Centricity
Patient Presentation

Images

T2-weighted axial

<table>
<thead>
<tr>
<th>Focus Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>12x9 mm</td>
<td>Low signal focus all also observed to be of low signal on T-1</td>
</tr>
<tr>
<td>3x3 mm</td>
<td>Weighted axial images</td>
</tr>
<tr>
<td>9x7 mm</td>
<td>None seemed to extend beyond the capsule</td>
</tr>
</tbody>
</table>

Regions of prostate cancer demonstrate decreased signal intensity relative to normal peripheral zone tissue due to increased cell density and loss of prostatic ducts.
Patient Presentation

Images

T2-weighted coronal

low-signal foci again seen

seminal vesicles normal

no evidence of lymphadenopathy
Patient Presentation

Impression:

1. “No MR evidence for extracapsular extension of prostate carcinoma.”

2. “Three potential areas of tumor. MR findings within the prostate gland are not specific for carcinoma and these areas are not diagnostic of neoplastic process.”

Question: Was this a useful study?
Limitations of MR

1. MR demonstrates only 81% accuracy in assessing macroscopic spread through the prostatic capsule, and is not sensitive to microscopic spread.


2. Hypointense lesions on T2-weighted imaging are not specific for the presence or spatial extent of prostate carcinoma. Other causes of T2 hypointensity include:

   a. hemorrhage
   b. chronic prostatitis
   c. benign prostatic hypertrophy
   d. intraglandular dysplasia
   e. trauma
   f. local therapy
Limitations of MR

given the findings, the staging of this patient’s disease could be anywhere from T2 - T3b.

Magnetic Resonance Spectroscopy Imaging

“Uses a strong magnetic field (3T) and radiowaves to non-invasively obtain metabolic information (spectra) based on the relative concentrations of endogenous metabolites in the cytosol of the cell and in extracellular spaces.”

Creates arrays of contiguous volumes (0.24-0.34 cc voxels) that can map entire organs and that can be directly overlaid on MRI images, since the data are acquired within the same exam (always at the end, adding 20 minutes).

Potential of MRSI in Prostate Cancer Imaging

Relative to surrounding peripheral zone tissue, prostate cancer cells:
1. produce more **choline** (involved in phospholipid synthesis)
2. produce less **citrate** and **polyamines** (synthesized by glandular tissue)
3. have similar levels of **creatinine**

Each of these metabolites has a unique spectral peak. The area under the curve at the peak is proportional to the concentration.

Potential of MRSI in Prostate Cancer Imaging

courtesy R. Baroni, MD, BIDMC
Potential of MRSI in Prostate Cancer Imaging
Potential of MRSI in Prostate Cancer Imaging

Spectroscopic data can be superimposed on the MRI as color, with higher intensity corresponding to a more cancer-like spectroscopic profile.

Potential of MRSI in Prostate Cancer Imaging

Benefits of MRI/MRSI correlation include:

1. improved staging by better prediction of extracapsular extension (Yu et al, *Radiology* 202:697-702, 1997)

2. improved intraglandular cancer localization: sensitivity and specificity as high as 94% and 98%, respectively (Scheidler et al, *Radiology* 213:473-80, 1999)

Potential of MRSI in Prostate Cancer Imaging

Clinical scenarios in which MRI/MRSI can be particularly helpful:

1. aids management decision of watchful waiting vs. more proactive therapy for patients with elevated PSA and positive biopsy
2. aids cancer detection in patients with elevated PSA but negative biopsies (due either to BPH, or tumor in locations that are difficult to biopsy)
3. provides more accurate assessment of post-therapy cancer recurrence, when PSA is a less accurate predictor

Potential of MRSI in Prostate Cancer Imaging

Currently, only a few academic centers world-wide have experience with this technology.

In the future:

- development of a commercially-available, clinically-tested software package
- identification of more prostate cancer-specific metabolite changes
References


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