MRI-TRUS Fusion Prostate Biopsy:
A Primer

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No Disclosures
Current standard of care for the diagnosis of suspected prostate cancer is transrectal ultrasound (TRUS) guided systematic biopsy.

No universal indications exist for TRUS guided prostate biopsy, and may depend on individualized risk assessment.

### EXAMPLE INDICATIONS

<table>
<thead>
<tr>
<th>Initial biopsy</th>
<th>Repeat after -ve initial biopsy</th>
<th>Repeat after +ve initial biopsy</th>
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<tbody>
<tr>
<td>• elevated PSA</td>
<td>• persistent suspicion (ex. rising PSA, emerging role of PCA3)</td>
<td>• atypical pathology (ASAP, HGPIN)</td>
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<td>• abnormality on DRE</td>
<td></td>
<td>• entry into active surveillance</td>
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<td></td>
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<td>• monitoring of AS patients</td>
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General technique for systematic TRUS biopsy

- Usually 10-12 x 18 gauge cores
- Standard sextant (apex, midgland, base) plus variable # of laterally directed cores depending on gland size
- +/- additional cores in suspicious areas

“Blind” biopsy technique, as ultrasound is not reliable for detecting PCa, i.e. essentially random samples obtained
However, known significant risk of sampling error with systematic biopsy.

- Frequently miss transition zone (20-30%), anterior and midline tumors
- False negative rate difficult to validate, but estimated 25-47%

Potentially misleading picture of tumor burden:
- not sampling most aggressive portion of tumor, underestimating Gleason grade
- detection of clinically insignificant cancers
- large volume of tissue missed with enlarged prostates
Increasing role of prostate mpMRI in tumor detection and localization

Combination of T2-weighted, diffusion-weighted/ADC mapping, and dynamic contrast enhanced images.

Currently most accurate technique for PCa detection and staging

Method of identifying and localizing suspicious lesions on imaging = ability to target biopsies using image guidance
MRI Guidance Method 1: MRI-guided cognitive biopsy

• Operator has knowledge of the suspicious area on MRI, directs TRUS biopsy to the corresponding area by visual estimation

• **PROS:** Fast, simple with minimal alteration to systematic technique

• **CONS:** Potential for error in visually extrapolating location, differences in orientation between axial MR slices and oblique ultrasound plane
MRI Guidance Method 2: Direct in-bore MRI biopsy

- Operator performs transrectal biopsy while patient in magnet
- **PROS:** Accurate – can visualize needle on MR image, exact localization
- **CONS:** ++ time consuming – re-imaging multiple times required, expensive, systematic usually not done - potential for false negatives
MRI Guidance Method 3: MRI-TRUS fusion biopsy

- MRI and ultrasound images digitally fused, operator targets lesion on TRUS with MRI overlay
MRI-TRUS Fusion Biopsy General Workflow

1. Radiologist interprets MRI, identifies targets
2. MRI data uploaded to fusion system, targets marked
3. Ultrasound data linked to fusion system for navigation
4. MRI and TRUS images fused +/- elastic registration
5. Targets are visualized on biopsy localization screen
6. Aim and fire
7. Post-biopsy images saved, sent to PACS
MRI-TRUS Fusion Biopsy General Workflow

Radiologist interprets MRI, identifies targets

MRI data uploaded to fusion system, targets marked

Ultrasound data linked to fusion system for navigation

Aim and fire

Targets are visualized on biopsy localization screen

MRI and TRUS images fused +/- elastic registration

Post-biopsy images saved, sent to PACS
Current strategies for tracking the 3D spatial location of the ultrasound transducer relative to the prostate and targets

1. Organ-based navigation (*Koelis, Artemis*)
   - Location of the prostate gland relative to the probe is determined by computer analysis of the ultrasound images +/- manual correction
   - Simple, however no real-time tracking (retrospective visualization)
Current strategies for tracking the 3D spatial location of the ultrasound transducer relative to the prostate and targets

2. GPS-like navigation (*Uronav, Hologic*)
   - Trackers are placed on the probe, +/- patient and location relative to a stationary “satellite” tracker arm determined (infrared, magnetic fields, angle sensors)
   - Requires manual calibration of ultrasound images, extra equipment, however able to follow in real-time
MRI-TRUS Fusion Biopsy General Workflow

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Elastic registration can account for deformity of the prostate when computing the spatial location of biopsy targets.

Deformation of the prostate gland can occur with:
- Distended bladder
- Endorectal coil during MRI
- Patient positioning (decubitus, supine)
- Endorectal ultrasound transducer
- Tissue distortion from biopsy needle, hemorrhage

Elastic registration uses the current prostate contour determined on TRUS images and corrects the MR data to match.

Potential to allow for more accurate targeting.
Elastic registration can correct for deformity of the prostate when computing the spatial location of biopsy targets

Costa et al. Radiographics May-June 2015
Other software and hardware options

Ultrasound transducer with biopsy guide mounted on an articulating robotic arm

- Reduces error due to operator motion after target registration
Other software and hardware options

“Virtual biopsy” (pre-fire image showing the projected trajectory of core)
  • Increases confidence of targeting

Post-biopsy disease mapping
  • Planning for repeat biopsy
  • Quality feedback

(koelis.com)
Several systems currently FDA approved

### Table 1

<table>
<thead>
<tr>
<th>Manufacturer/trade name</th>
<th>US image acquisition</th>
<th>Biopsy route</th>
<th>Tracking mechanism</th>
<th>Year of FDA approval</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>Philips/PercuNav</td>
<td>Manual US sweep from base to apex</td>
<td>Transrectal</td>
<td>External magnetic field generator</td>
<td>2005</td>
<td>Prospective targeting, integrated with existing ultrasound device, freehand manipulation</td>
</tr>
<tr>
<td>Eigen/Artemis</td>
<td>Manual rotation along fixed axis</td>
<td>Transrectal</td>
<td>Mechanical arm with encoders</td>
<td>2008</td>
<td>Prospective targeting, stabilized TRUS probe</td>
</tr>
<tr>
<td>Koelis/Urostation</td>
<td>Automatic US probe rotation, three different volumes elastically registered</td>
<td>Transrectal or transperineal</td>
<td>Real-time TRUS-TRUS registration</td>
<td>2010</td>
<td>Retrospective targeting, real-time elastic registration</td>
</tr>
<tr>
<td>Hitachi/Hi-RVS (real-time virtual sonography)</td>
<td>Real-time biplanar TRUS</td>
<td>Transrectal or transperineal</td>
<td>External magnetic field generator</td>
<td>2010</td>
<td>Prospective targeting, integrated with existing ultrasound device</td>
</tr>
<tr>
<td>BioJet/Jetsoft/GeoScan</td>
<td>Manual US sweep in sagittal</td>
<td>Transrectal or transperineal</td>
<td>Mechanical arm with encoders; uses stepper</td>
<td>2012</td>
<td>Prospective targeting, rigid registration</td>
</tr>
</tbody>
</table>

FDA, US Food and Drug Administration; US, ultrasound.  

Marks et al. Curr Opin Urol (Jan 2013)
Several systems currently FDA approved

- Artemis (Eigen)
- Uronav (Phillips)
- Urostation (Koelis)
Our experience at VGH

- Hologic system
- GPS-like navigation, real-time tracking, rigid fusion, freehand probe
- Targeting on real-time reconstructed MRI, ultrasound images used as backup check for localization (cognitive component)
- Patient in lithotomy position
- Routinely perform systematic after fusion
Our experience at VGH

343 Patients since 2012  
Increasing each year

In a cohort of 95 consecutive patients

Percentage of positive cores

Of positive cores how many showed significant PCa

When MRIs retrospectively reclassified with PIRADS v2, 77 lesions would not have been biopsied, potentially improving this to ~26%

Fusion vs Systematic

16.5% vs 10.5%

66% vs 53%

Most common indications

1. Rising PSA despite negative systematic biopsy
2. Suspicious lesion detected on active surveillance

Mean age of patients 65
Current applications of MRI guided prostate biopsy

**Patients with ongoing suspicion of cancer despite previous negative biopsy**

- Current literature suggest improved biopsy yield and efficiency; i.e. fewer cores required to detect clinically significant cancer
- Improved detection of clinically significant cancers (16-33% more than systematic), more tumor volume in cores (5.6mm vs 4.7mm), more efficient (% positive cores 21-36% fusion vs 5-12% systematic)
- False negatives – in part depends on targeting accuracy, MR study quality

**Determination of eligibility for active surveillance**

- One definition: Gleason 6, <= 2 positive cores, <50% of a core, PSA <10ng/ml
- Can target most high yield areas with fewer cores, more consistent risk stratification, potential alternative to saturation biopsy

**Suspected progression on active surveillance**

- Using MR to monitor progression
- Able to reproduce needle placement, site of suspected progression can be directly targeted

**Focal therapy candidates**
Several issues to consider with this technology...

EXTREMELY dependent on quality of MRI acquisition and interpretation
- Performance of fusion technique only as good as the MRI study that it draws the targeting data from
- Prostate MRI is still evolving
- Protocol optimization, radiologist education and standardization of reporting (i.e., PIRADS) is key
- Whole mount prostatectomy specimens as gold standard

Learning curve can be steep
- UI and workflow not always intuitive
- Requires good hand-eye coordination and spatial thinking ability
- May require significant extra time to re-review the MRI, pre-biopsy image contouring
Several issues to consider with this technology...

Not clear yet how cost effective this is
- Compatibility of existing ultrasound systems
- How much extra hardware to buy
- Sufficient impact on long-term patient outcomes?

Can we forgo the systematic biopsy?
- 101 patients who had both systematic and fusion bx, 10/55 cancers detected on systematic alone, 10/55 fusion alone, 35 with both (Pinto et al, 2015)
- Our experience in cohort of 88 cases, detection of sPCa: 15 systematic alone, 7 fusion alone, 49 with both

Who performs the biopsy?
- Radiology or Urology
Take-home messages

• MRI-TRUS fusion biopsy is a promising technique to improve diagnostic accuracy of PCa and active surveillance risk stratification/monitoring

• A variety of technologies are available, choice will depend on operator preference and evidence-based validation

• Highly dependent on quality MRI acquisition and interpretation – thus protocol optimization, education and standardization (ie. PIRADS) is paramount


Thank-you for listening!