Declaration of Relevant Financial Interests or Relationships

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I have no relevant financial interest or relationship to disclose with regard to the subject matter of this presentation.
Quantification of intra-procedural gland motion during transperineal MRI-guided prostate biopsy

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Prostate Cancer

• Estimated incidence at 230K in 2013 in US (ACS)
• Challenge: early accurate detection of the disease
• Standard of care: TRUS-guided systematic biopsy
  – ~50% of cancers are iso-echoic in TRUS
  – Up to 30% of cancers are missed by the initial biopsy
• MRI-targeted biopsy
  – Multi-parametric MRI (mpMRI) for target selection
  – Directed sampling of suspicious areas under MR or US guidance
  – Imaging for confirmation of needle location
MRI-guided transperineal biopsy at BWH

- MRI-guided targeted prostate biopsy program since 1997
- Biopsy planning:
  - T2w, ADC (b500, b1400), DCE (5 sec/frame), endorectal coil, GE SignaHDx 15.0 3T
  - Consensus targets based on mpMRI + pharmacokinetic maps multirater review
- Biopsy approach:
  - Wide bore 3T (Siemens Magnetom Verio)
  - Transperineal access, lithotomy position
  - Conscious sedation, no endorectal coil

More details: See abstract ID 1770 by Penzkofer et al. 4-6pm poster session TODAY

"Multiparametric MRI including pharmacokinetic maps for prostate cancer detection: value for multireader target identification prior to transperineal biopsy"

Motivation: Biopsy target tracking

- Biopsy planning
  - 1 hour scanner time
  - Weeks before the procedure

- Initial intra-procedural MRI
  - 5 minutes scan time
  - Beginning of the procedure

- Needle confirmation intra-procedural MRI
  - <1 minute scan time
  - Every 1-5 minutes
  - 1-2 hour long procedure

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Purpose

1. Evaluate the utility of image registration for tracking prostate gland position
2. Use image registration results to quantify prostate gland motion during biopsy procedure
Methods: Image registration

- Image-based registration
- Automated
- Rigid + Deformable

Key ideas:
- Limit similarity metric computation to prostate region
- Initialize close to solution
- Based on 3D Slicer BRAINSFit registration module

http://slicer.org
Methods: Registration evaluation

- **Qualitative:**
  - Visual inspection of the registration result to confirm *improvement* in image alignment

- **Quantitative:**
  - Improvement in the overlap for the prostate gland segmentation in the initial T2 and final needle confirmation T2
    - Dice similarity coefficient (DSC) = \( \frac{2 \times \text{spatial intersection}}{\text{union of segmentation masks}} \)

*Fig. 1 from Zou et al. Statistical validation of image segmentation quality based on a spatial overlap index. Academic radiology. 2004 February;11(2):178–89.*
Methods: Procedure/Imaging

- 40 MRI-guided prostate biopsy procedures
- T2w intra-procedural imaging
  - Multi-slice acquisition, full gland coverage
  - Initial intra-op scan: 3 x 0.4 x 0.4 mm, ~5 minutes
  - Needle confirmation scan: 3.6 x 0.9 x 0.9 mm, ~1 minute
- MR-compatible 18g biopsy needle was used for biopsy sample collection
Methods: Prostate motion quantification

- Registration applied retrospectively
- Registration transformation applied to track centroid location
- Motion relative to the initial position quantified
  - Axial in-plane (2d) and 3d motion
Results: Biopsy procedure summary

• Total of 538 needle confirmation scans collected during 40 cases:
  – Targets per case: median 4, range 2-11
  – Scans per case: median 13, range 2-26
  – Procedure time: median 89 min (27-172)

• Moderate correlation between number of scans/targets and procedure time ($r=0.63$ [0.4,0.8], $p<0.001$)
Results: Registration evaluation

Before registration

After registration

DSC before registration vs. DSC after registration
Results: In-plane prostate motion

- In-plane motion magnitude:
  - Mean 3.4 ± 2.4 mm
  - Range 0-16mm

- Up-down motion magnitude dominates (mean 2.7 vs 1.5 mm, p<0.001)

Max displacement (weakly) correlated with procedure time: r=0.34 [0.03,0.6], p=0.03
Results: In-plane prostate motion
Results: 3d prostate motion

- 3d motion magnitude:
  - Mean 8.7 ± 5.4 mm
  - Range 0-35mm

Max displacement (weakly) correlated with procedure time: $r=0.38 \ [0.07,0.6]$, $p=0.02$
Discussion

• Head-feet motion dominates
  – Explained by transperineal biopsy approach
• Weak correlation with procedure time
  – Push/pull by the biopsy needle
• High variability in prostate motion observed across patients
  – Needle deflection/insertion trajectory
  – Target location
Summary

- **Image registration:**
  - Effective in tracking prostate gland motion
  - Computation time promising for intra-procedural applications

- **In-plane motion (axial):**
  - >5mm (clinically significant disease): 19% of cases
  - >2mm (simulated accuracy for targeting tumor foci): 67% of cases

- **Out-of-plane motion (head-feet):**
  - >17mm (biopsy needle notch length): 6% of cases

Conclusions

• Motion during prostate biopsy can be significant to *potentially* lead to missed cancer targets

• Image registration is fast and robust to assist in tracking prostate motion