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"Discovery, Innovation & Application – Advancing MR for Improved Health"

Declaration of Relevant Financial Interests or Relationships

Speaker Name: Andriy Fedorov

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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- The content is solely responsibility of the authors and does not necessarily represent the official views of the US National Cancer Institute or the National Institutes of Health

Prostate Cancer

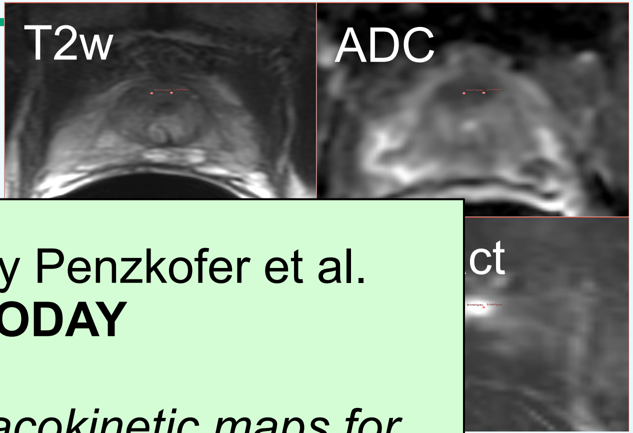
- Estimated incidence at 230K in 2013 in US (ACS)
- *Challenge: early accurate detection of the disease*
- Standard of care: TRUS-guided systematic biopsy
  - ~50% of cancers are iso-echoic in TRUS
  - Up to 30% of cancers are missed by the initial biopsy
- MRI-targeted biopsy
  - Multi-parametric MRI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

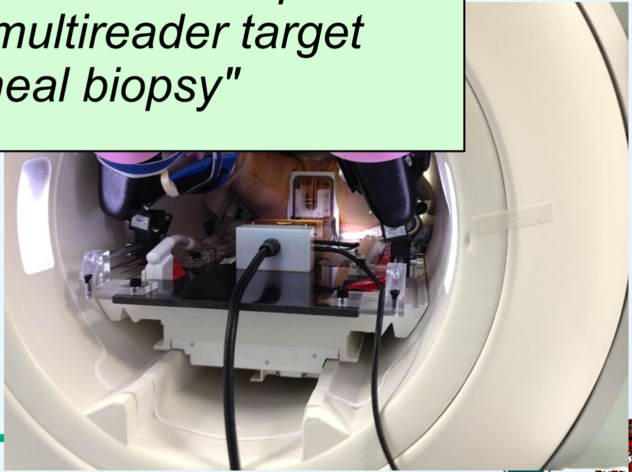
MRI-guided transperineal biopsy at BWH

- MRI-guided targeted prostate biopsy program since 1997
- Biopsy pla
  - T2w, A
    endore
  - Conse
    pharma
- Biopsy ap
  - 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"





Tokuda et al. 2012. In-bore setup and software for 3T MRI-guided transperineal prostate biopsy. Physics in medicine and biology. 57(18):5823–40.

Motivation: Biopsy target tracking

Biopsy planning

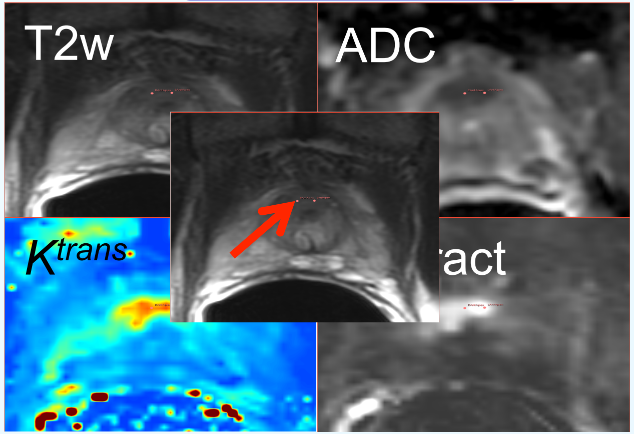
- 1 hour scanner time
- Weeks before the procedure

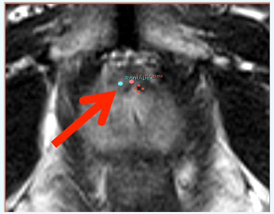
Initial intra-procedural MRI

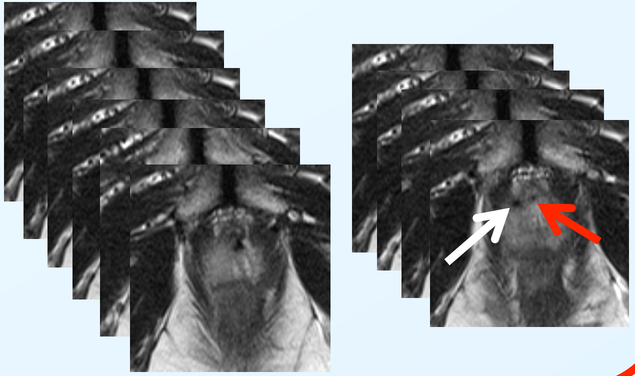
- 5 minutes scan time
- Beginning of the procedure

Needle confirmation intra-procedural MRI

- <1 minute scan time
- ***Every 1-5 minutes***
- ***1-2 hour long procedure***





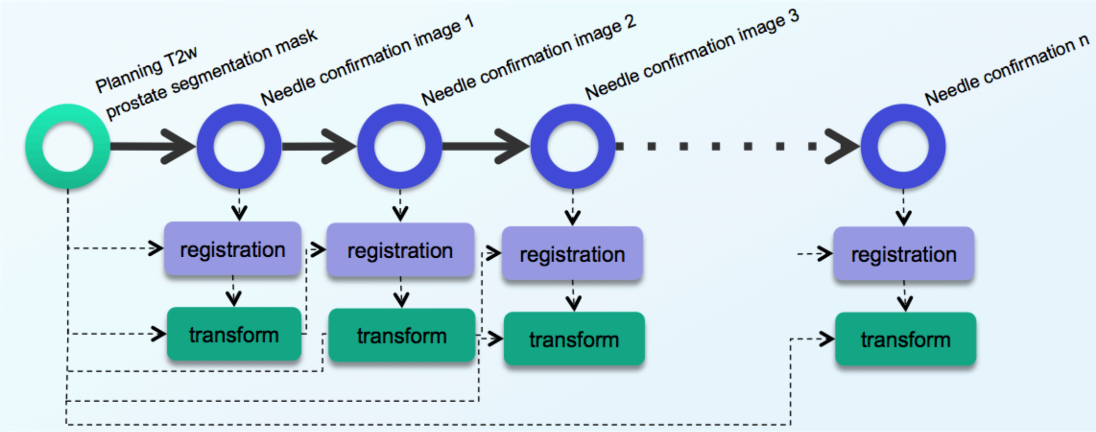


Fedorov et al. 2012. Image registration for targeted MRI-guided transperineal prostate biopsy. JMRI. 36(4):987–992.

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

3DSlicer

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) = (2*spatial intersection) / (union of segmentation masks)

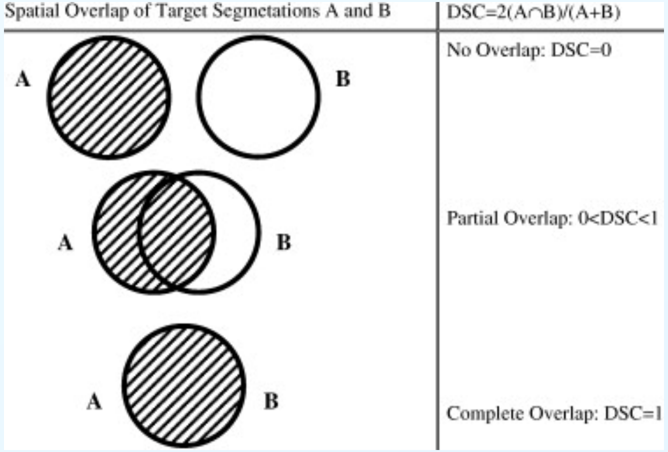


Fig.1 from Zou et al. Statistical validation of image segmentation quality based on a spatial overlap index. Academic radiology. 2004 February;11(2):178–89.

Methods: Procedure/Imaging

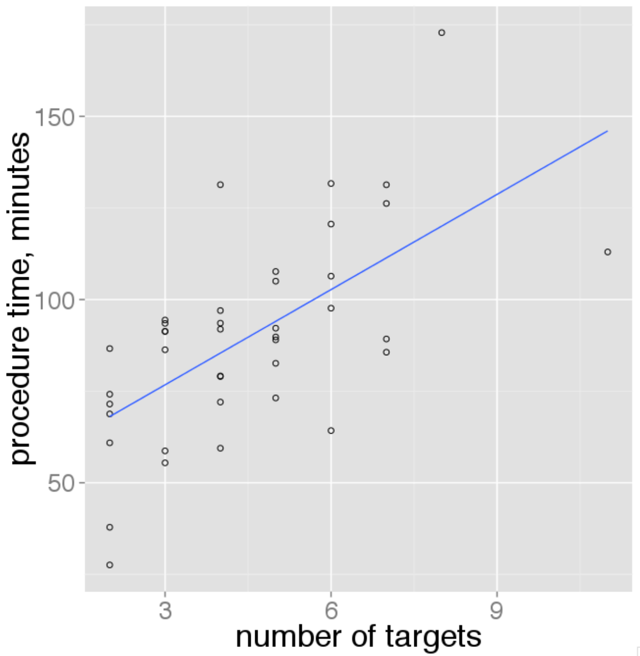
- 40 MRI-guided prostate biopsy procedures
- T2w intra-procedural imaging
  - Multi-slice acquisition, full gland coverage
  - Initial intra-op scan: 3 x 0.4 x 0.4 mm, ~5 minutes
  - Needle confirmation scan: 3.6 x 0.9 x 0.9mm, ~1 minute
- MR-compatible 18g biopsy needle was used for biopsy sample collection

Methods: Prostate motion quantification

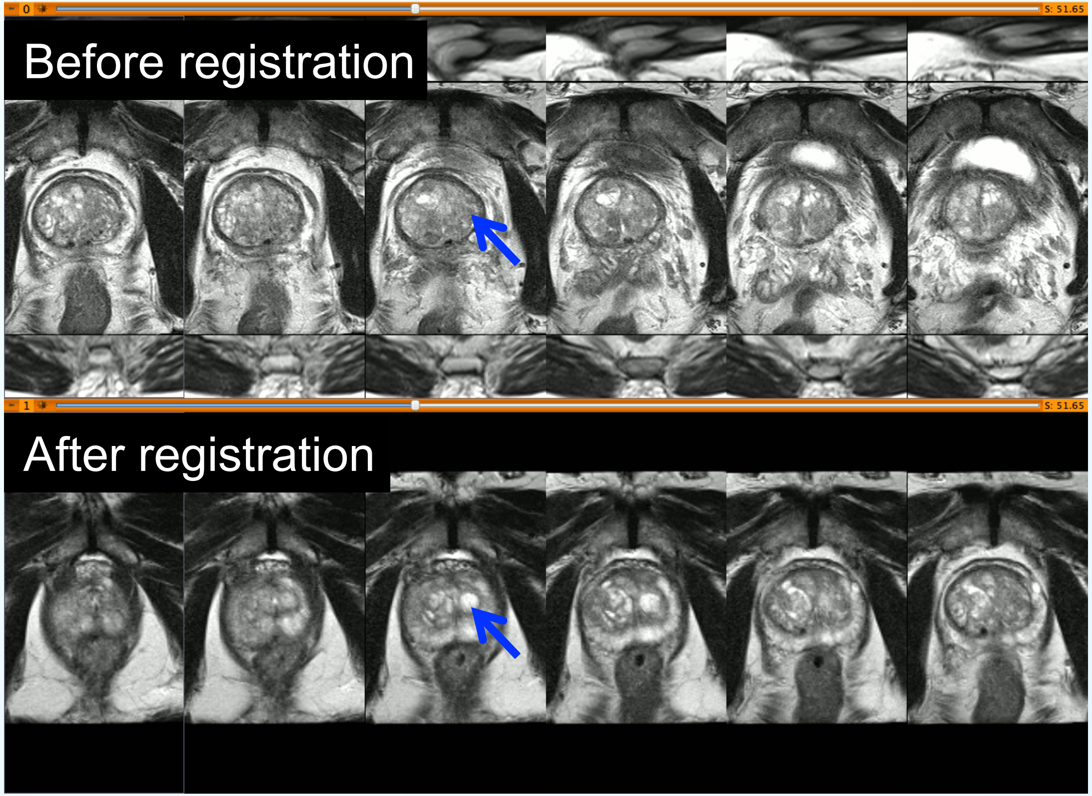
- Registration applied retrospectively
- Registration transformation applied to track centroid location
- Motion relative to the initial position quantified
  - Axial in-plane (2d) and 3d motion

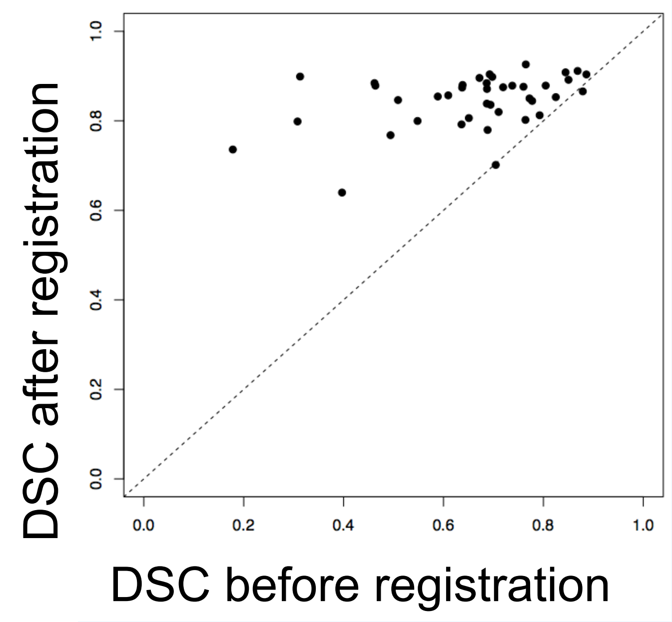
Results: Biopsy procedure summary

- 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)



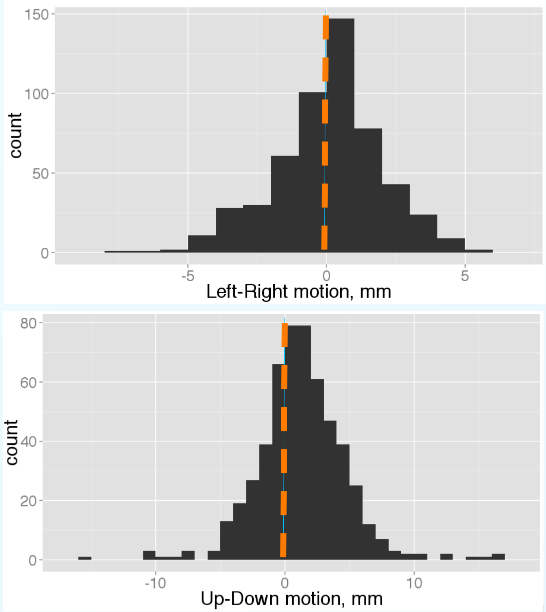
Results: Registration evaluation

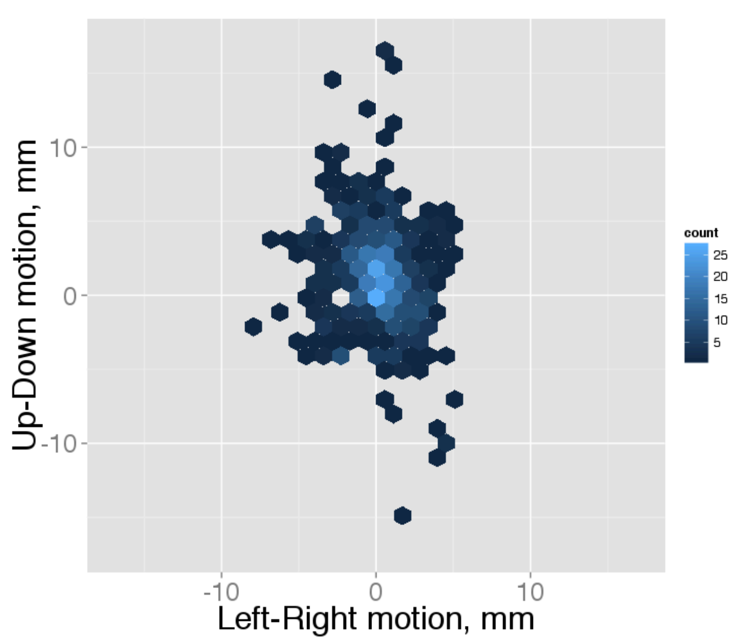




Results: In-plane prostate motion

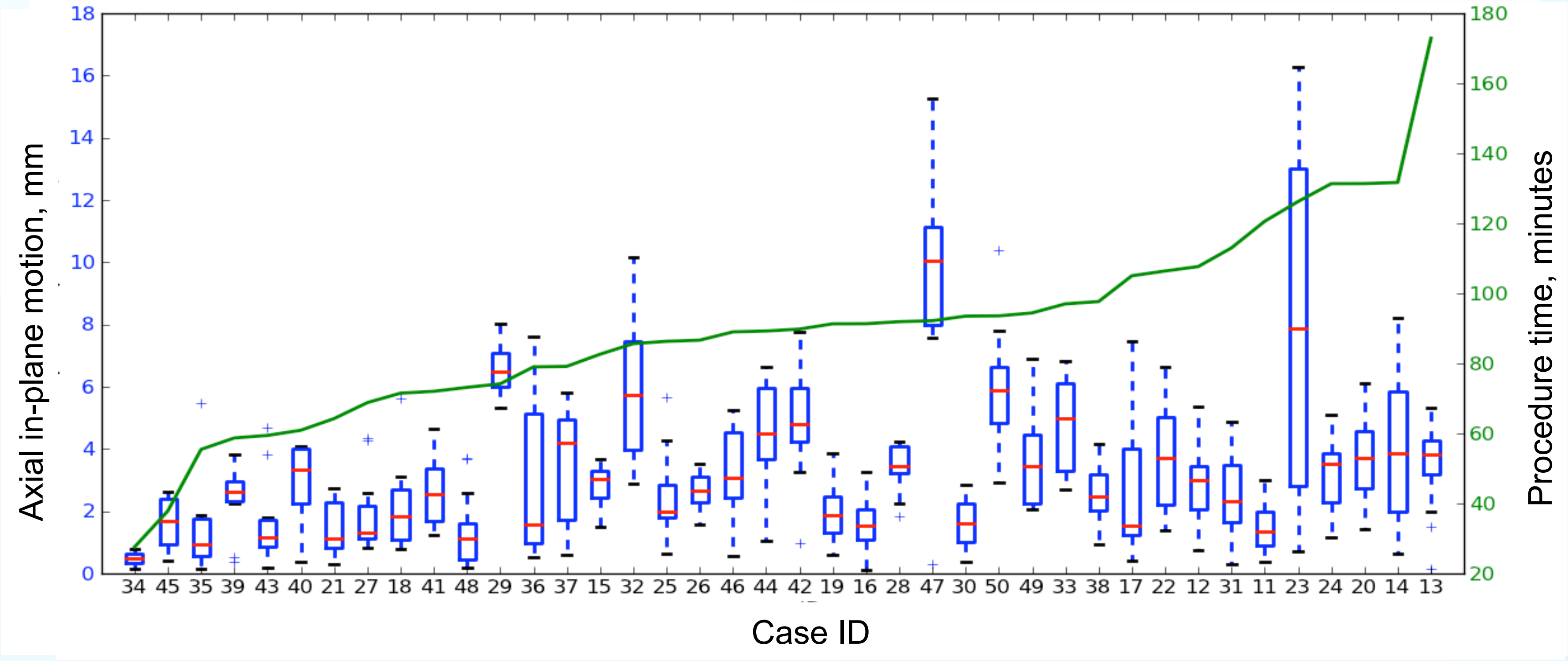
- In-plane motion magnitude:
  - Mean 3.4 ± 2.4 mm
  - Range 0-16mm
- Up-down motion magnitude dominates (mean 2.7 vs 1.5 mm, $p<0.001$)





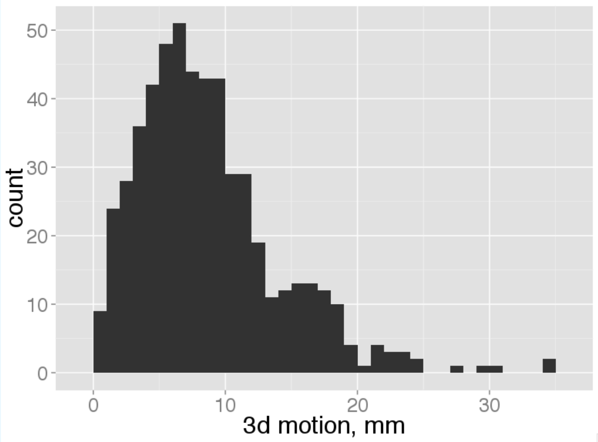
Max displacement (weakly) correlated with procedure time: r=0.34 [0.03,0.6], p=0.03

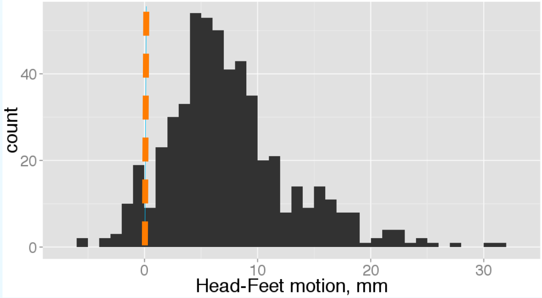
Results: In-plane prostate motion

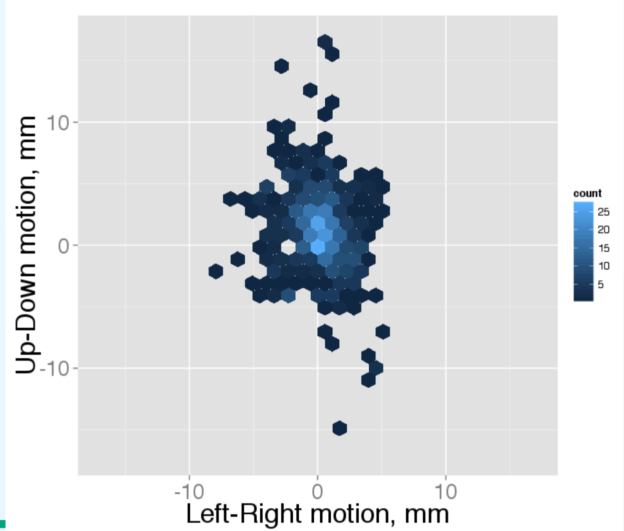


Results: 3d prostate motion

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



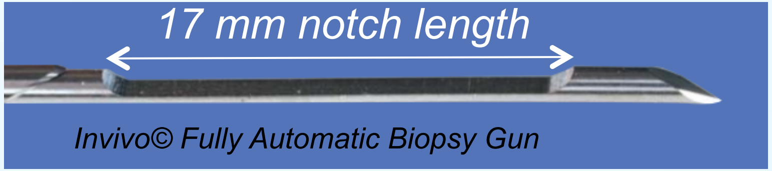


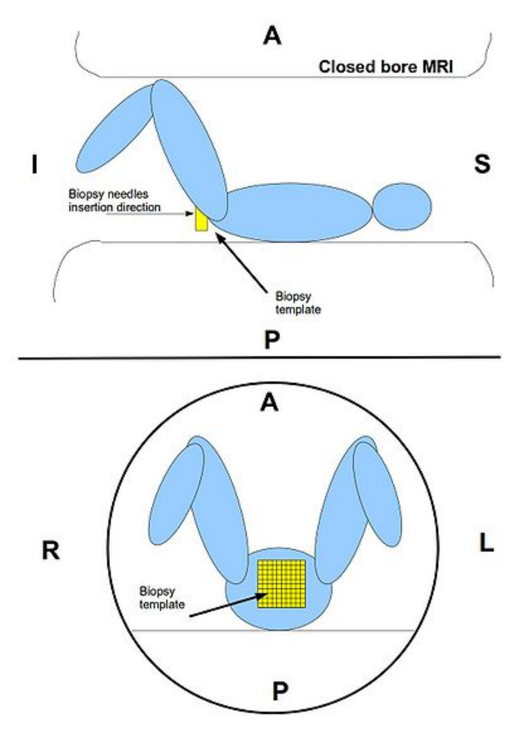


Max displacement (weakly) correlated with procedure time: r=0.38 [0.07,0.6], p=0.02

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[van de Ven]): 67% of cases
- Out-of-plane motion (head-feet):
  - >17mm (biopsy needle notch length): 6% of cases

van de Ven et al. Simulated required accuracy of image registration tools for targeting high-grade cancer components with prostate biopsies. European radiology. 2012.

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