

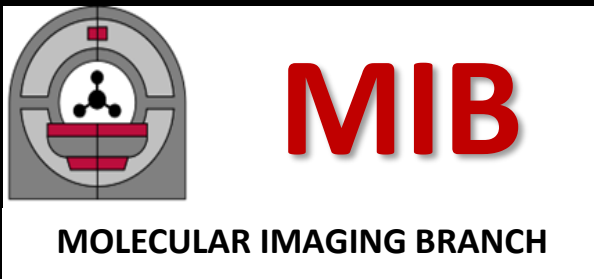
# Three Generations of AI-assisted Prostate Cancer Detection on mpMRI: "What We Learned from Radiologist-AI Interaction"

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Associate Research Physician

Molecular Imaging Branch, NCI, NIH

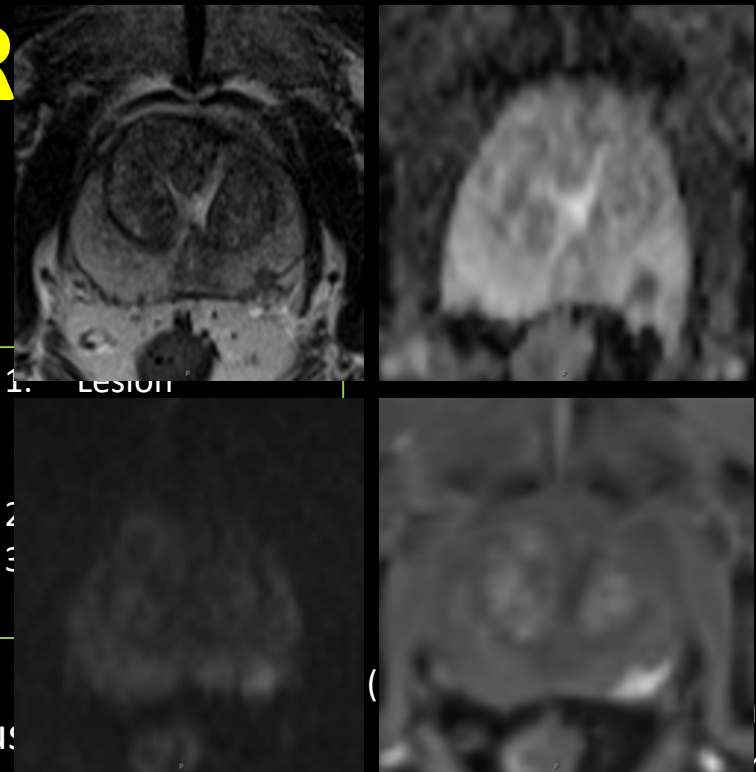
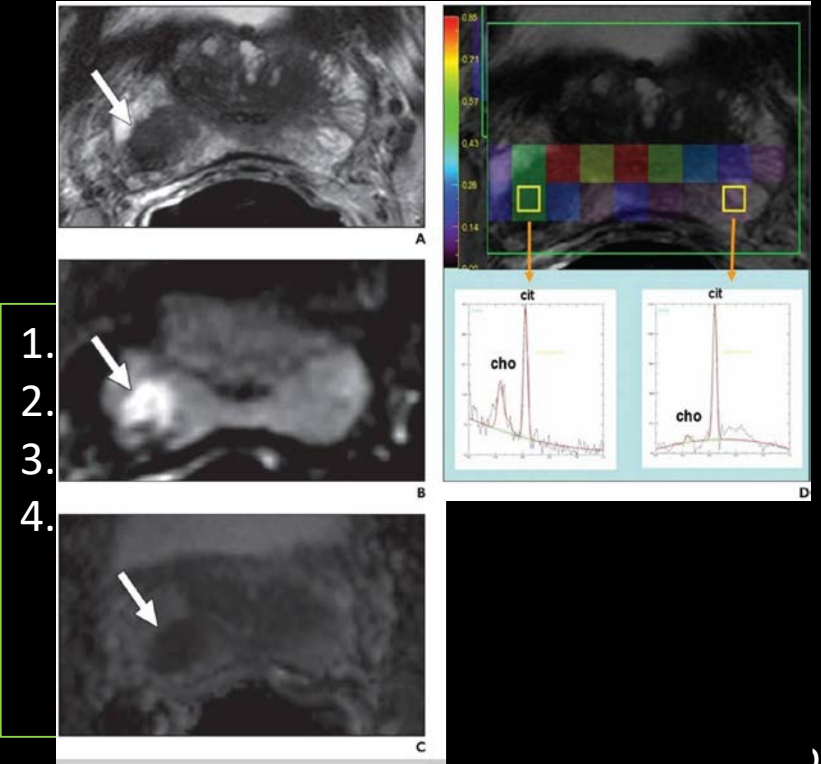
05/09/2019



# Disclosures

- Cooperative research and development agreements (CRADAs) with NVIDIA and Philips Medical Systems.
- Royalties from US Government patents for MRI-US fusion biopsy, computer aided diagnosis software.

# Prostate MR



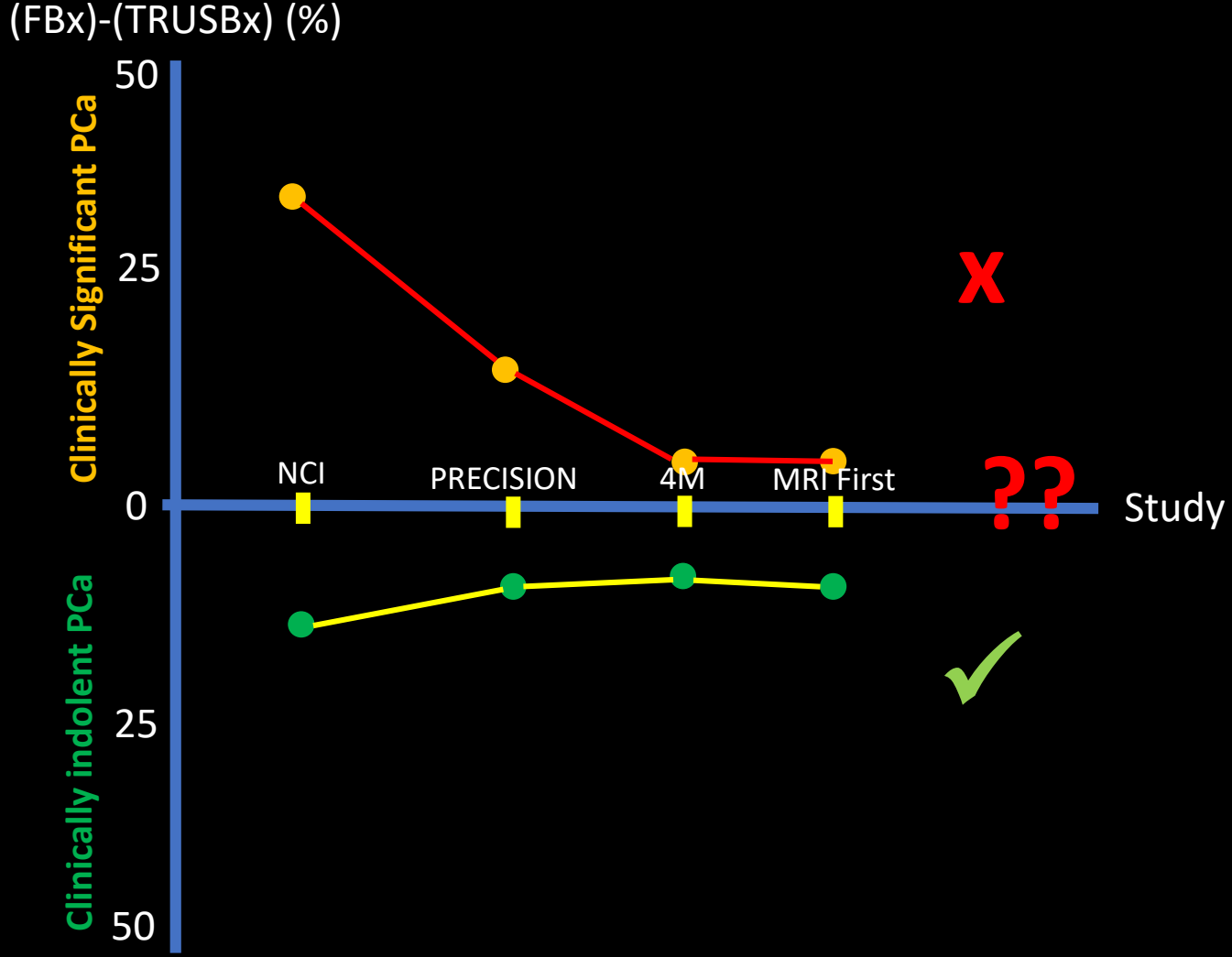
MR-guided biopsy  
in NCI

Wide use  
TRUS/MRI Fbx

PI-RADSv2

PIRADSv2.1  
released

2000 2007 2010 2013 2015 2016 2018 2019



- Different patient populations
- Different medical practices
- Different machines
- Different.....
- Different .....
- Different.....

## Standard of Care (12-core TRUS Guided Bx)

- Patient preparation
- TRUS guided standard biopsy procedure (150-200 cases/training year)
  - Standard equipment

## MRI Guided Bx

- Image acquisition
  - 3T vs. 1.5T
  - ERC vs. non-ERC
- Image interpretation
  - Lesion detection
  - Lesion scoring/PIRADS
  - Lesion measurement
- Image processing
  - Prostate segmentation
  - Target delineation
- TRUS acquisition
- TRUS/MRI registration
- Maintenance of TRUS/MRI registration
  - Freehand devices

# Limitations of Prostate MRI

- Moderate interobserver agreement:

- Single-center study (K=20)
- Multi-center study (n=20)
- Multi-center study (n=20)

## PI-RADS™ v2 Assessment Categories

PI-RADS 1 – Very low (clinically significant cancer is highly unlikely to be present)

PI-RADS 2 – Low (clinically significant cancer is unlikely to be present)

PI-RADS 3 – Intermediate (the presence of clinically significant cancer is equivocal)

PI-RADS 4 – High (clinically significant cancer is likely to be present)

PI-RADS 5 – Very high (clinically significant cancer is highly likely to be present)

- Low-

- Multi-center NIH study (n=4) (Smith and Harmon et al. JMRI 2019)

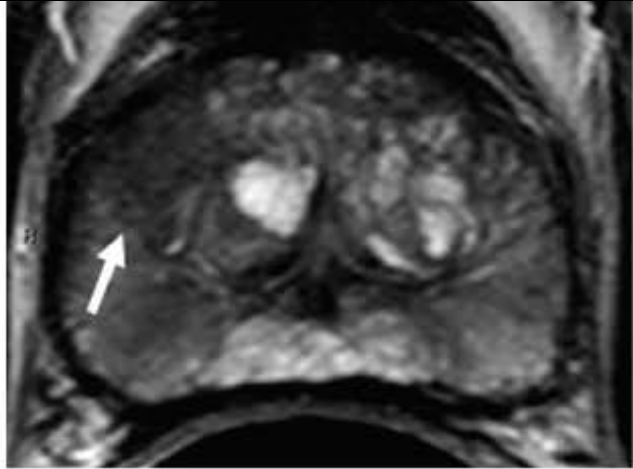
5)

gy

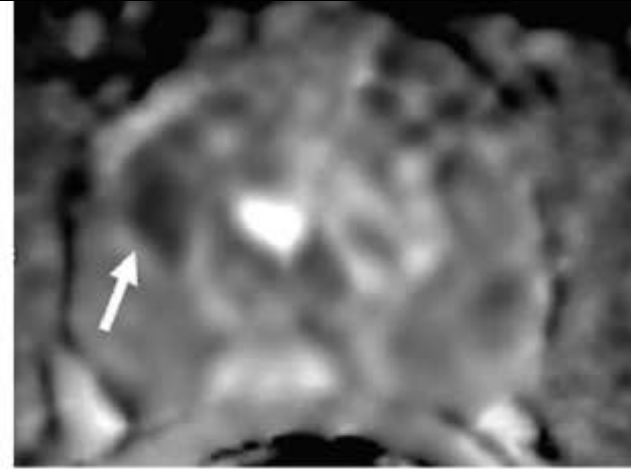
=59%

JMRI

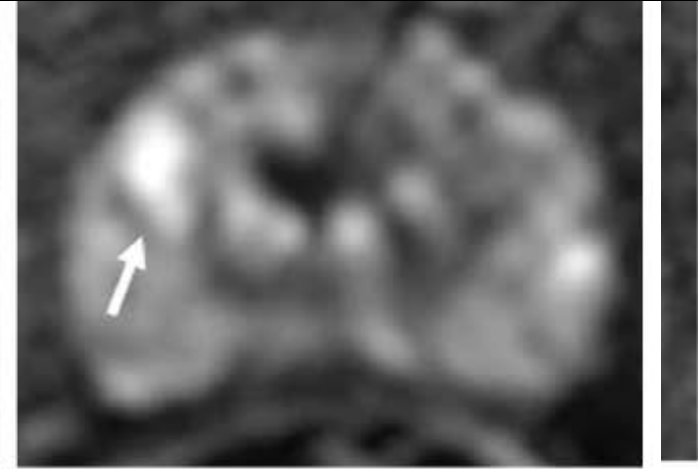
# Missed/Underestimated Cancers at Prostate MRI



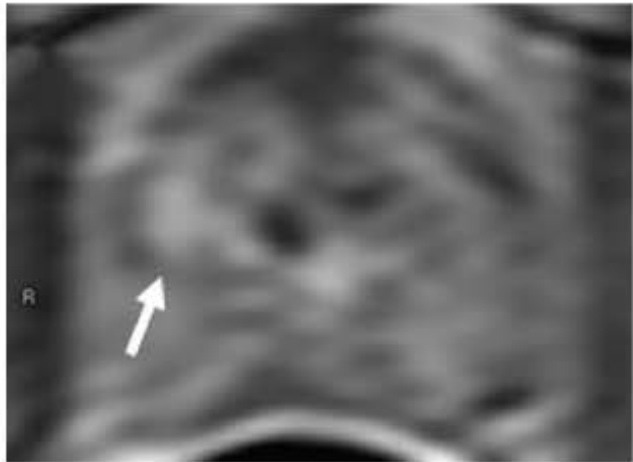
a.



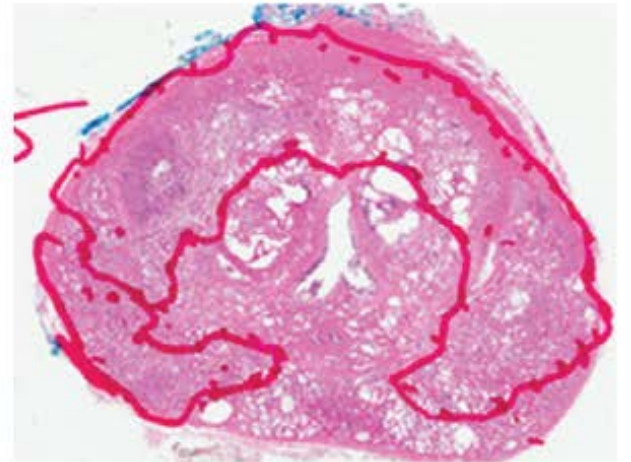
b.



c.



d.



e.

PI-RADS Score versus Gleason Score for Missed Lesions

PI-RADS Score	Gleason Score					Total
	3+3	3+4	4+3	4+4	4+5	
1	0	5	0	3	0	8
2	0	4	0	3	0	7
3	0	5	1	0	0	6
4	0	3	0	1	1	5
5	0	0	0	0	0	0
<b>Total</b>	0	17	1	7	1	26

Note.—Data are number of lesions.

## Standard of Care (12-core TRUS Guided Bx)

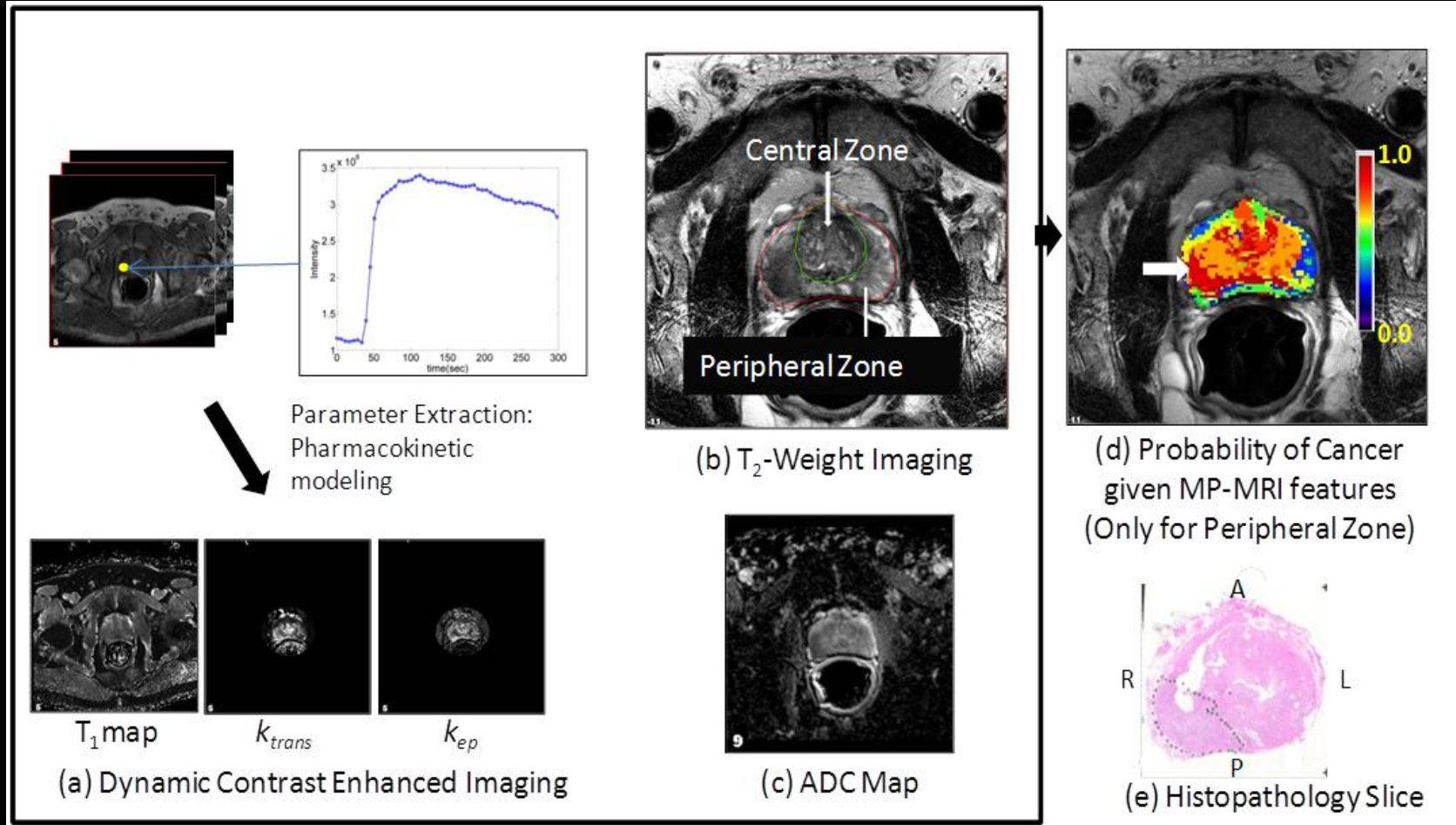
- Patient preparation
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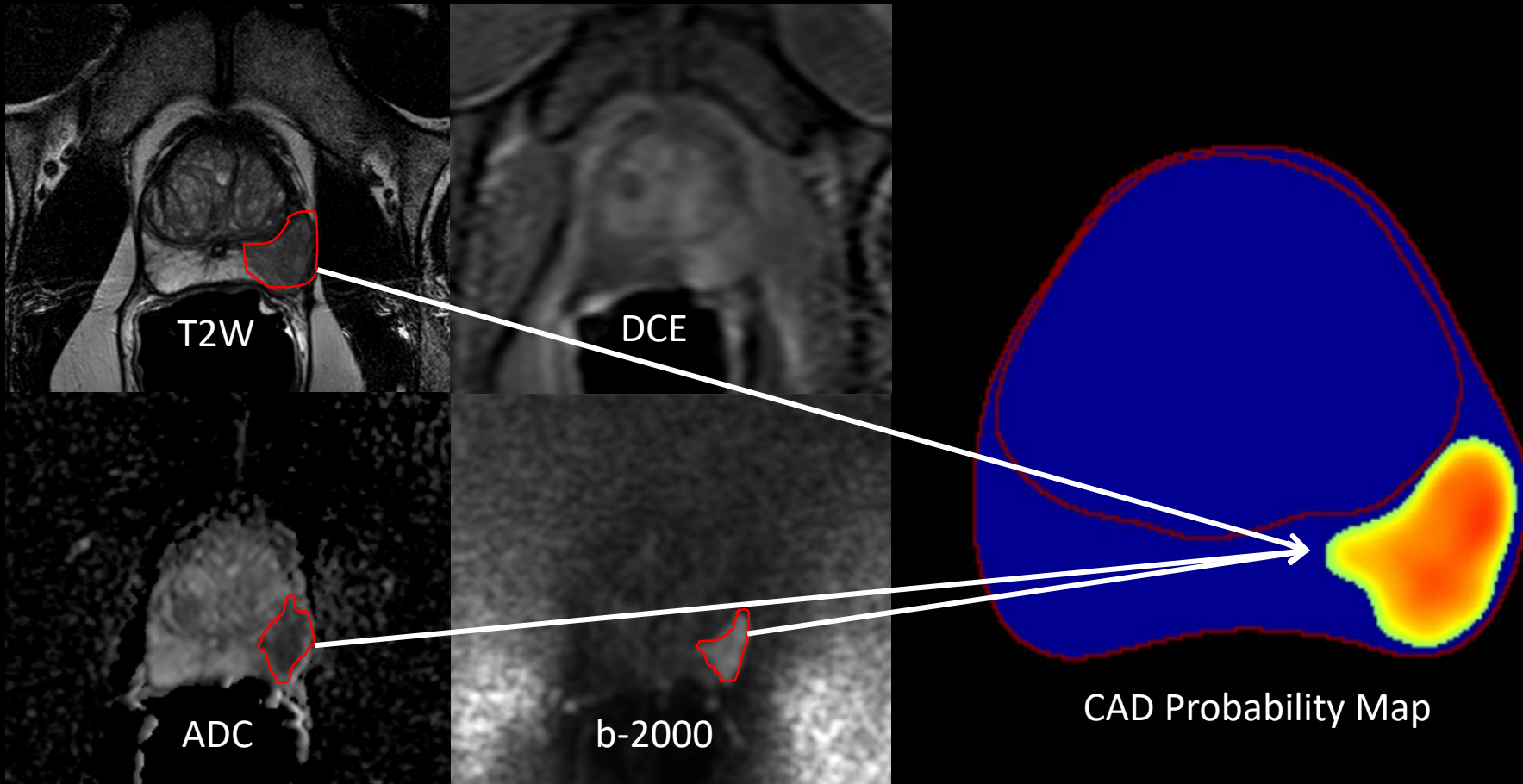
# AI/CAD 1.0 (made in MIP)



	Pathology Cancer	Pathology Not Cancer	Precision
Predicted Cancer	203	27	88%
Predicted Not Cancer	22	237	92%
Class Recall	90% [Sensitivity]	90% [Specificity]	90%

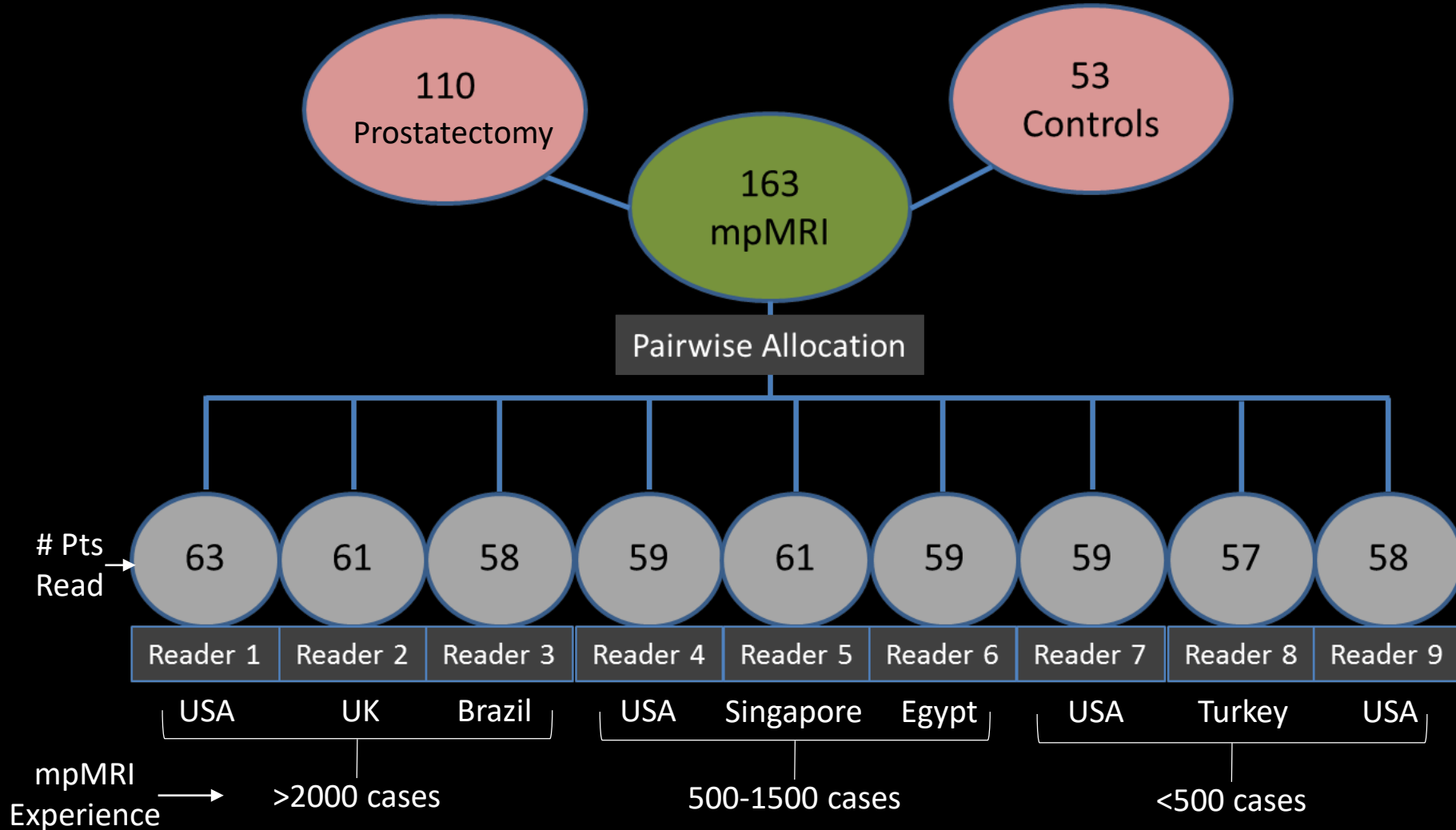
**Shah V et al. 2012  
Medical Physics**

# AI/CAD 2.0 (Inside NIH Validation)

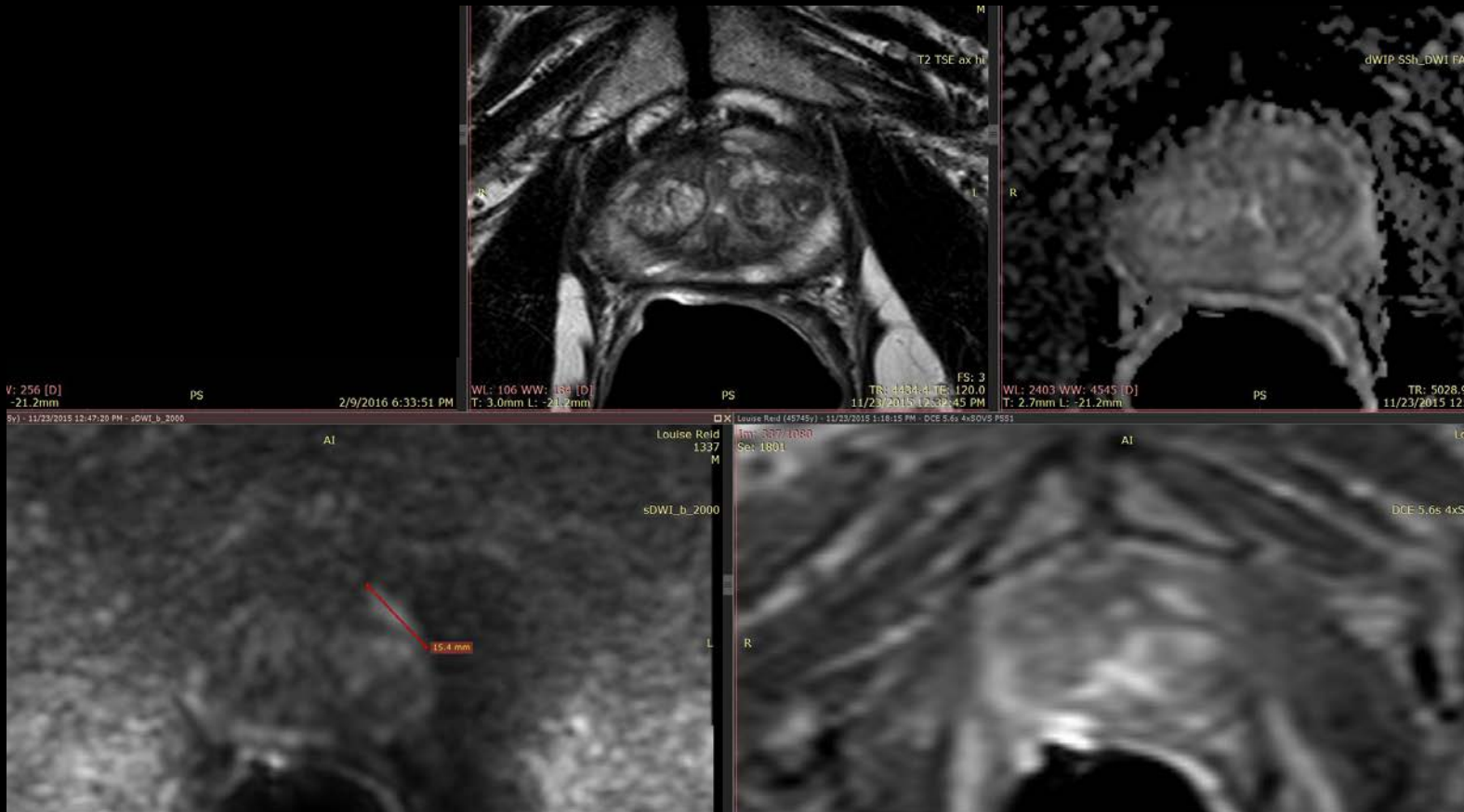


- Trained on segmentations of tumor proven biopsy regions
- Intensity-based and Haralick-based features for texture analysis
- Random forest classifier

# AI/CAD 2.0 (Inside NIH Validation)



# AI/CAD 2.0 (Inside NIH Validation)



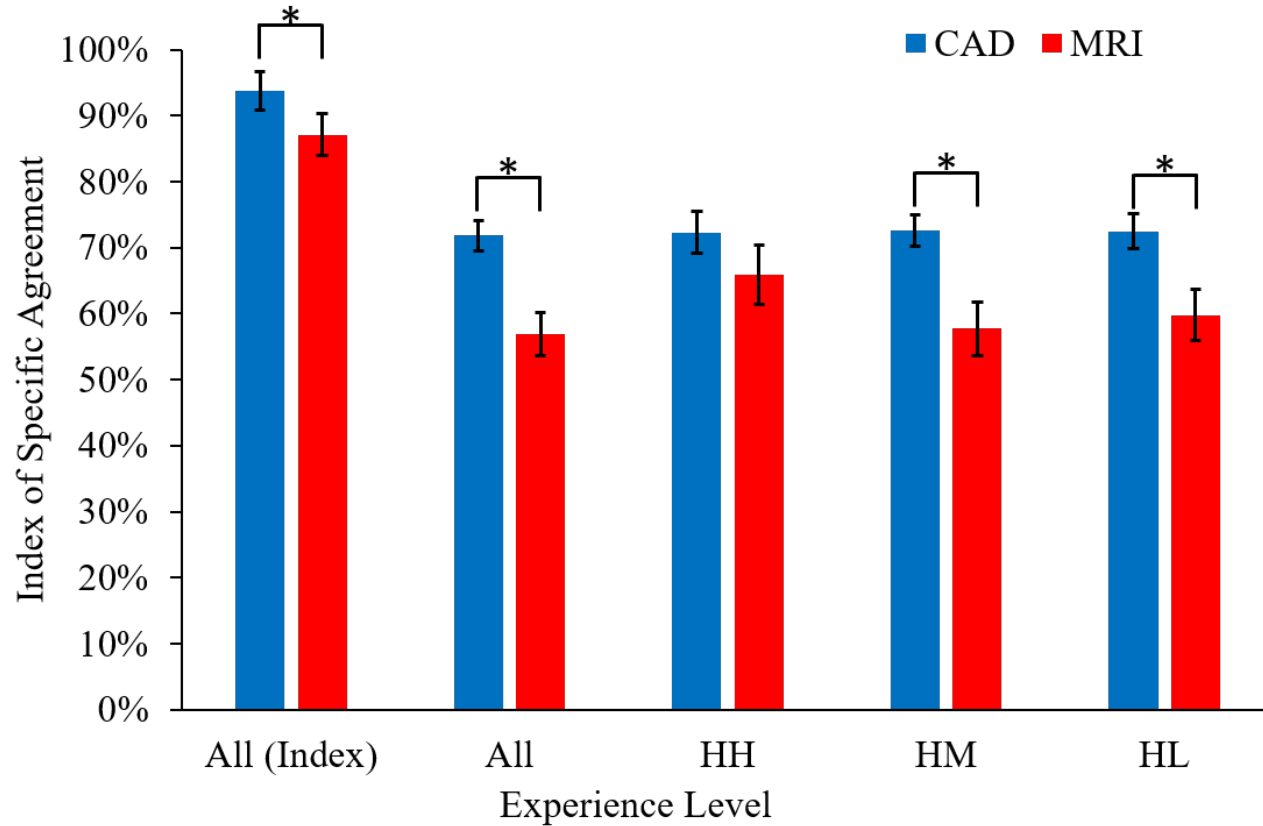
PI-RADS Score For Each Reader

Reader	1	2	3	4	5	6	7	8	9
MRI	4	ND	4	4	4	ND	4	ND	ND

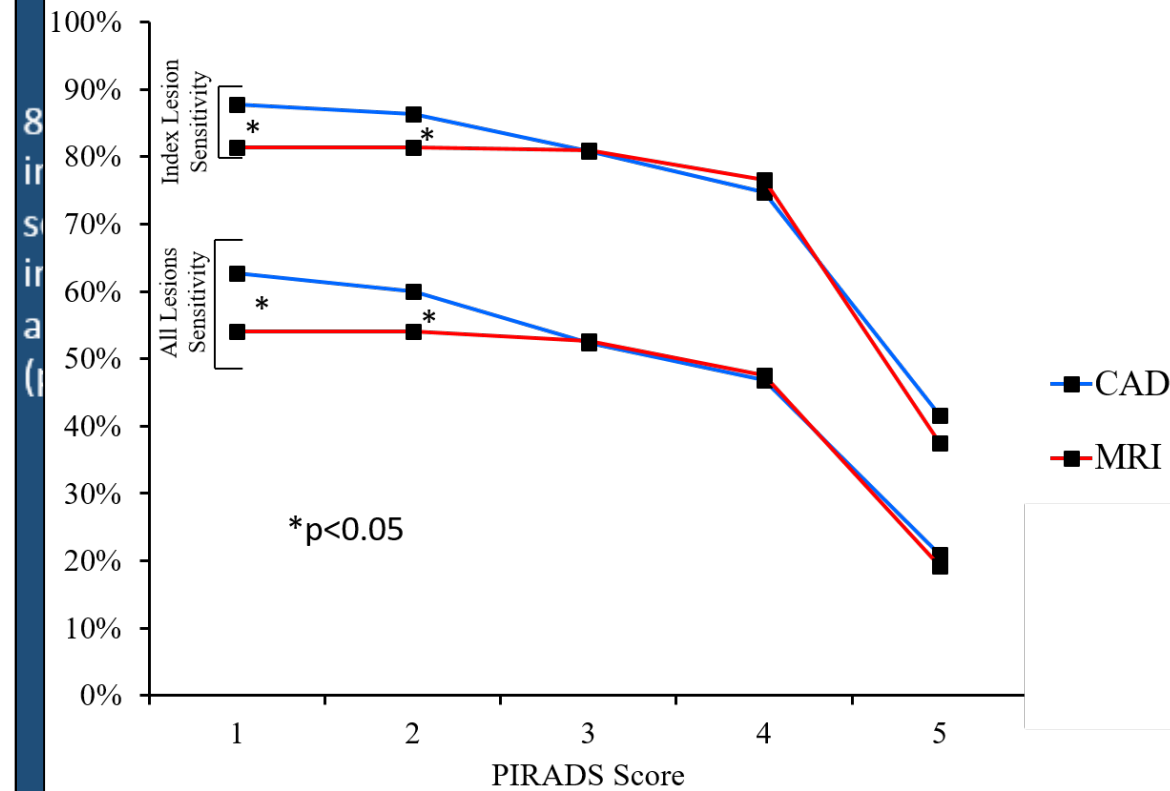
\*ND= Not Detected

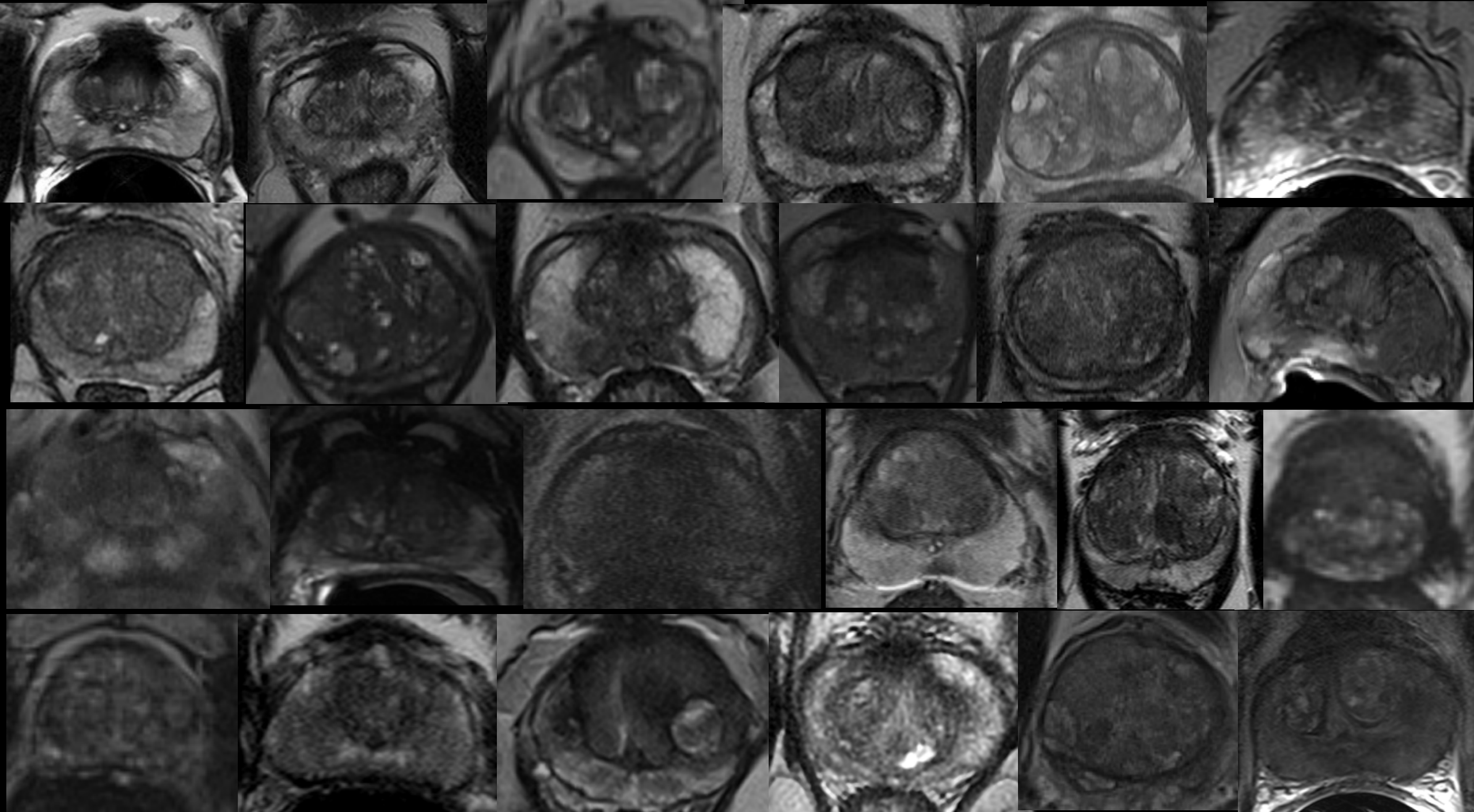
M. Greer et al. European Radiology (04/12/2018)

# AI/CAD 2.0 (Inside NIH Validation)

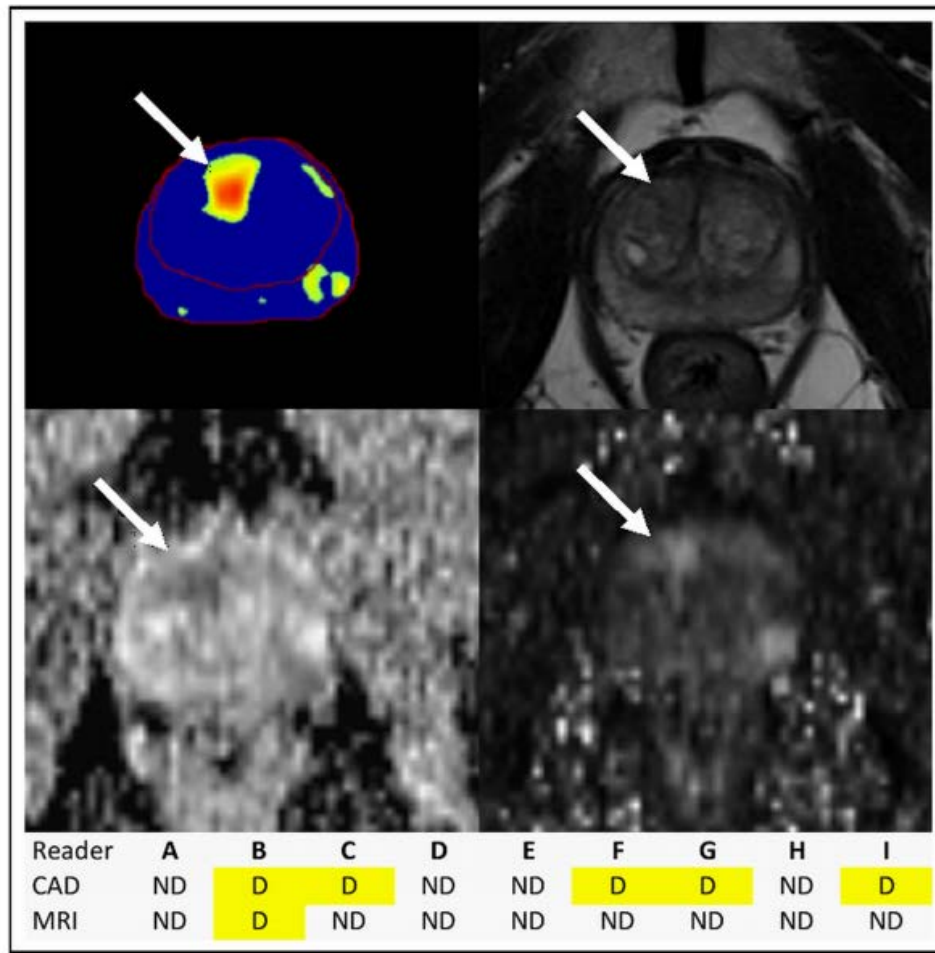


reader experience





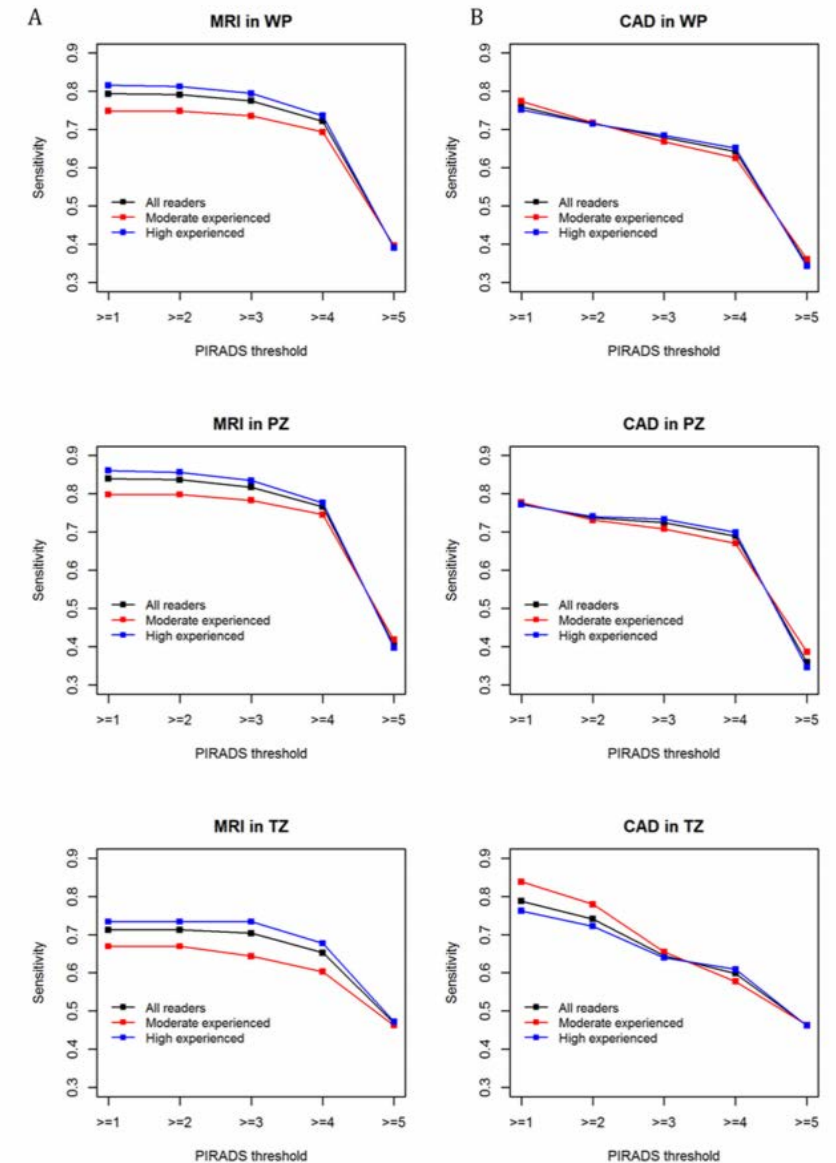
# AI/CAD 2.0 (Outside NIH Validation)



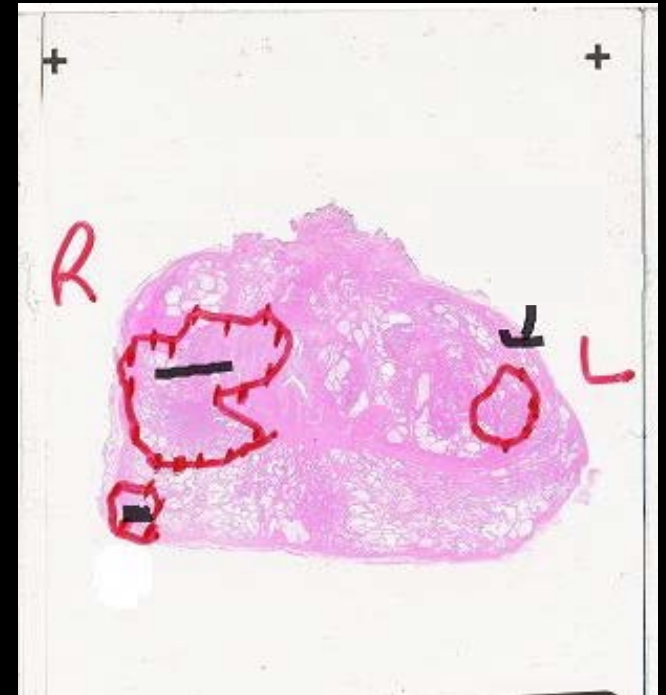
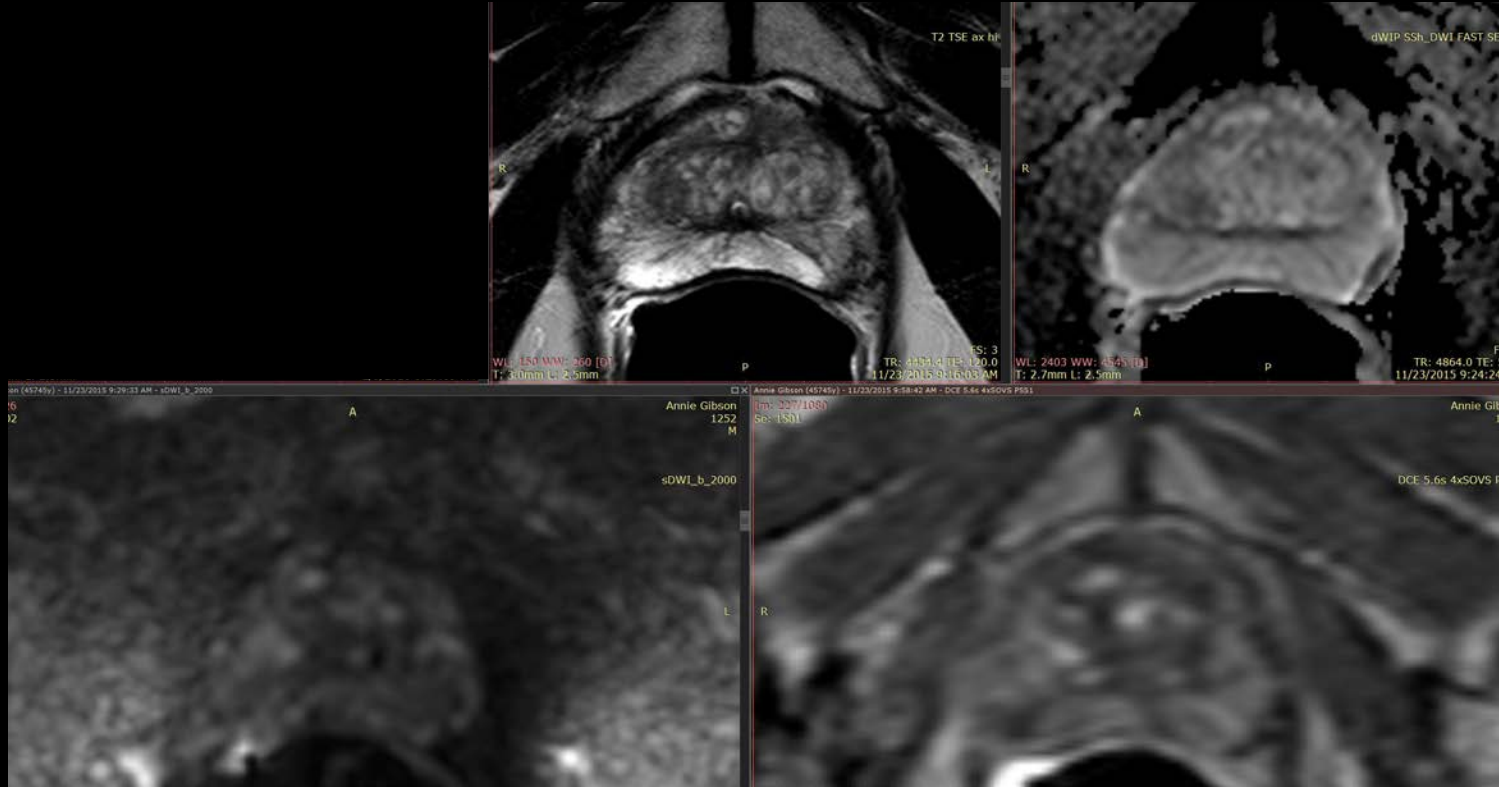
**Figure 2: Benefit of CAD in TZ tumor identification.** CAD (top left) picked up a tumor (arrows) in the right apical anterior TZ, identified by more readers on MRI (T2W top right, ADC map bottom left, b-1500 bottom right) with CAD assistance. ND = not detected, D = detected; the tumor was found by 5 readers with CAD assistance versus 1 reader with mpMRI alone. Radical prostatectomy histopathology mapping revealed Gleason 4+5 prostatic adenocarcinoma within this lesion.

mag  
6 col

1  
4  
7



# Challenges with AI/CAD 2.0



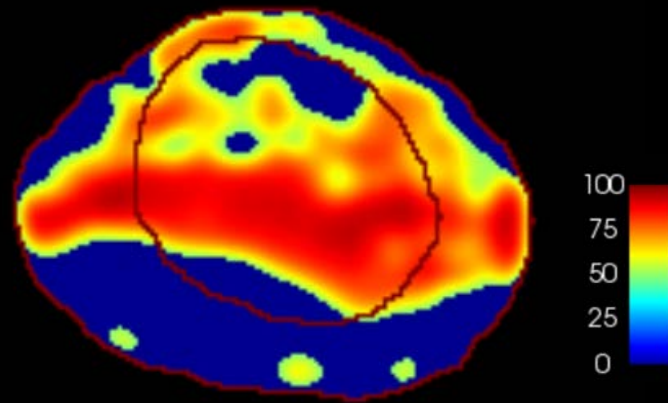
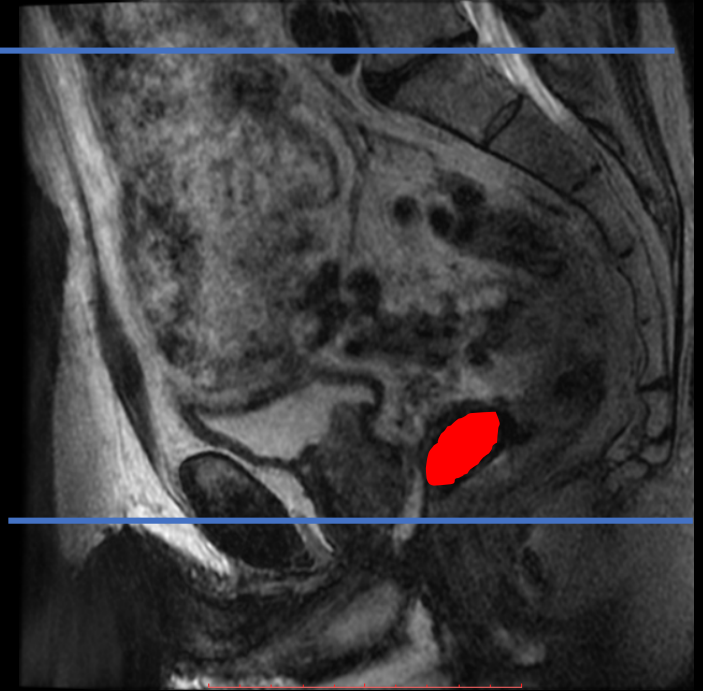
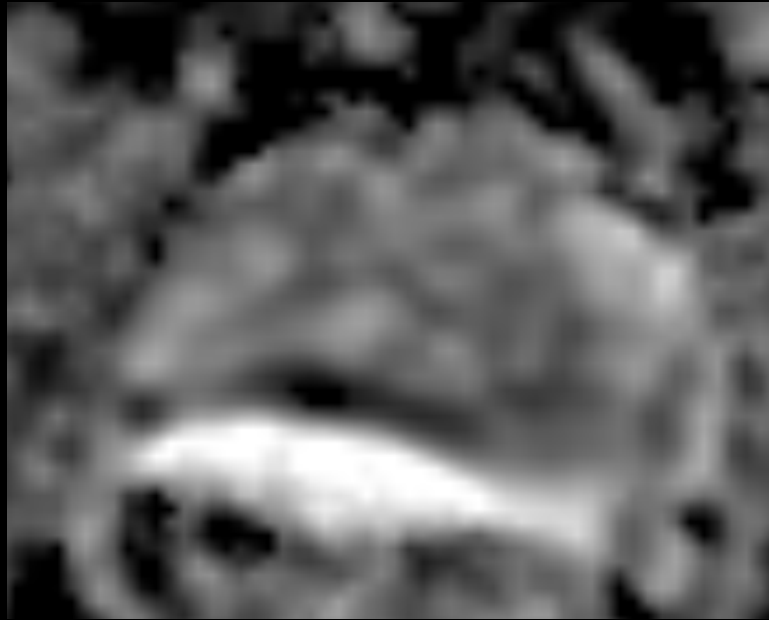
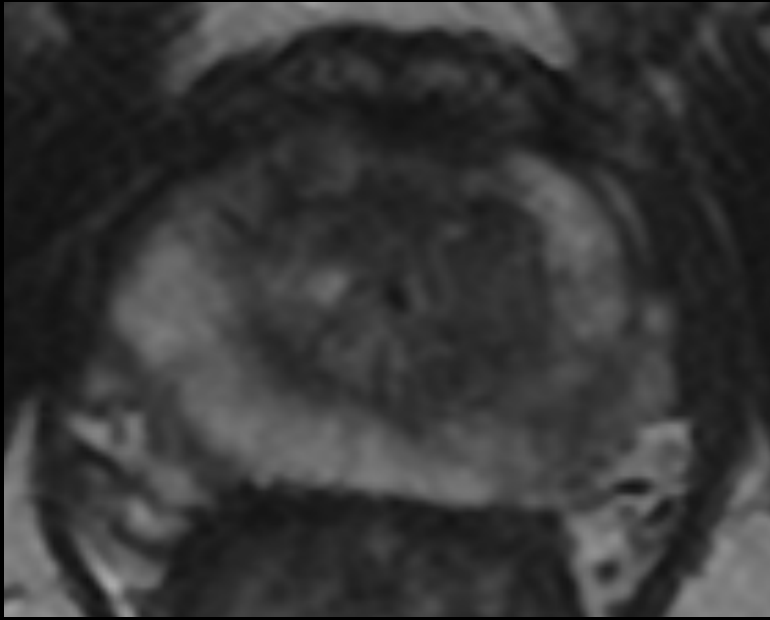
PI-RADS Score For Each Reader

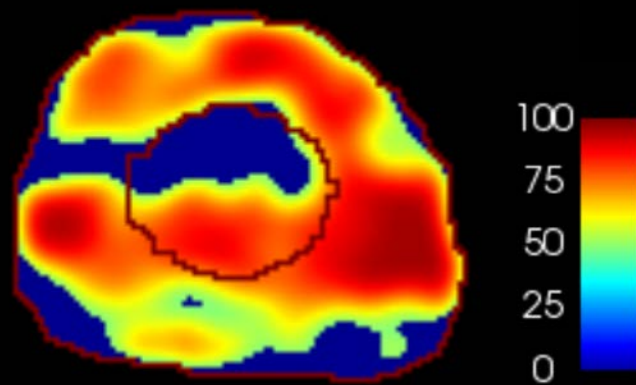
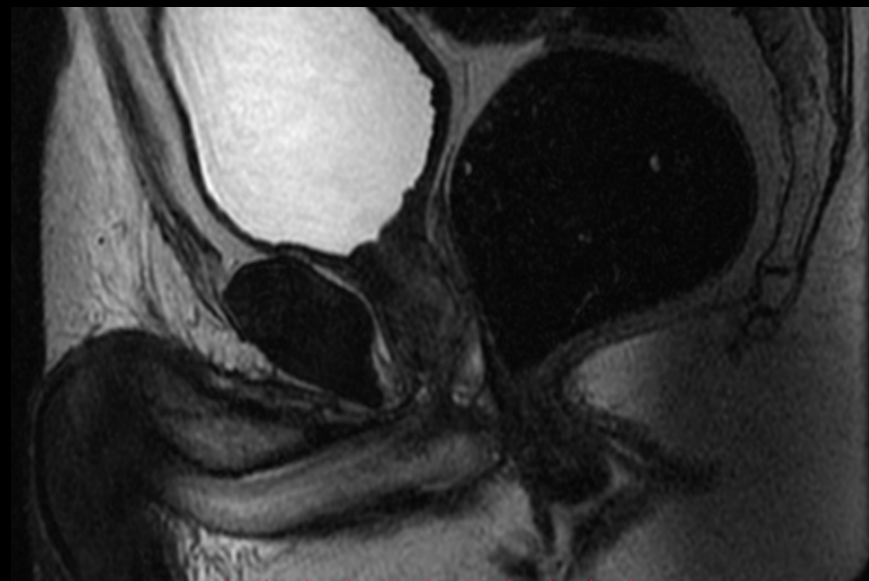
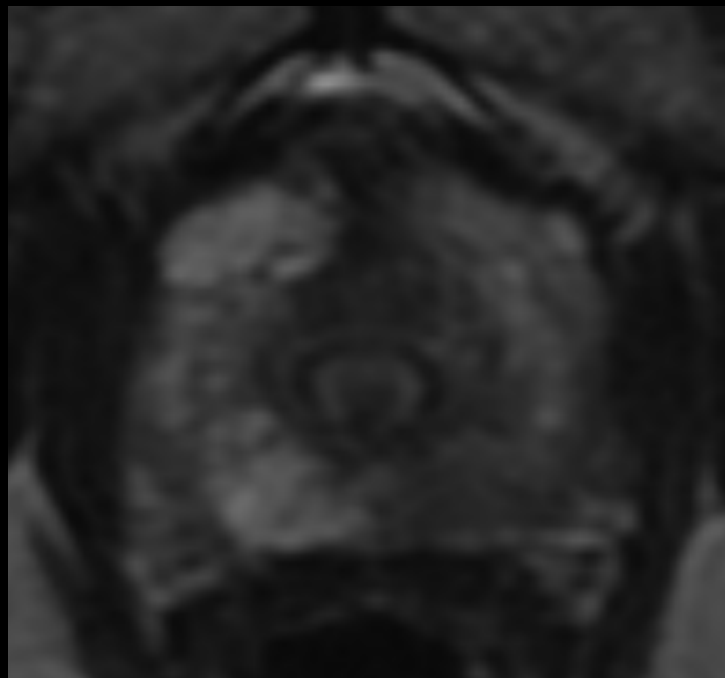
Reader	1	2	3	4	5	6	7	8	9
MRI	ND	ND	ND	3	3	ND	ND	ND	3

\*ND= Not Detected

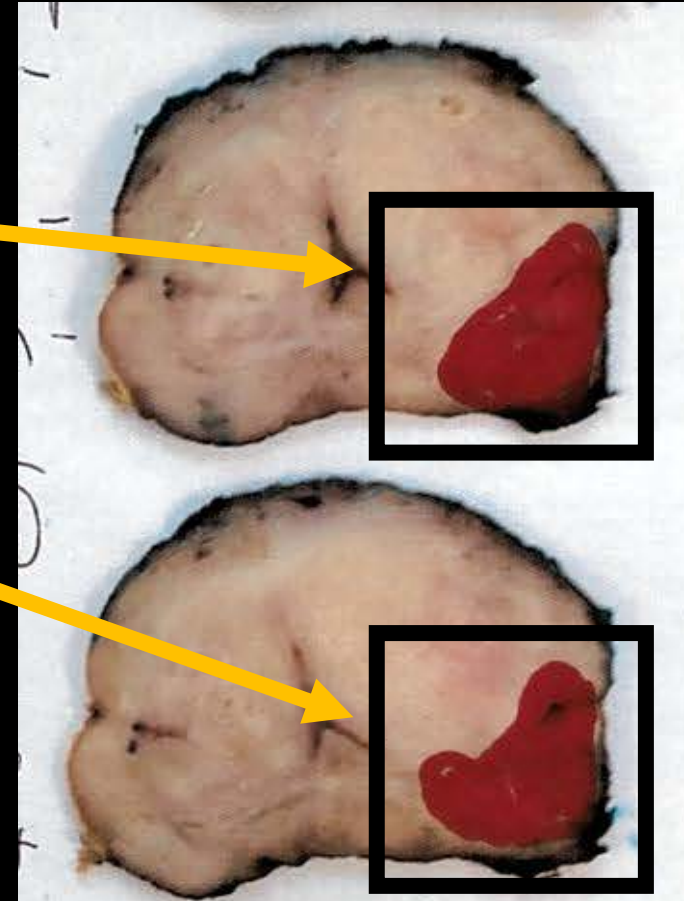
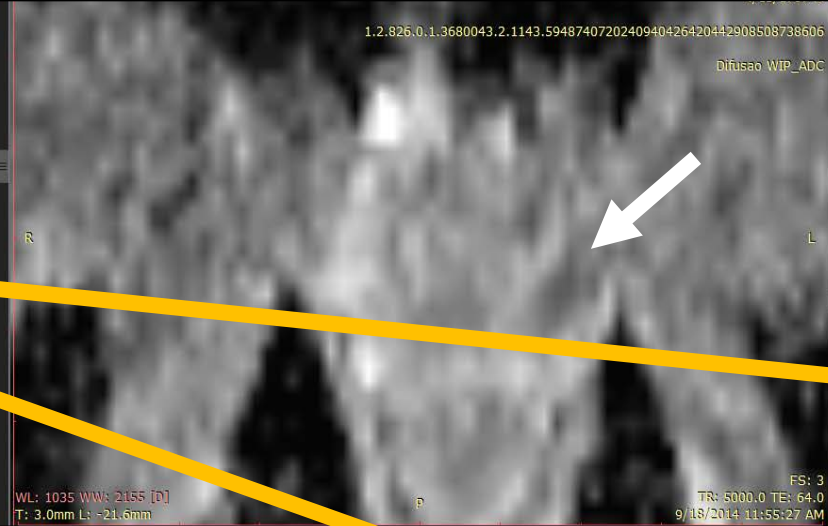
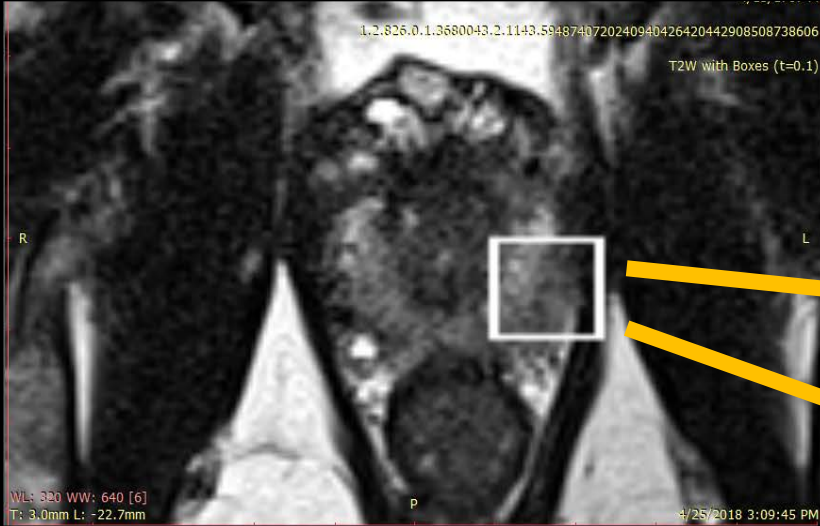
M. Greer et al. European Radiology (04/12/2018)







# AI/CAD 3.0 (Outside NIH Validation)



# AI/CAD 3.0 (Preliminary Results)

Sensitivity	Overall	High Experience	Intermediate Experience	Low Experience
mpMRI alone	62.2%	63%	65.3%	58.2%
AI-assisted	66.5%	67.8%	71.7%	59.9%

Specificity	Overall	High Experience	Intermediate Experience	Low Experience
AI-assisted	81.1%	86.3%	70.2%	86.2%

Molecular Imaging Program, NCI, 2019, unpublished  
Mehralivand et al. Submitted to RSNA 2019





# MIP Deep Learning Group for Prostate Cancer



- Data annotation (target is 10K subjects from multiple institutions) **1500 subjects**
- Current research portfolio:
  - Prostate MRI
  - Conventional imaging (CT)
  - Digital pathology
- Core Team:
  - Baris Turkbey M.D.
  - Stephanie Harmon Ph.D.
  - Thomas Sanford M.D.
  - Sherif Mehralivand M.D.
  - Jonathan Sackett B.S.
  - Jeff Brender Ph.D.
  - Marcial Garmendia B.S.
  - Sheng Xu Ph.D.
  - Deepak Kesani D.O.
  - **Onsite radiologist volunteers:**
    - **Manuel Madariaga M.D.**
    - **Sena Tuncer M.D.**
  - **Onsite non-radiologist volunteers:**
    - **Mojdeh Mir Momen M.D.**
    - **Moozhan Nikpanah M.D.**

# Conclusion

- Prostate MRI is a powerful imaging technique
  - Initial success stories are not observed in larger studies
  - It is not without limitations (quality, detection, reproducibility)
- AI/CAD can potentially solve these limitations
- AI-Radiologist interaction is not optimized
  - Data diversity and quality is a big problem



MIB

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Thomas Sanford  
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Deepak Kesani  
Sonia Gaur  
Clayton Smith  
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Liza Lindenberg  
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Esther Mena  
Rose Berman  
Freddy Escorcía  
Frank Lin  
Ilhan Lim  
Dagane Daar  
Thieu Hoa  
Philip Eclarinal  
Alicia Forest  
Juanita Weaver  
Joy Zou  
Karen Wong  
Jyoti Roy  
Steve Adler  
Gary Griffiths  
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Peter A. Pinto  
Vladimir Valera  
Marston Linehan  
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Haydar Celik  
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Ravi Madan  
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CPDR (WRMC)  
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Aytekin Oto (U Chicago)  
Ronaldo Baroni (Brazil)  
Andrei Purysko (CCF)  
Burak Argun (Istanbul-TR)  
Erdem Canda (Ankara-TR)  
Anna Laucis (U Michigan)  
Ashkan Malayeri (Harvard)  
Pingkun Yan (NY)  
Haytham Shebel (Mansoura-EGY)  
Mehmet Coskun (Izmir-TR)  
Yan Mee Law (Singapore)  
Anne Walton-Diaz (Santiago-Chile)  
Tristan Barrett (Cambridge-UK)



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and their  
families**

**Thank you...**

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