

# Your Prostate in the Metaverse

## The Future of Prostate Imaging

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UsTOO March 17, 2022

# Disclosure

Consultant for Promaxo, Inc.

# Overview

Qualitative Versus Quantitative Imaging

What is Artificial Intelligence? How Can AI Be Used for Prostate Imaging?

Near Term and Long Term

# Prostate Imaging Reporting and Data Systems v2.1:

# “PI-RADS”

# >20 publications prove PI-RADS v2 the Standard for Prostate MRI

- ACR website or (updated last month) *European Urology*
- Technique
- Normal appearance
- Assessment and reporting
- Staging

available at [www.sciencedirect.com](http://www.sciencedirect.com)  
journal homepage: [www.europeanurology.com](http://www.europeanurology.com)

**eau**

European Association of Urology

Platinum Priority – Prostate Cancer

Editorial by Jelle O. Barentsz, Jeffrey C. Weinreb, Sadna Verma et al on pp. 41–48 of this issue

## PI-RADS Prostate Imaging – Reporting and Data System Version 2

Jeffrey C. Weinreb<sup>a,†,\*</sup>, Jelle O. Barentsz<sup>b,†</sup>, Peter L. Choyke<sup>c</sup>, Francois Cornud<sup>d</sup>,  
Masoom A. Haider<sup>e</sup>, Katarzyna J. Macura<sup>f</sup>, Daniel Margolis<sup>g</sup>, Mitchell D. Schnall<sup>h</sup>,  
Faina Shtern<sup>i</sup>, Clare M. Tempany<sup>j</sup>, Harriet C. Thoeny<sup>k</sup>, Sadna Verma<sup>l</sup>

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European Association of Urology

Platinum Priority – Review – Prostate Cancer  
Editorial by XXX on pp. x–y of this issue

## Prostate Imaging Reporting and Data System Version 2.1: 2019 Update of Prostate Imaging Reporting and Data System Version 2

Baris Turkbey<sup>a,†,\*</sup>, Andrew B. Rosenkrantz<sup>b,†,\*</sup>, Masoom A. Haider<sup>c</sup>, Anwar R. Padhani<sup>d</sup>,  
Geert Villeirs<sup>e</sup>, Katarzyna J. Macura<sup>f</sup>, Clare M. Tempany<sup>g</sup>, Peter L. Choyke<sup>h</sup>, Francois Cornud<sup>i</sup>,  
Daniel J. Margolis<sup>j</sup>, Harriet C. Thoeny<sup>k</sup>, Sadna Verma<sup>l</sup>, Jelle Barentsz<sup>l,‡</sup>, Jeffrey C. Weinreb<sup>m,‡</sup>

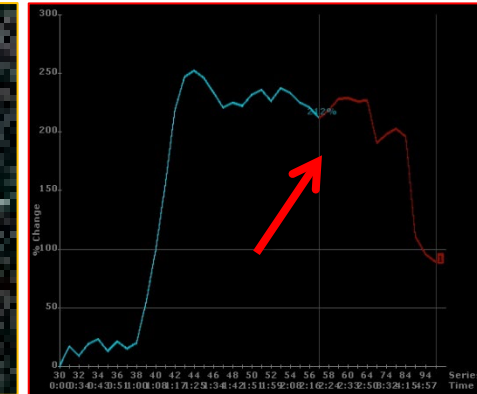
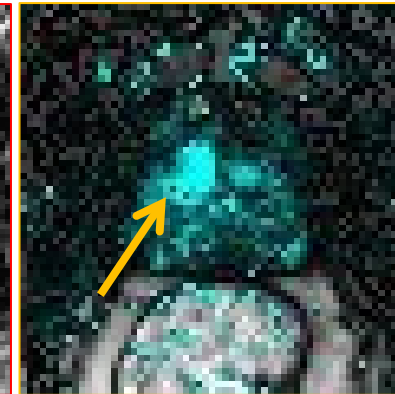
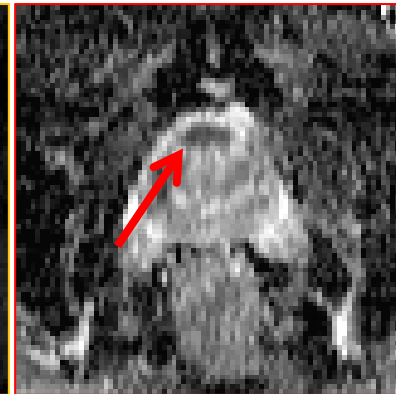
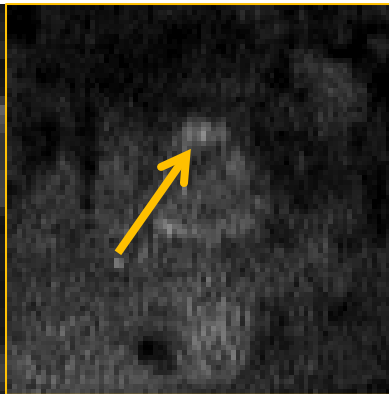
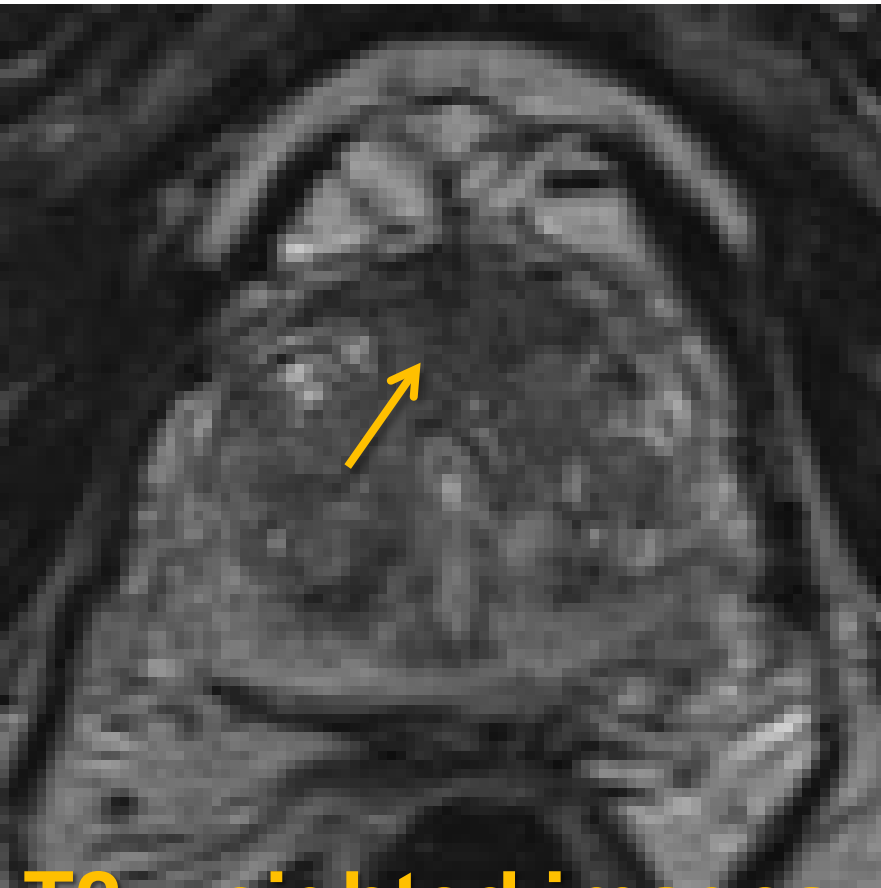
<sup>a</sup>Molecular Imaging Program, National Cancer Institute, NIH, Bethesda, MD, USA; <sup>b</sup>Department of Radiology, NYU Langone Medical Center, New York, NY, USA; <sup>c</sup>University of Toronto, Lunenfeld-Tanenbaum Research Institute, Sinai Health System, Toronto, Canada; <sup>d</sup>paul Strickland Scamner Centre, Mount Vernon Cancer Centre, Northwood, UK; <sup>e</sup>Department of Radiology, Ghent University Hospital, Ghent, Belgium; <sup>f</sup>Department of Radiology and Radiological Science, Johns Hopkins University School of Medicine, Baltimore, MD, USA; <sup>g</sup>Department of Radiology, Brigham and Women's Hospital, Boston, MA, USA; <sup>h</sup>Department of Radiology, Hôpital Cochin, Université Paris Descartes, Paris, France; <sup>i</sup>Weill Cornell Medical College, Cornell University, New York, NY, USA; <sup>j</sup>Department of Radiology, Hôpital Cantonal de Fribourg HFR, University of Fribourg, Fribourg, Switzerland; <sup>k</sup>Department of Radiology, University of Cincinnati, College of Medicine, Cincinnati, OH, USA; <sup>l</sup>Department of Radiology and Nuclear Medicine Radboudumc, Nijmegen, The Netherlands; <sup>m</sup>Department of Radiology, Yale School of Medicine, New Haven, CT, USA



ACR  
PI-RADS™  
Reporting



# mpMRI Components

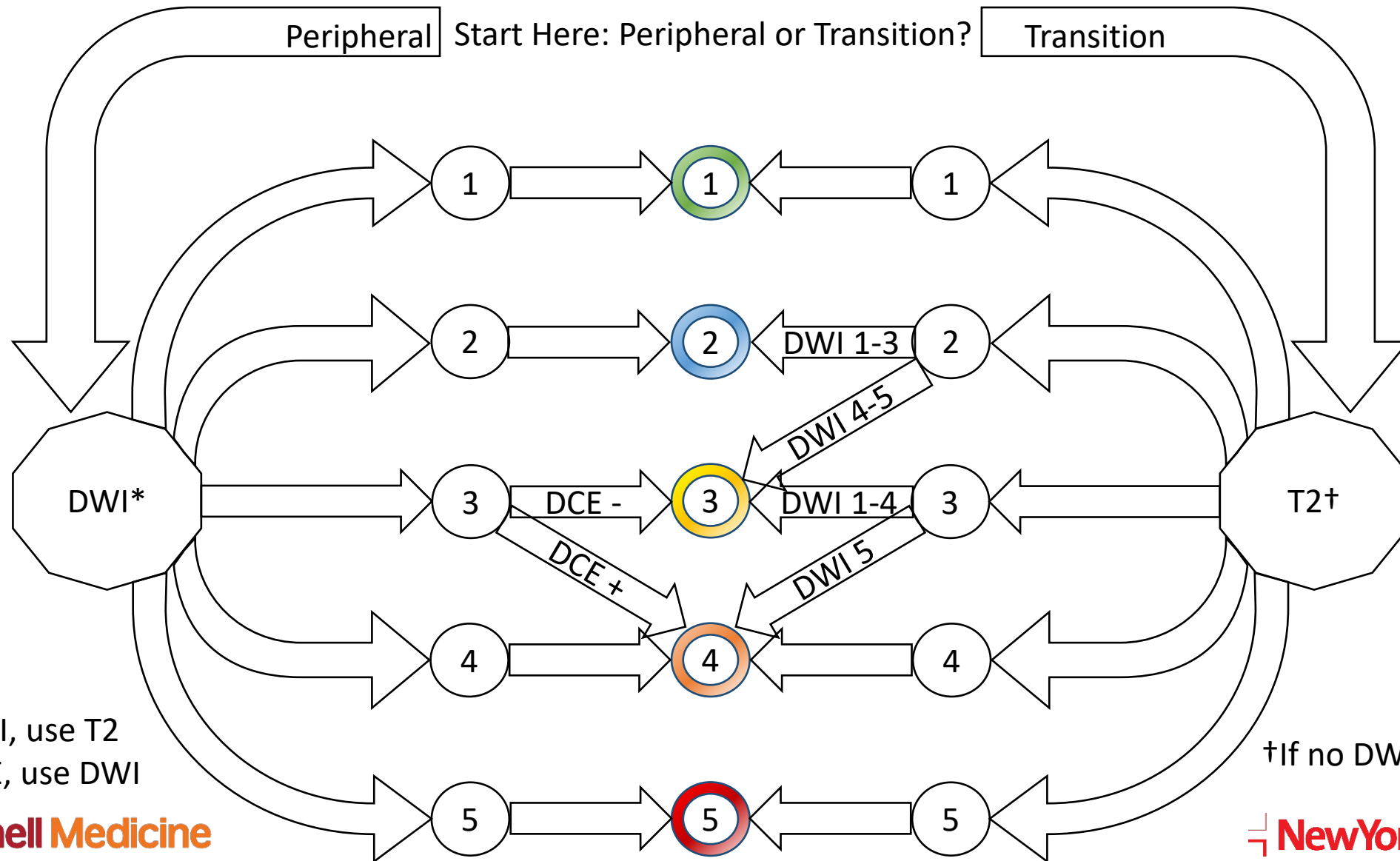


**T2-weighted images:**  
transition zone  
characterization &  
staging

**Diffusion-weighted imaging + apparent diffusion coefficient map:**  
most specific

**Dynamic contrast-enhanced perfusion imaging with optional enhancement curve:**  
most sensitive

# Assess Based on Flow Chart

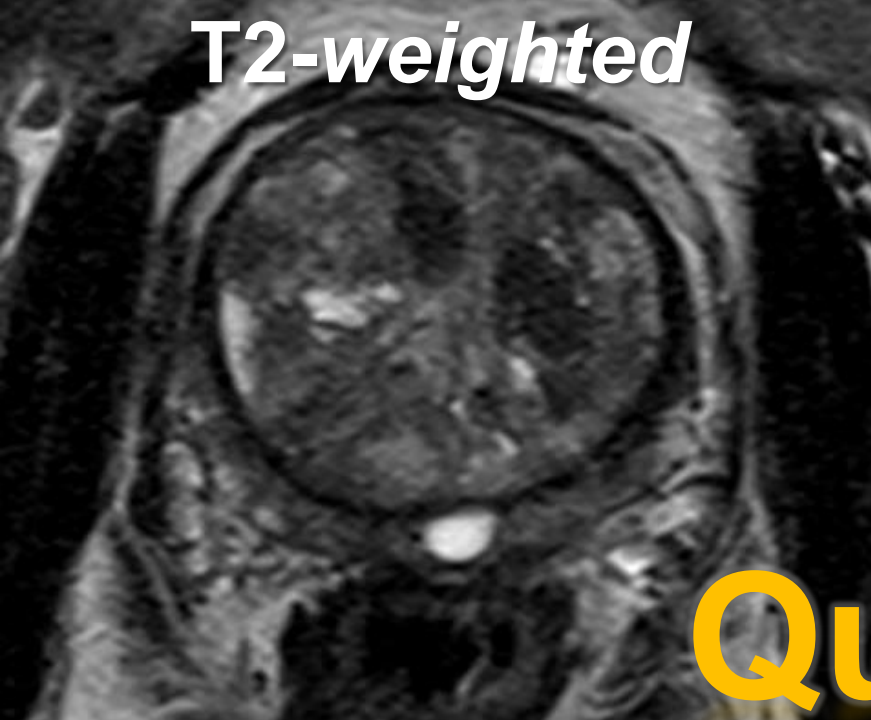


\*If no DWI, use T2  
If no DCE, use DWI

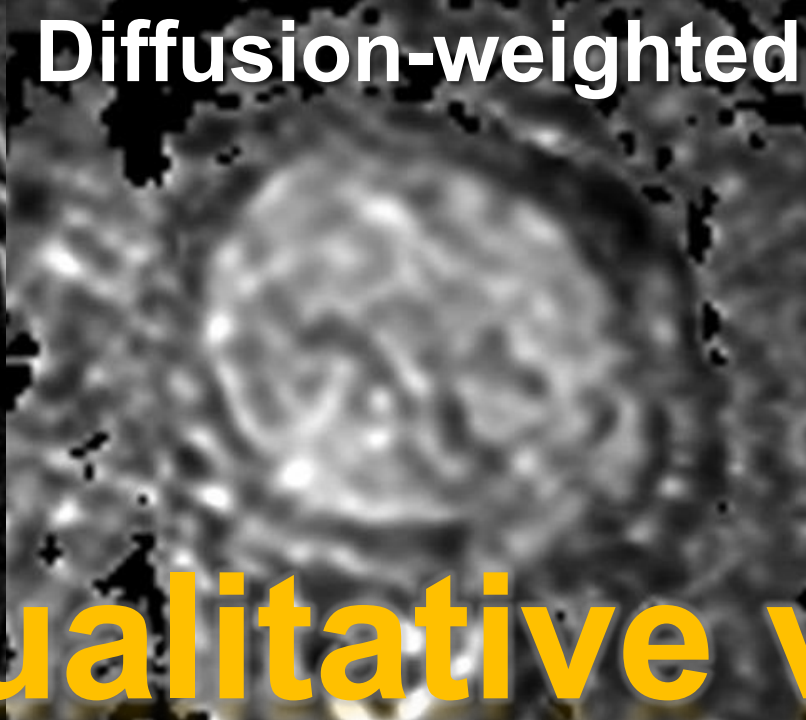
†If no DWI, use DCE

# Qualitative vs. Quantitative Imaging

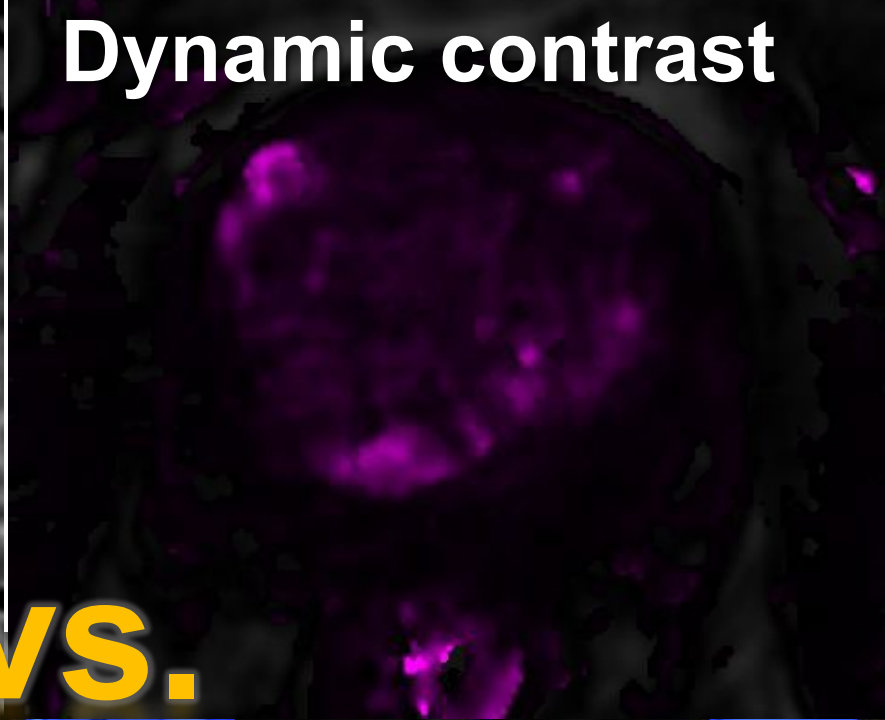
T2-weighted



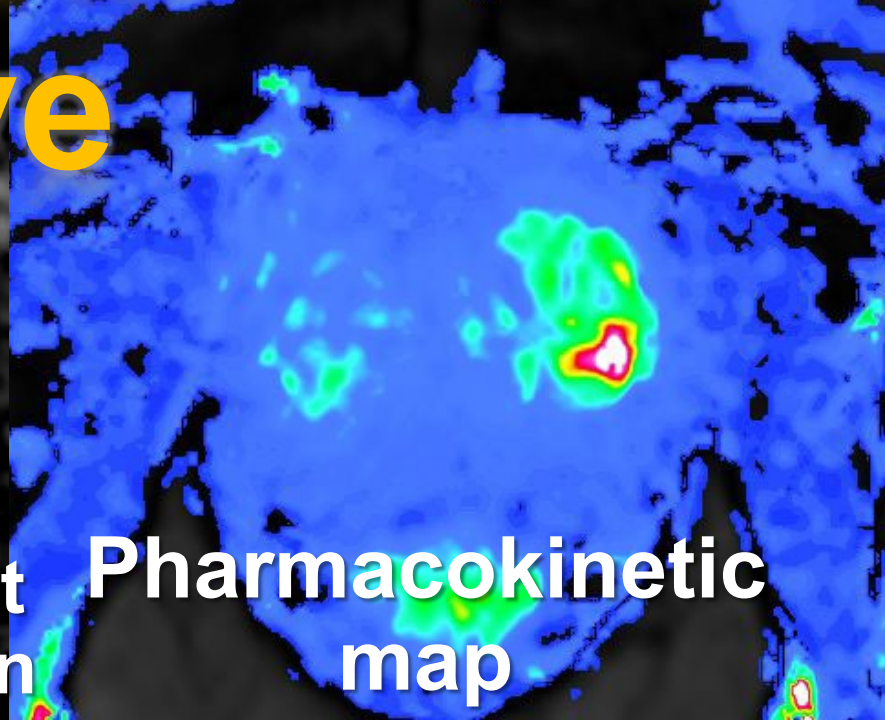
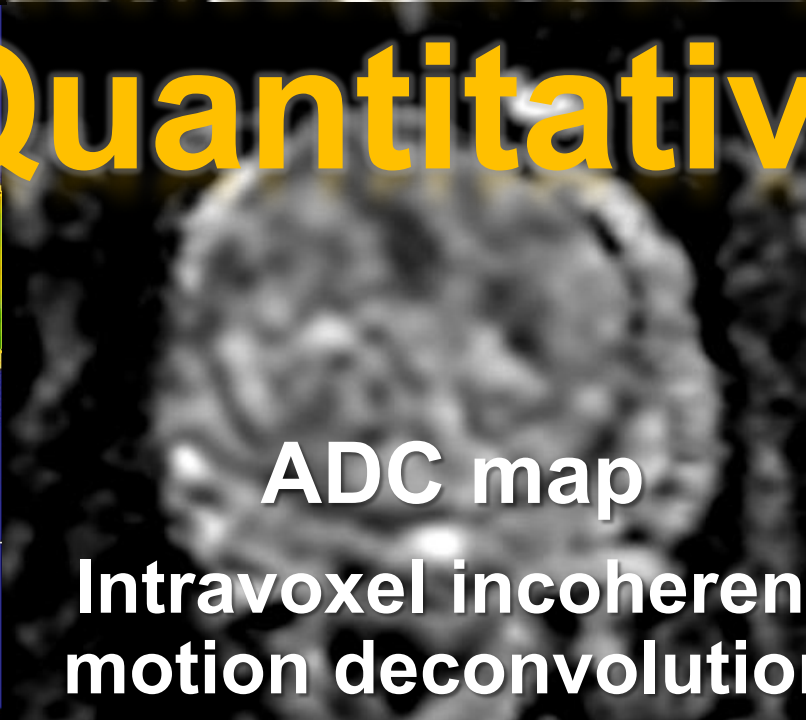
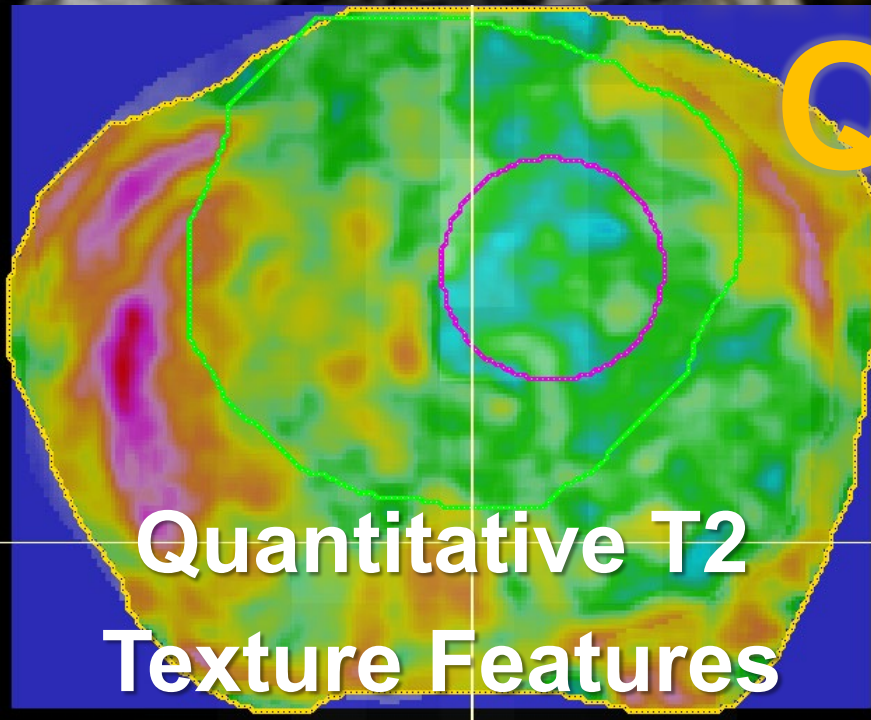
Diffusion-weighted



Dynamic contrast



# Qualitative vs. Quantitative



ADC map

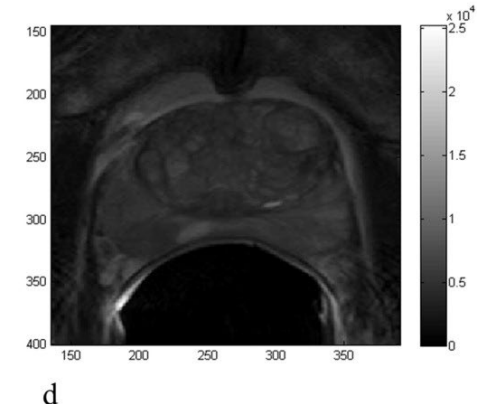
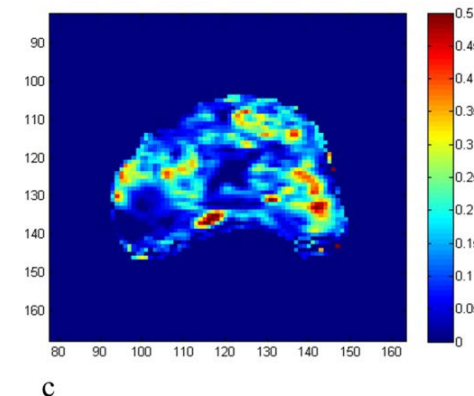
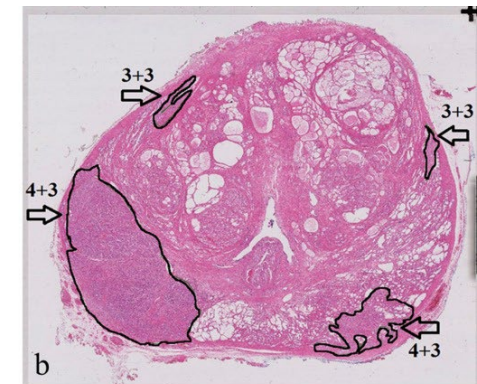
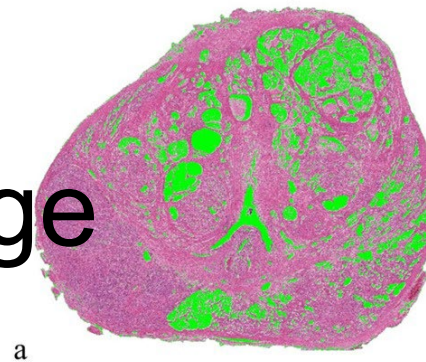
Intravoxel incoherent motion deconvolution

Pharmacokinetic map

Quantitative T2 Texture Features

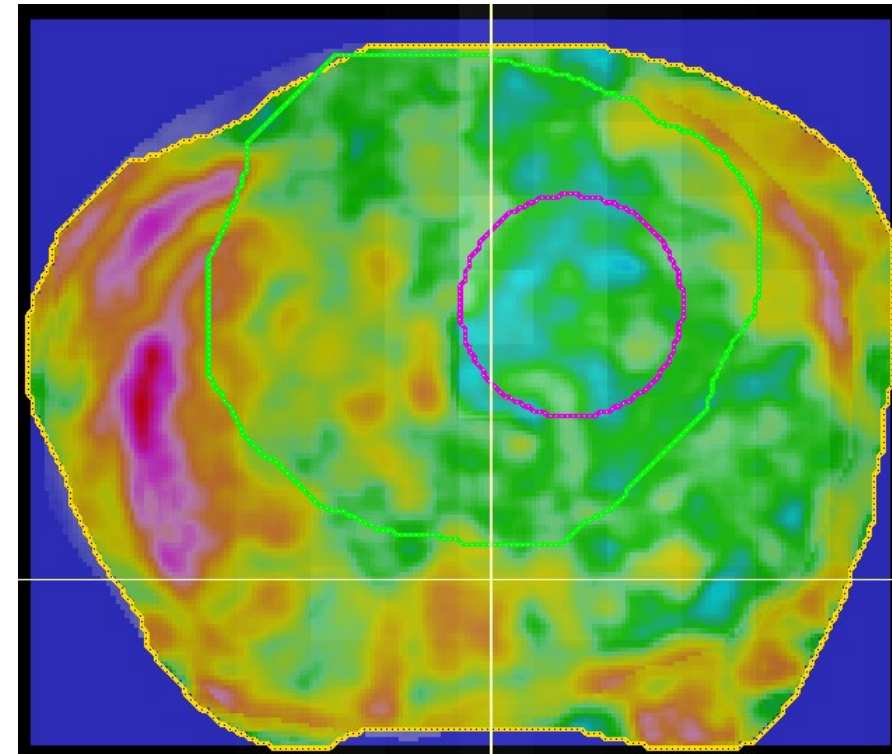
# Quantitative T2

- Quantitative T2 measurement: time consuming 2-4x
- T2 of cancer  $\ll$  normal tissue, high  $\ll$  low grade
- No significant detection advantage
- Lower resolution



# T2 Texture Features

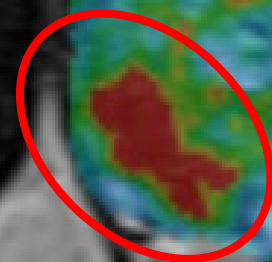
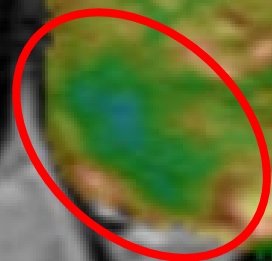
- **Quantitative** analysis of **qualitative** T2WI
  - All post-processing = no extra scan time
- Second-order: energy, entropy
- High-order: Haralick, Gabor
- Detection similar to ADC



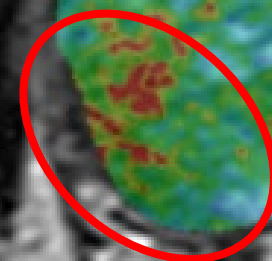
T2-weighted

Entropy

Energy

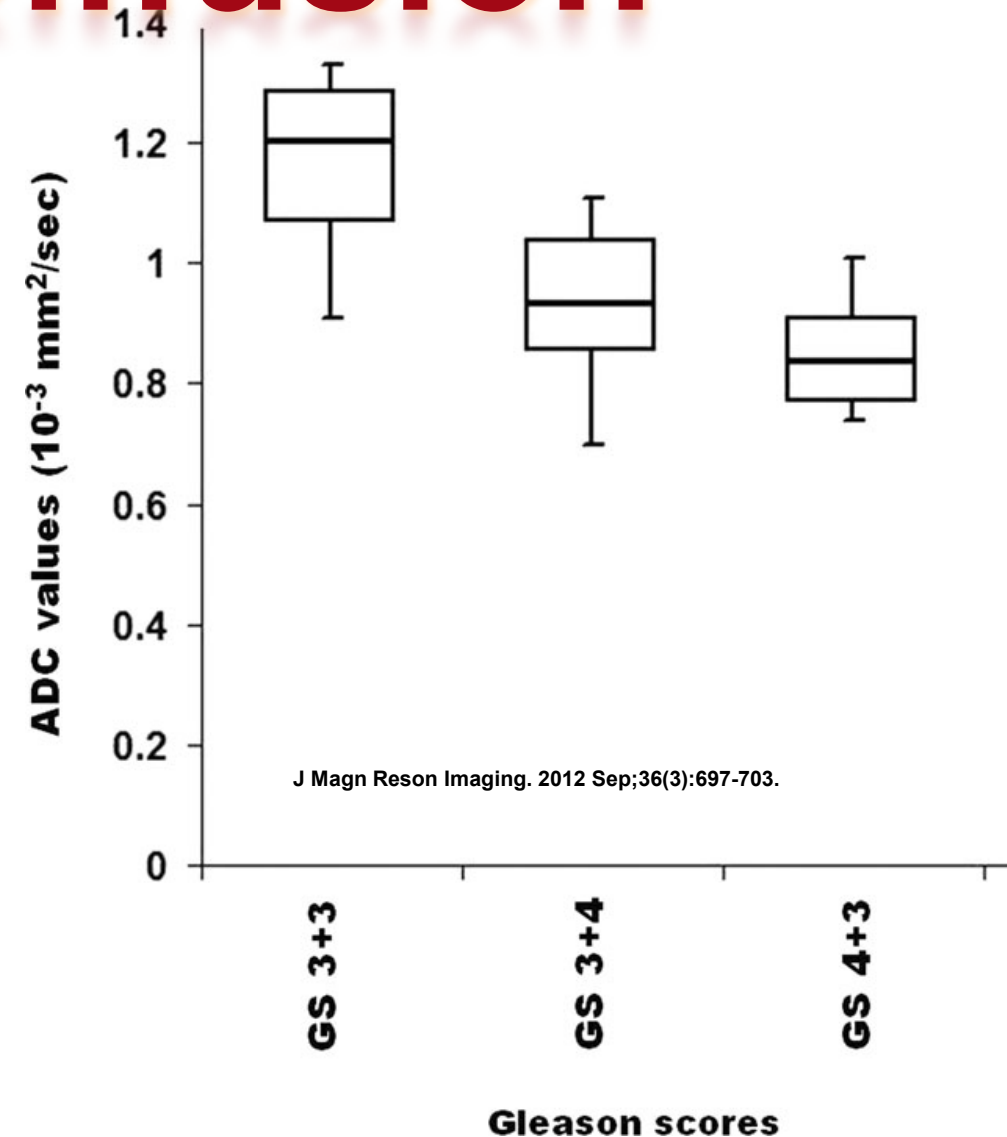


**Texture Features: Response**



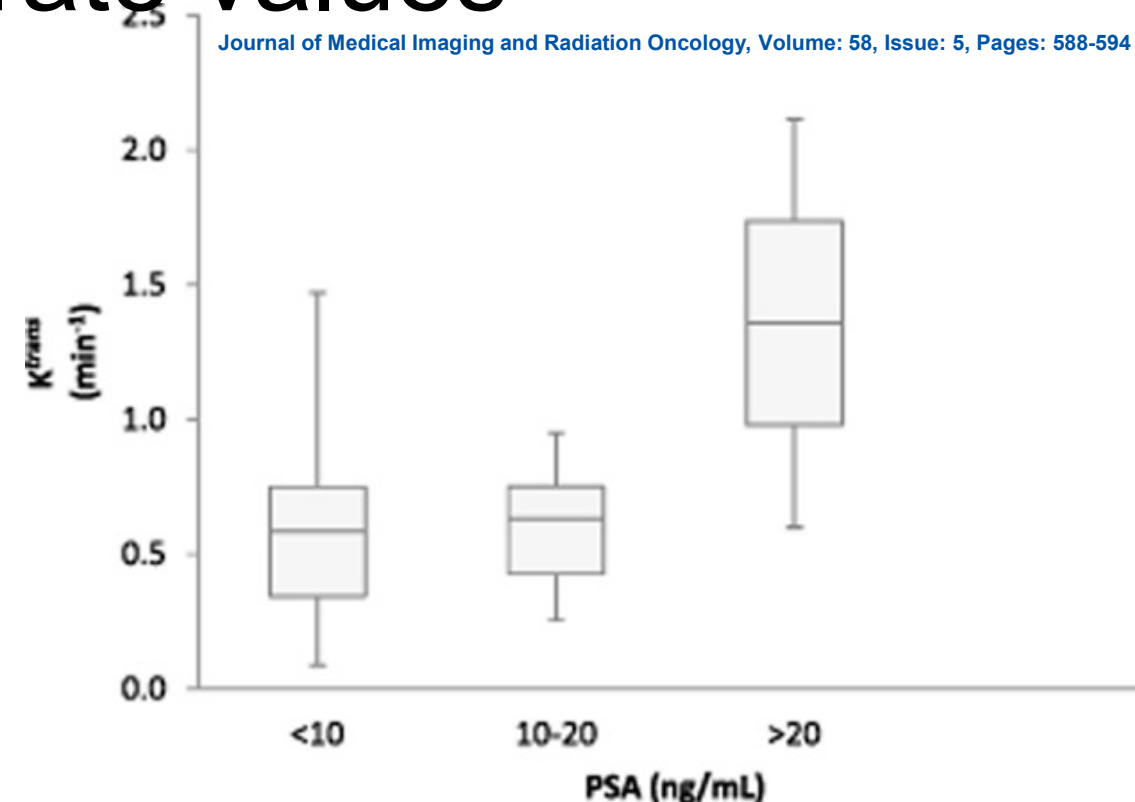
# Quantitative Diffusion

- ADC is the slope of diffusion intensities
- monoexponential model  
$$\text{ADC} = -\ln [S/S(0)]/b$$
- One of the first validated quantitative metrics
  - However, overlap with prostatitis and hyperplasia



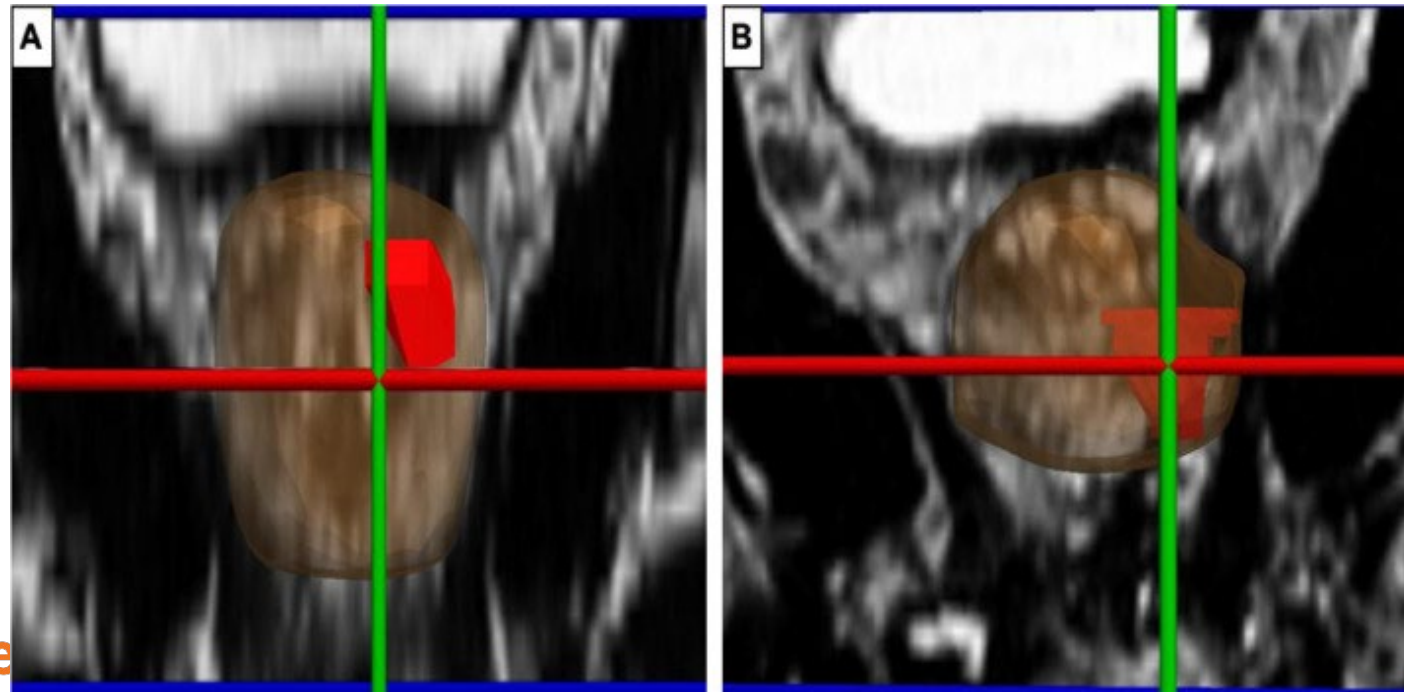
# Quantitative Perfusion

- Based on dynamic contrast-enhancement
- Many workstations will generate values
  - $K^{trans}$
  - $K_{ep}$
  - $V_e$
- These detect cancer, too
  - But can be model-dependent



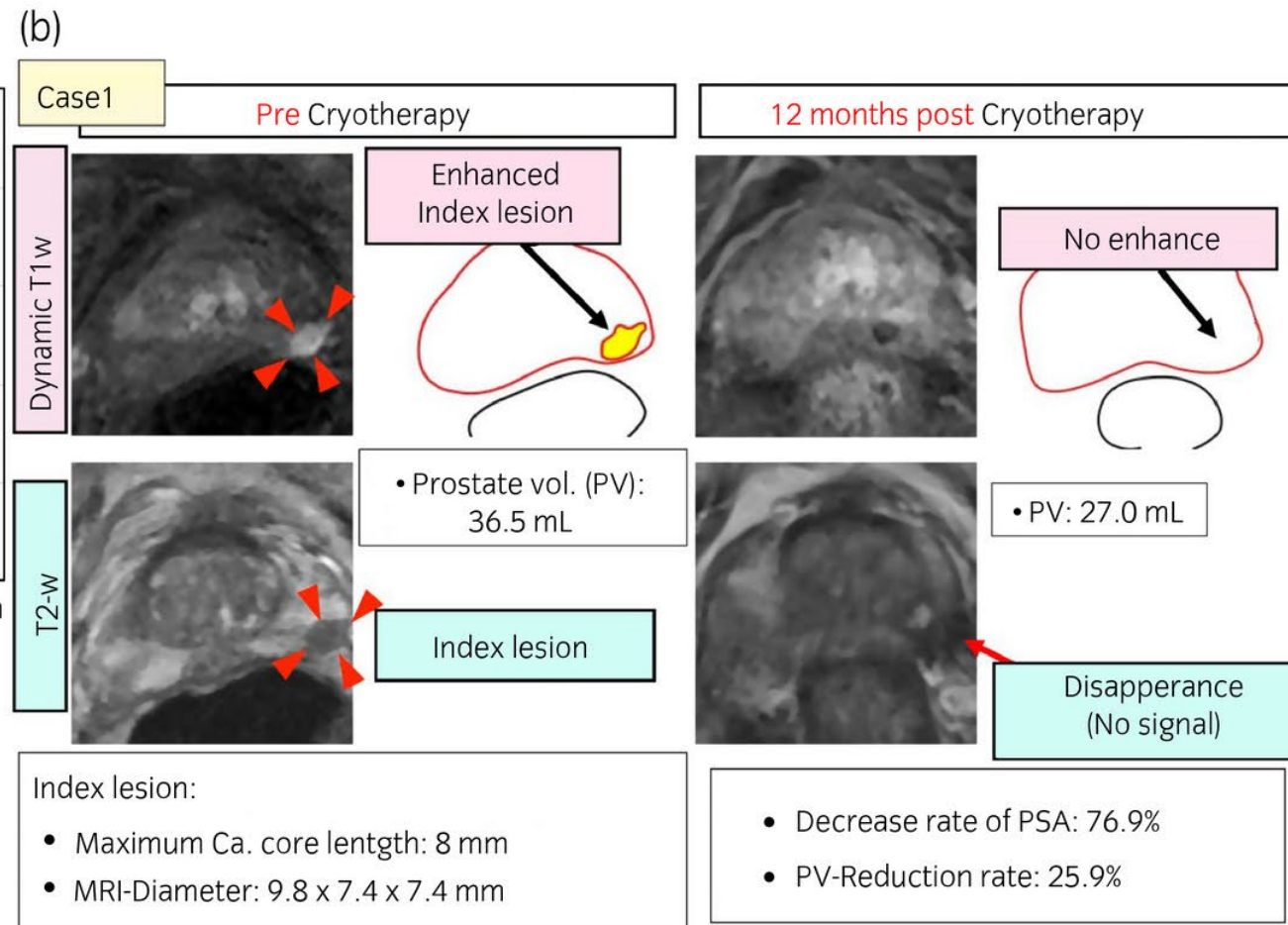
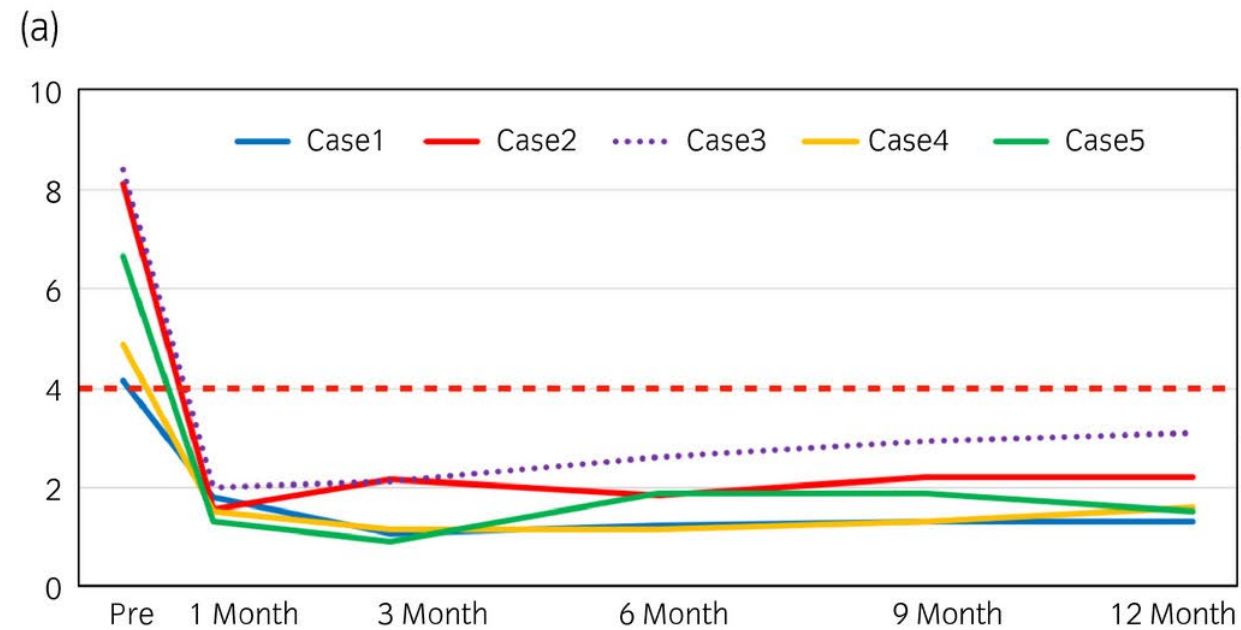
# Quantitative 3D Size Change

- Al Hussein *et al* Urology. 2020 Apr;138:98-105
- Pre- and post-treatment
- Shape of treatment zone + whole prostate changes



# Size + Biochemical Change

• Inoue Int J Urol. 2019 Feb;26(2):317-319

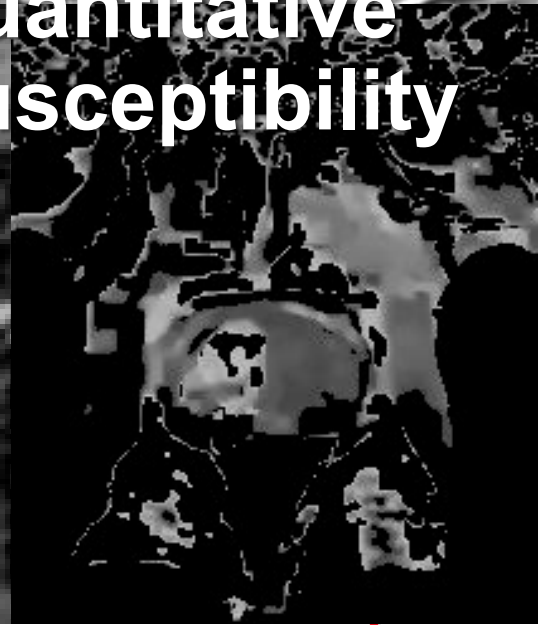
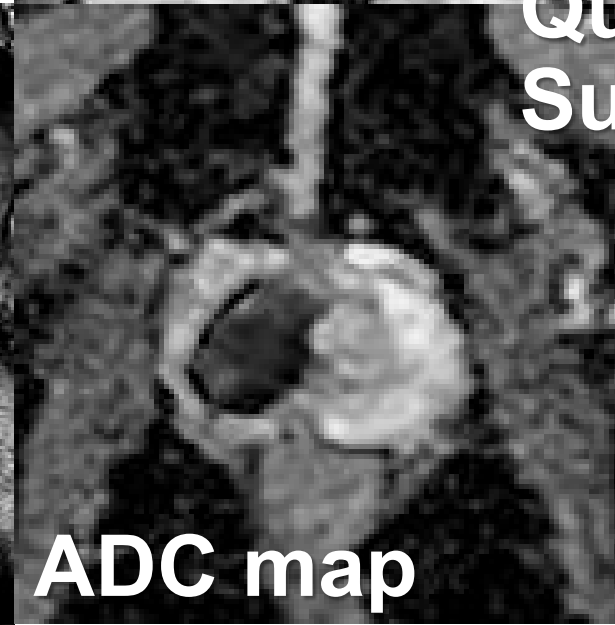
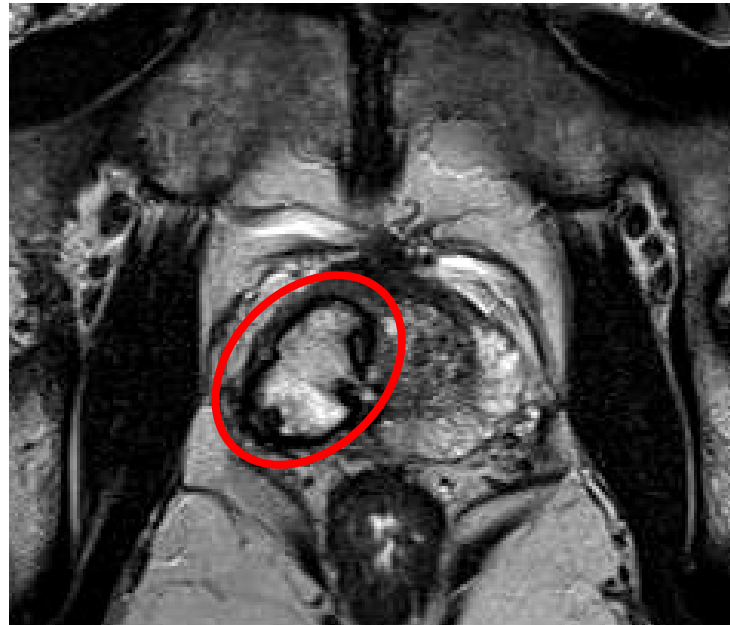
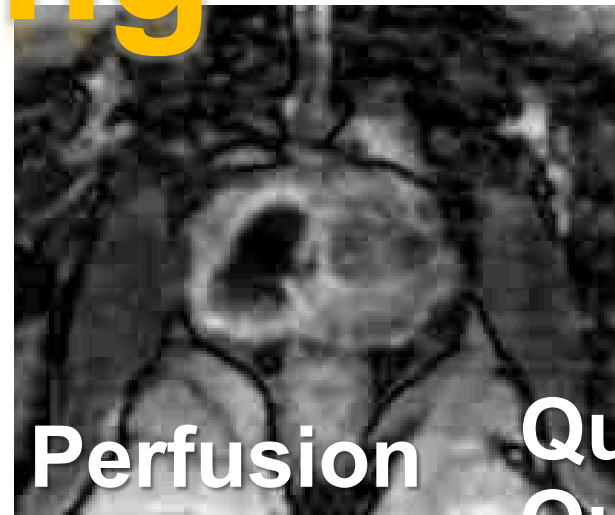


	Pre	1 Month	3 Month	6 Month	9 Month	12 Month
PSA (ng/mL)	6.63	1.55	1.17	1.85	1.86	1.58
Decrease rate of PSA	-	76%	75%	71%	72%	69%

# Future Directions

# Susceptibility-Weighted Imaging

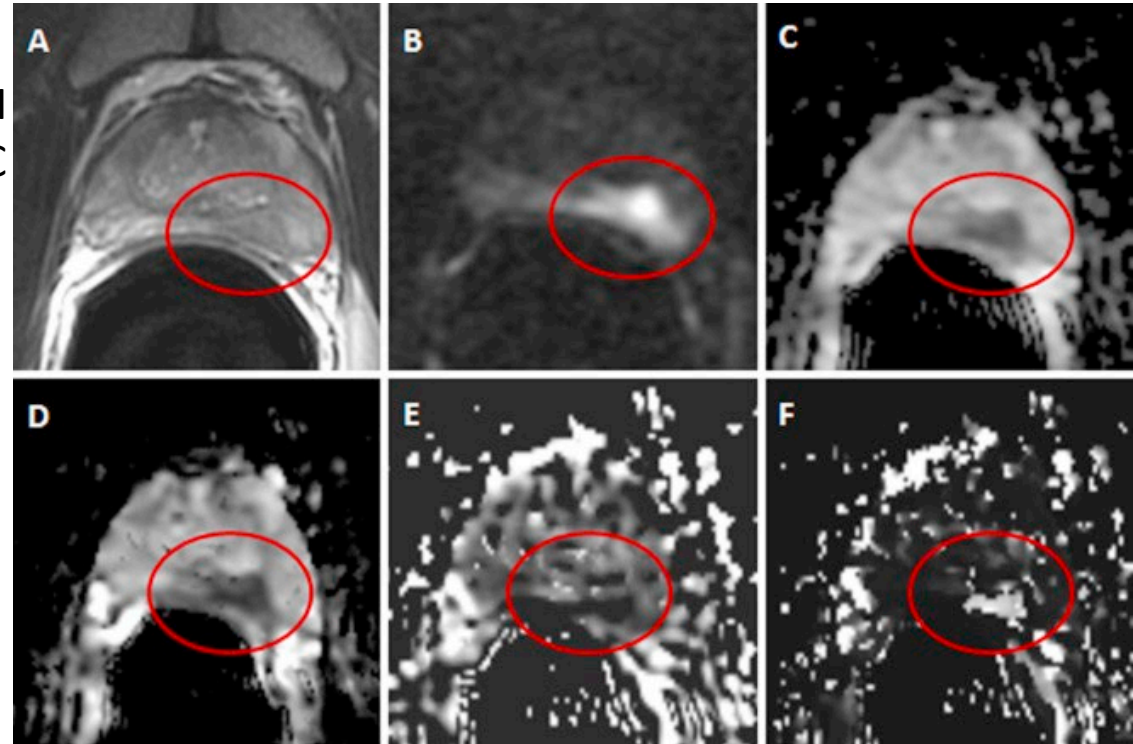
- Quantifies magnetic susceptibility
- Best correlates to mineral deposition
- Potentially identifies hemorrhage



# Complex Diffusion Imaging

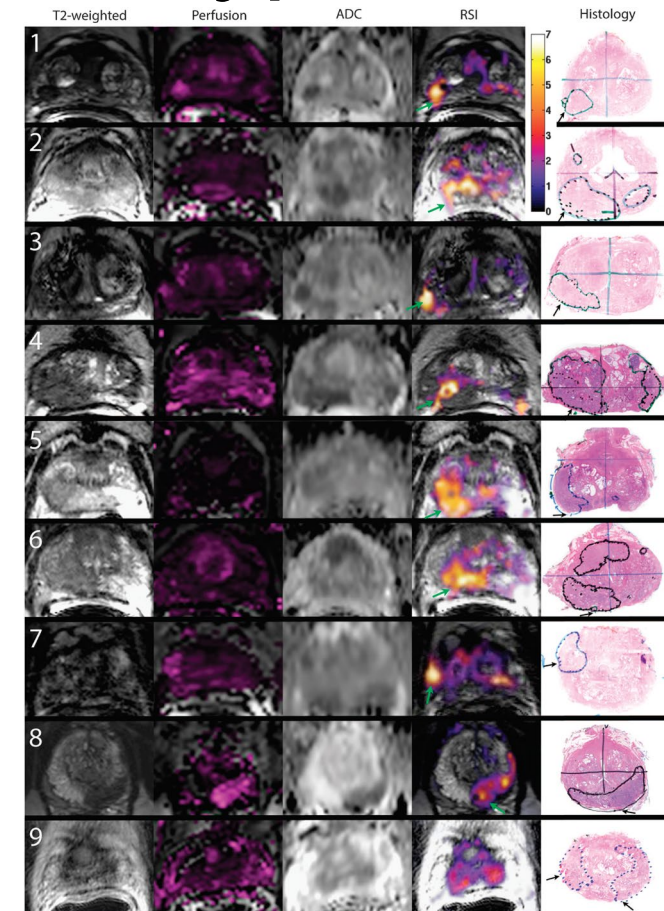
- Intravoxel incoherent motion (IVIM) deconvolution
  - $D$  molecular diffusion
  - $f$  fractional perfusion
  - $D^*$  perfusion-diffusion
- Diffusion kurtosis
  - High b-value signal deviation
- Both show variable improvement over ADC

A. T2  
B. DWI  
C. ADC  
D.  $D$   
E.  $f$   
F.  $D^*$



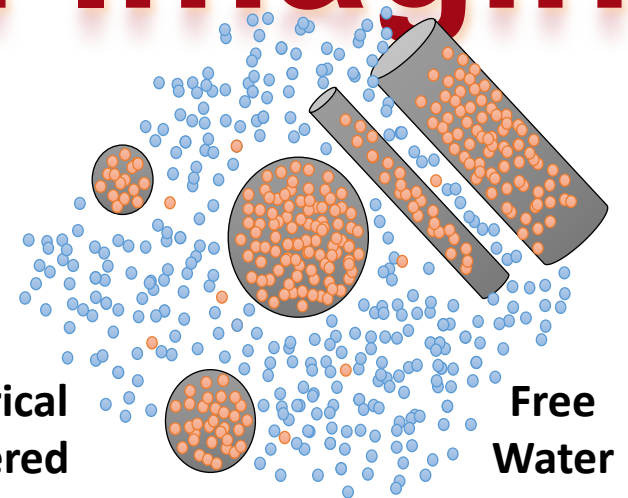
# Advanced Diffusion

- Complex acquisition can discriminate cell types
  - Restriction-spectrum imaging
  - Luminal water imaging (also T2)
  - VERDICT
- Improved performance vs. ADC alone
- RSI FDA approved soon
- U Chicago, VERDICT research only



# Restriction Spectrum Imaging

Apparent Diffusion "Spectrum"



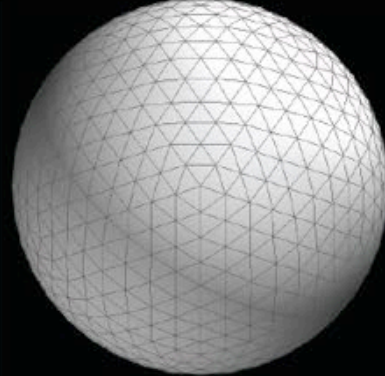
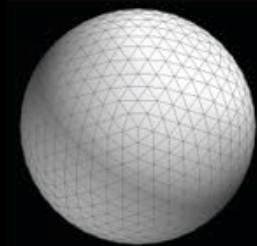
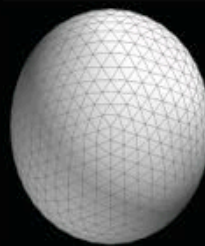
Spherical Restricted

Cylindrical Restricted

Cylindrical Hindered

Spherical Hindered

Free Water

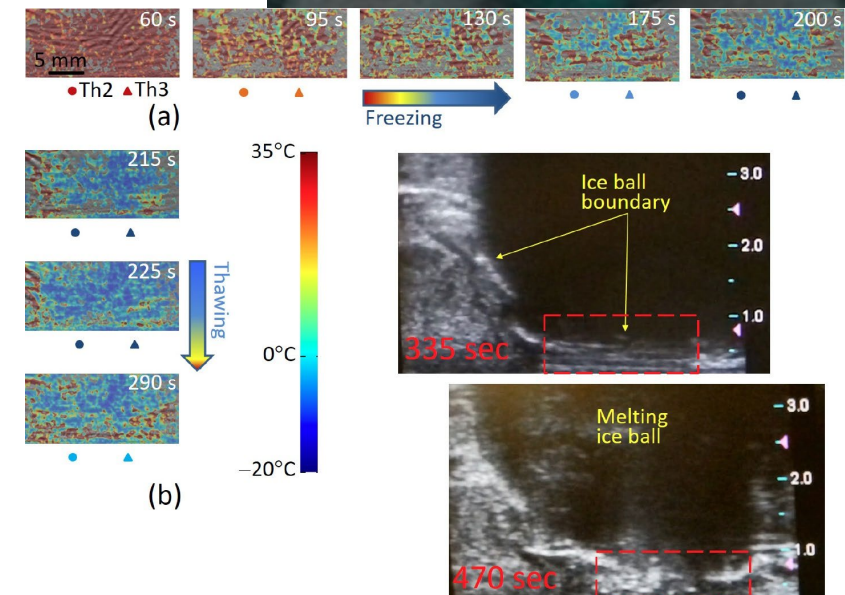
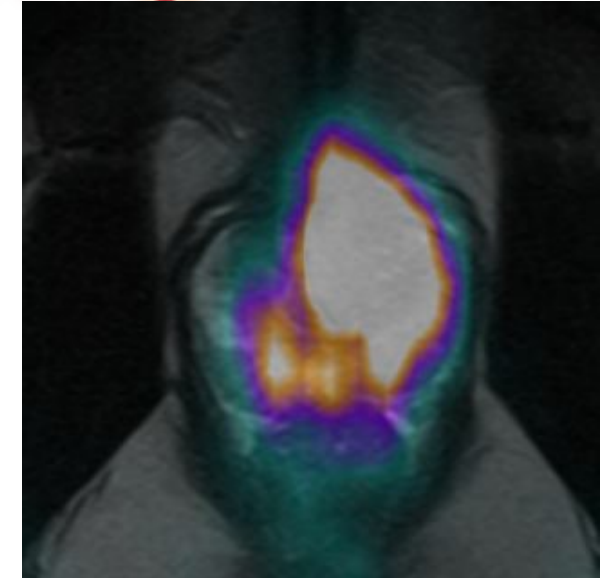


Restricted

Hindered

# Combination Imaging

- PSMA PET-MRI
  - Local + regional detection for recurrence
  - Performance of PSMA undetermined
- Thermoacoustic imaging
  - Petrova *et al* Phys Med Biol. 2018 Mar 21;63(6):064002
  - Combination of grayscale ultrasound and temperature measurement



# What is Artificial Intelligence?

How Can AI Be Used for Prostate Imaging?

# ARTIFICIAL INTELLIGENCE

Early artificial intelligence stirs excitement.

# MACHINE LEARNING

Machine learning begins to flourish.

# DEEP LEARNING

Deep learning breakthroughs drive boom.

**From nvidia (the graphics card)**

1950's

1960's

1970's

1980's

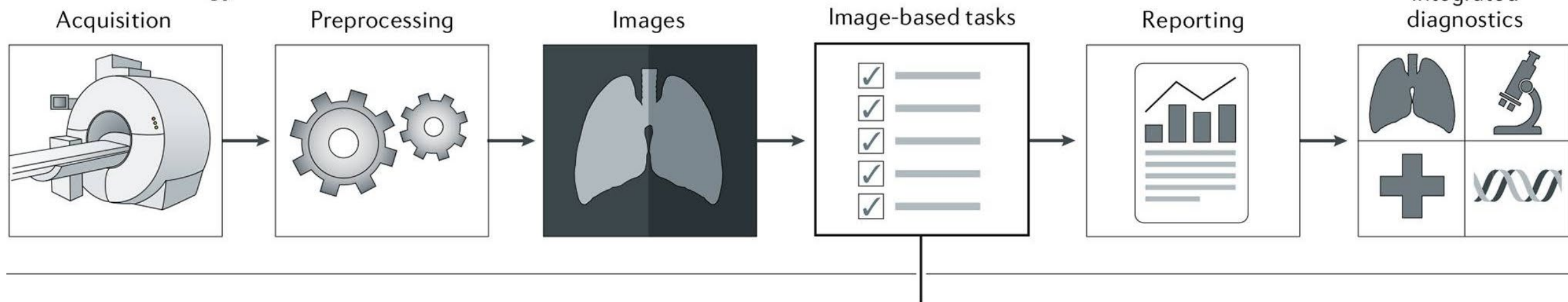
1990's

2000's

2010's

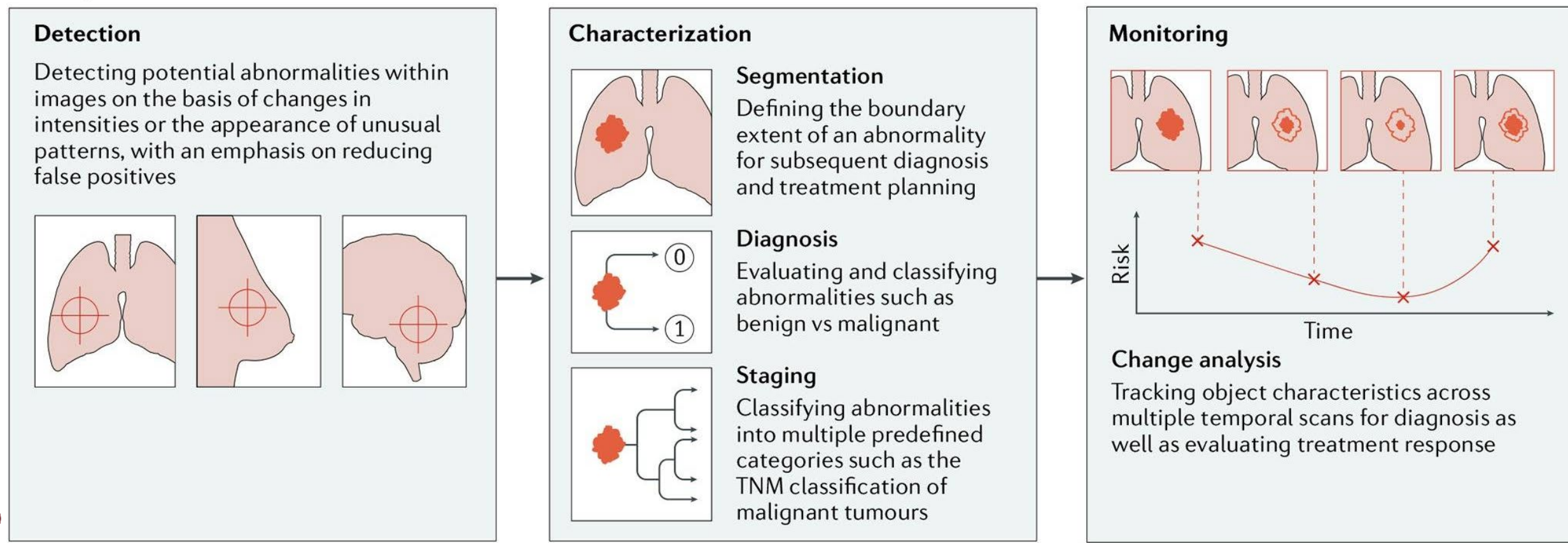
Since an early flush of optimism in the 1950s, smaller subsets of artificial intelligence – first machine learning, then deep learning, a subset of machine learning – have created ever larger disruptions.

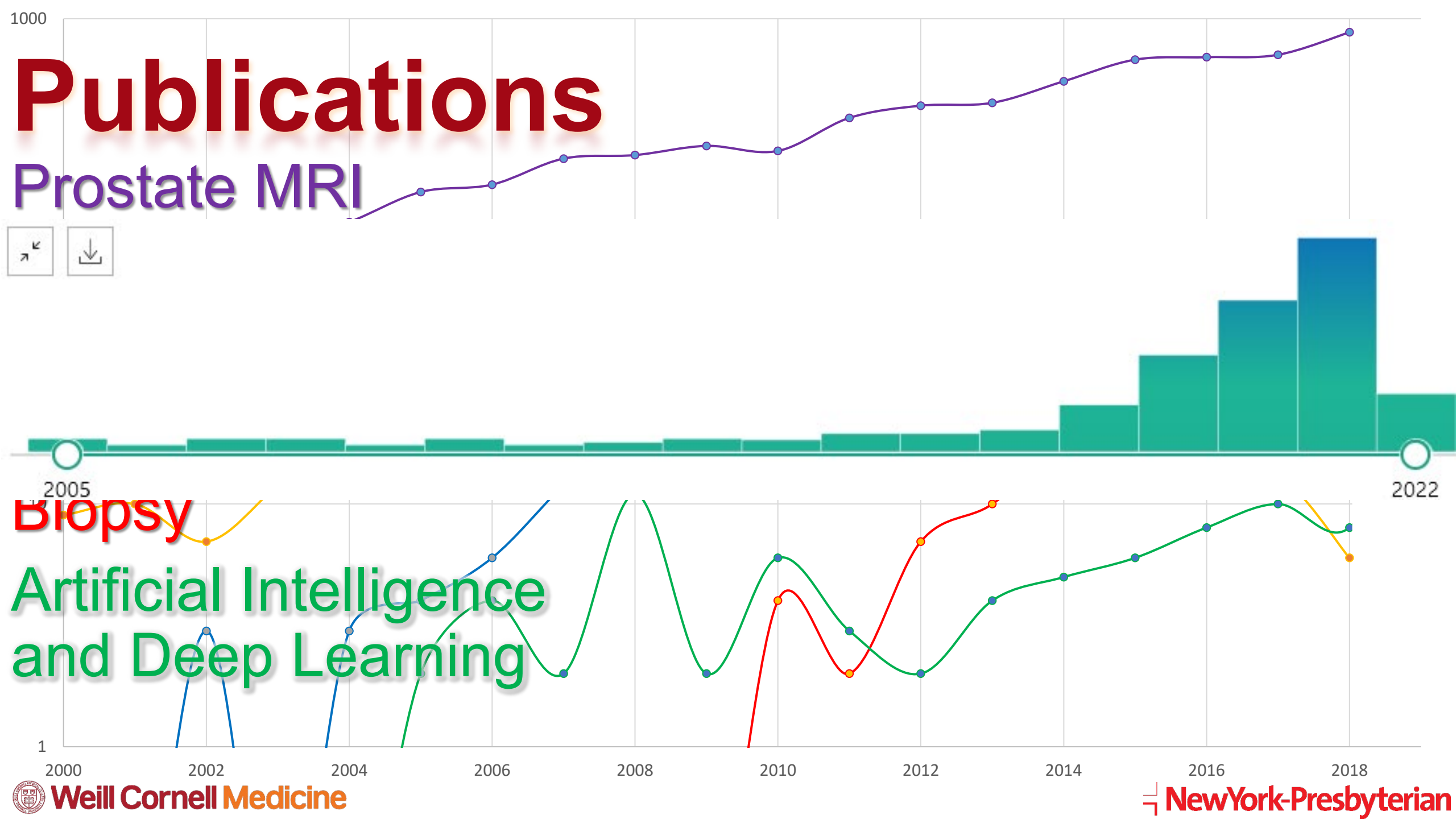
## a Clinical radiology workflow



## b Image-based tasks

From Hosny *et al* National Review of Cancer 2018





# Publications

## Prostate MRI

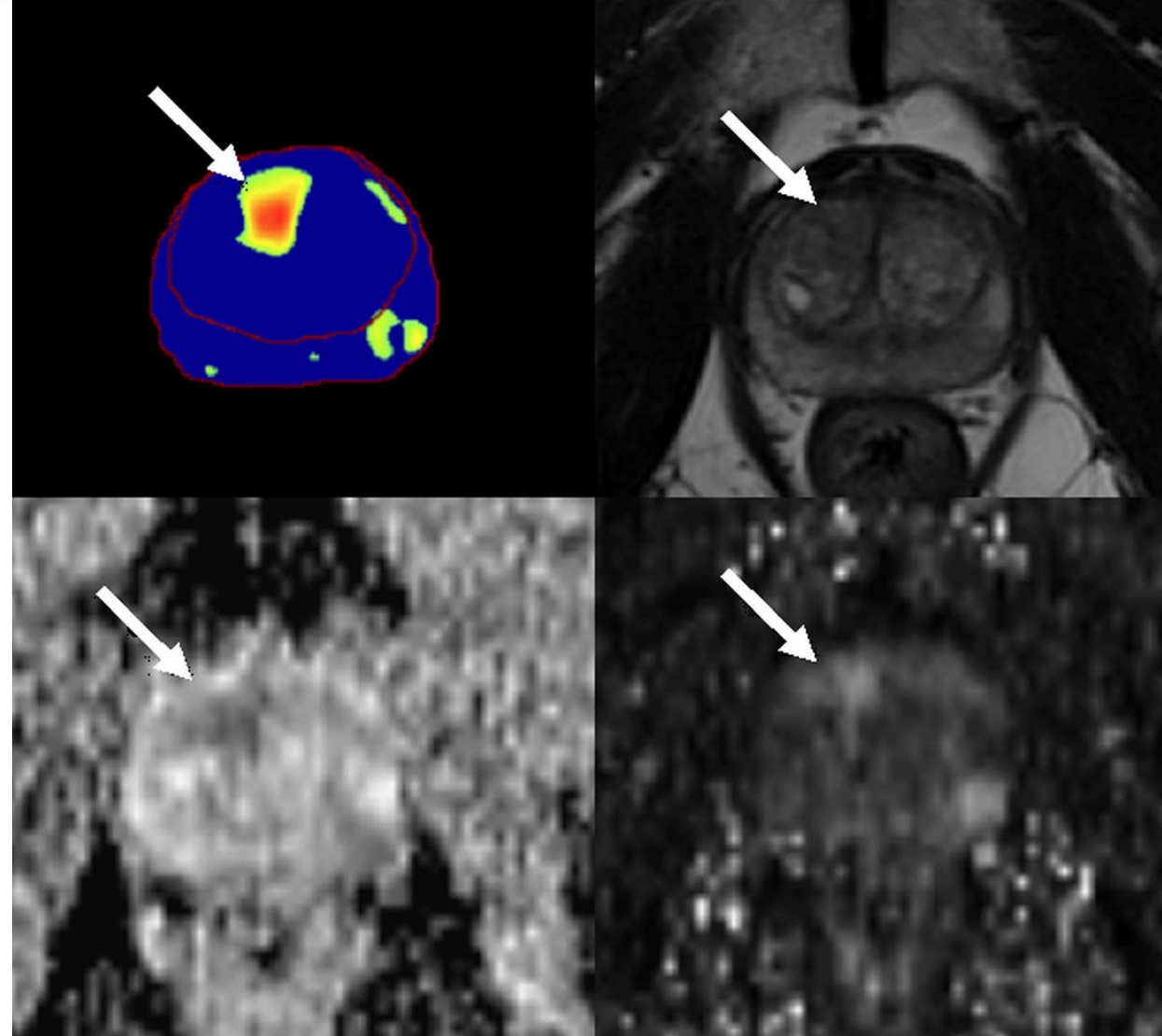


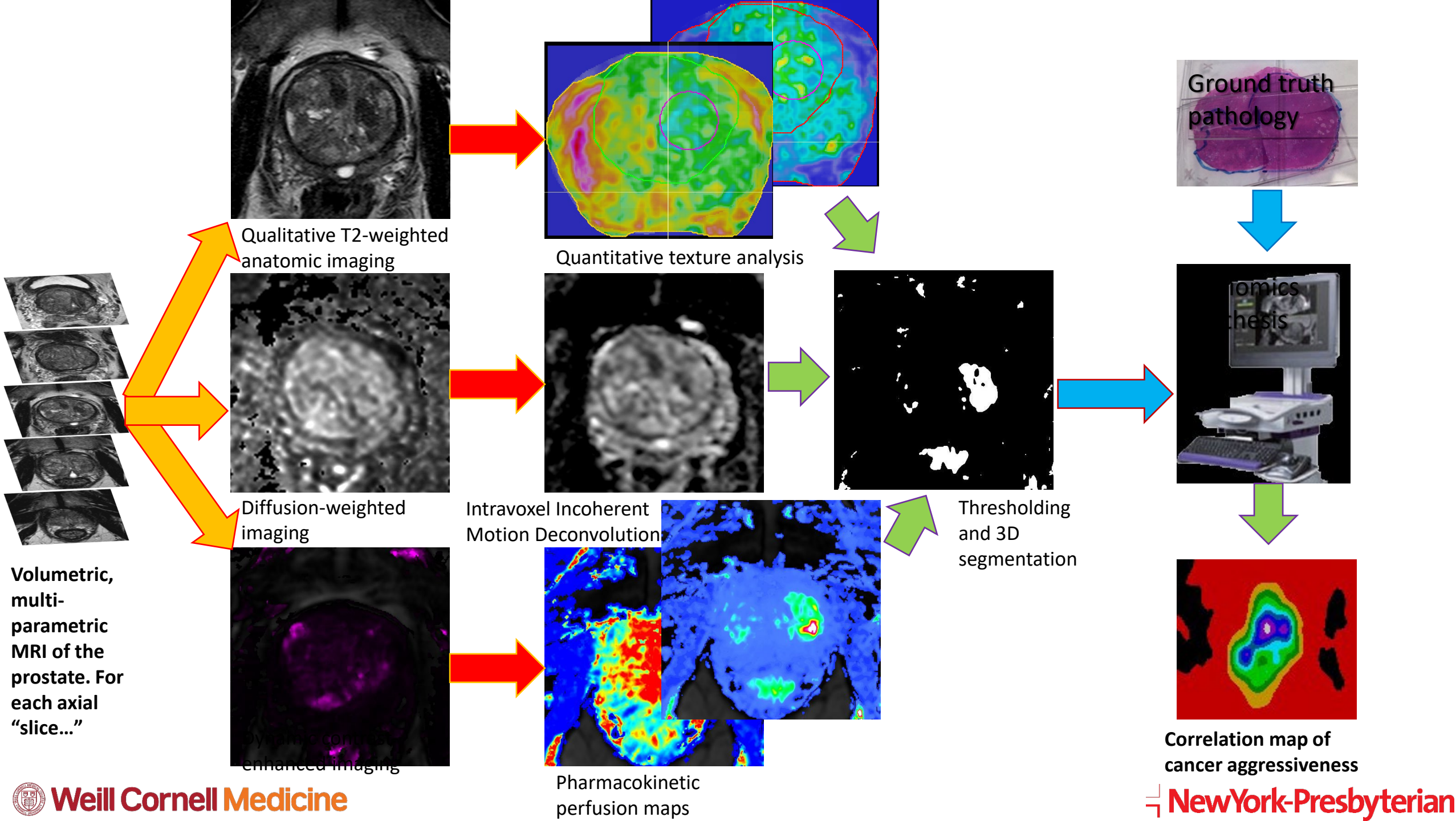
# Biopsy

## Artificial Intelligence and Deep Learning

# AI for Prostate MRI?

- But of course!
- Many commercial solutions being developed
- Approach is varied
  - Guided vs. holistic
  - T2 only vs. multiple series
  - Target vs. whole prostate
- Best use: QC?

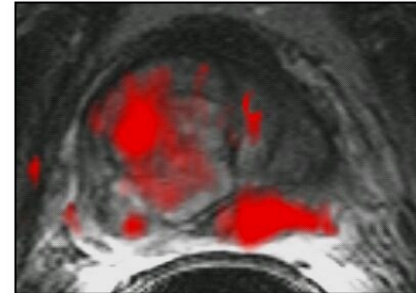
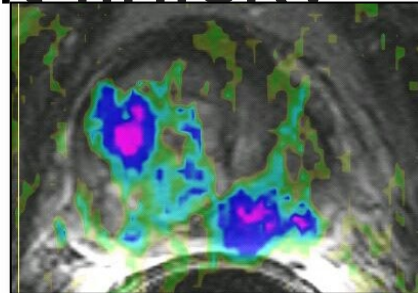
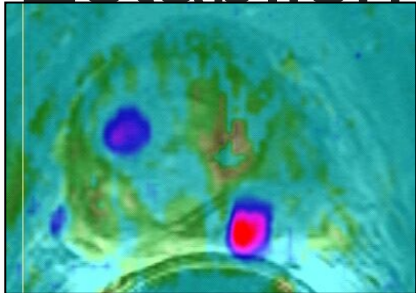
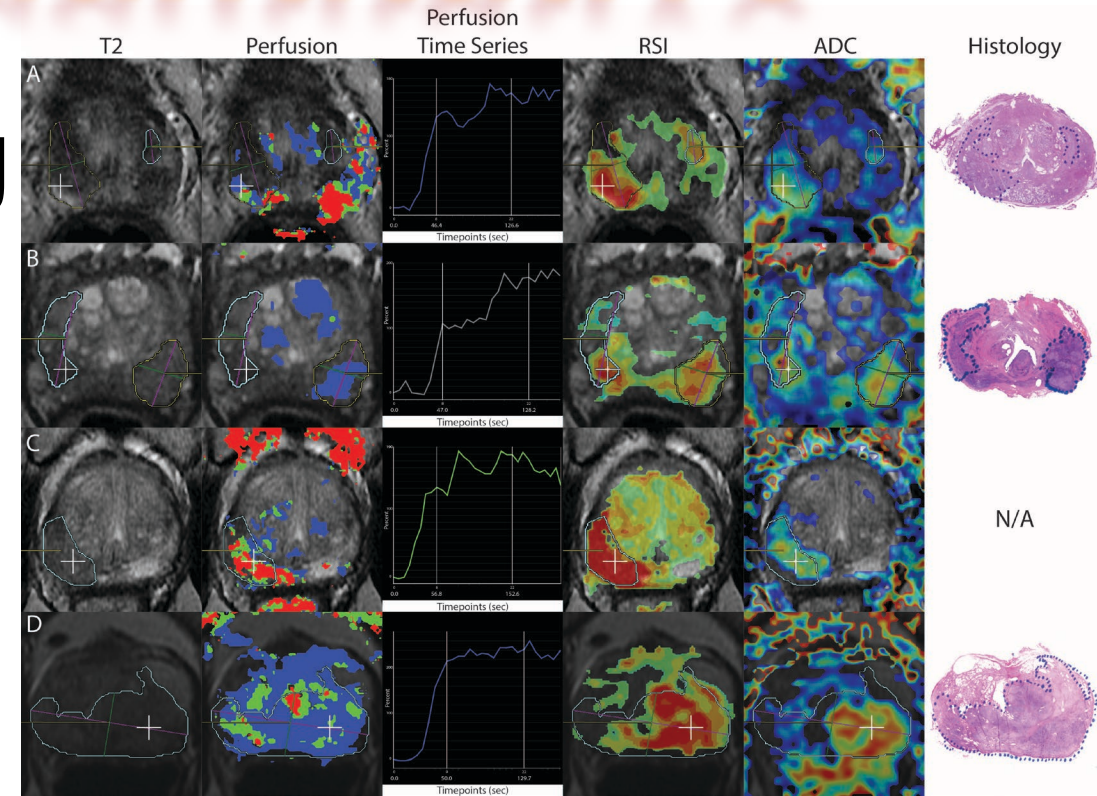




# Near Term and Long Term

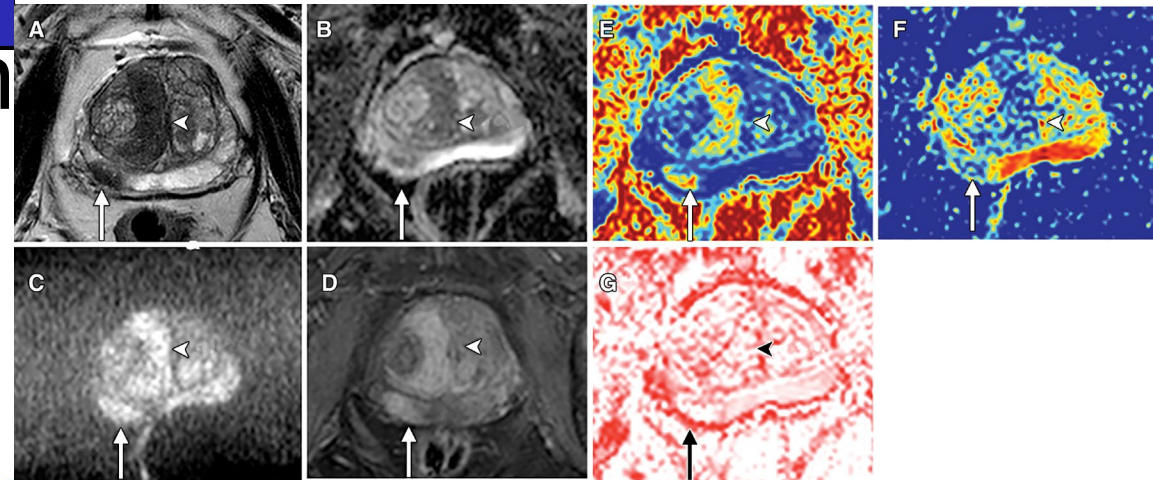
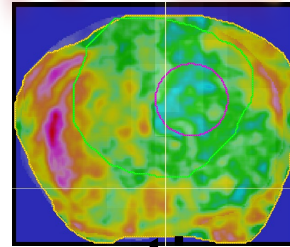
# Near Term: Quantitative

- Restriction Spectrum Imaging
  - Best non-contrast scan?
- Dynamic Contrast Modeling
  - Established, but finicky

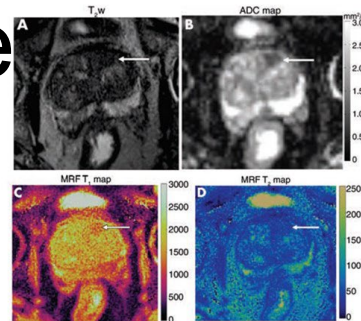


# Long Term: Quantitative

- T2 Texture Features
  - Answer looking for a question
- VERDICT
  - Validated but not available
- “MRI Fingerprinting”
  - Multiple scans at once
  - Validated in brain



MR Fingerprinting and ADC Mapping for Characterization of Lesions in the Transition Zone of the Prostate Gland

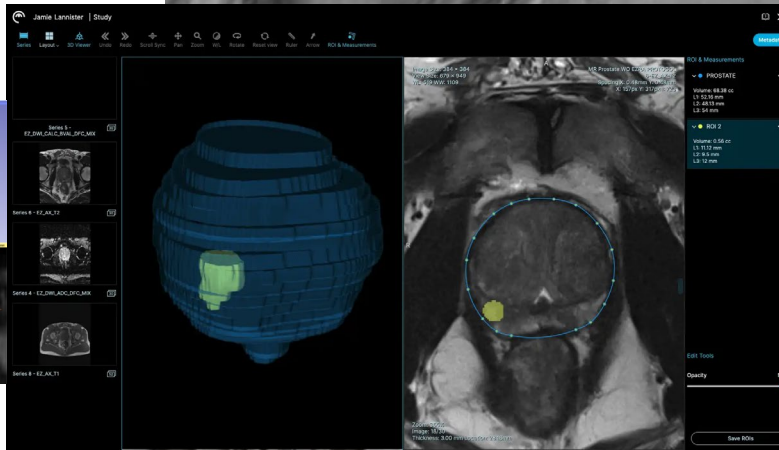
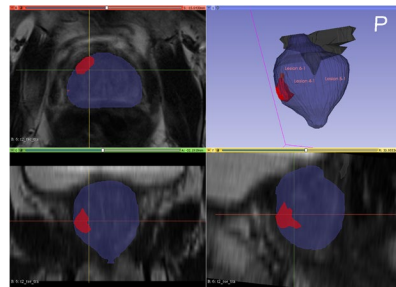
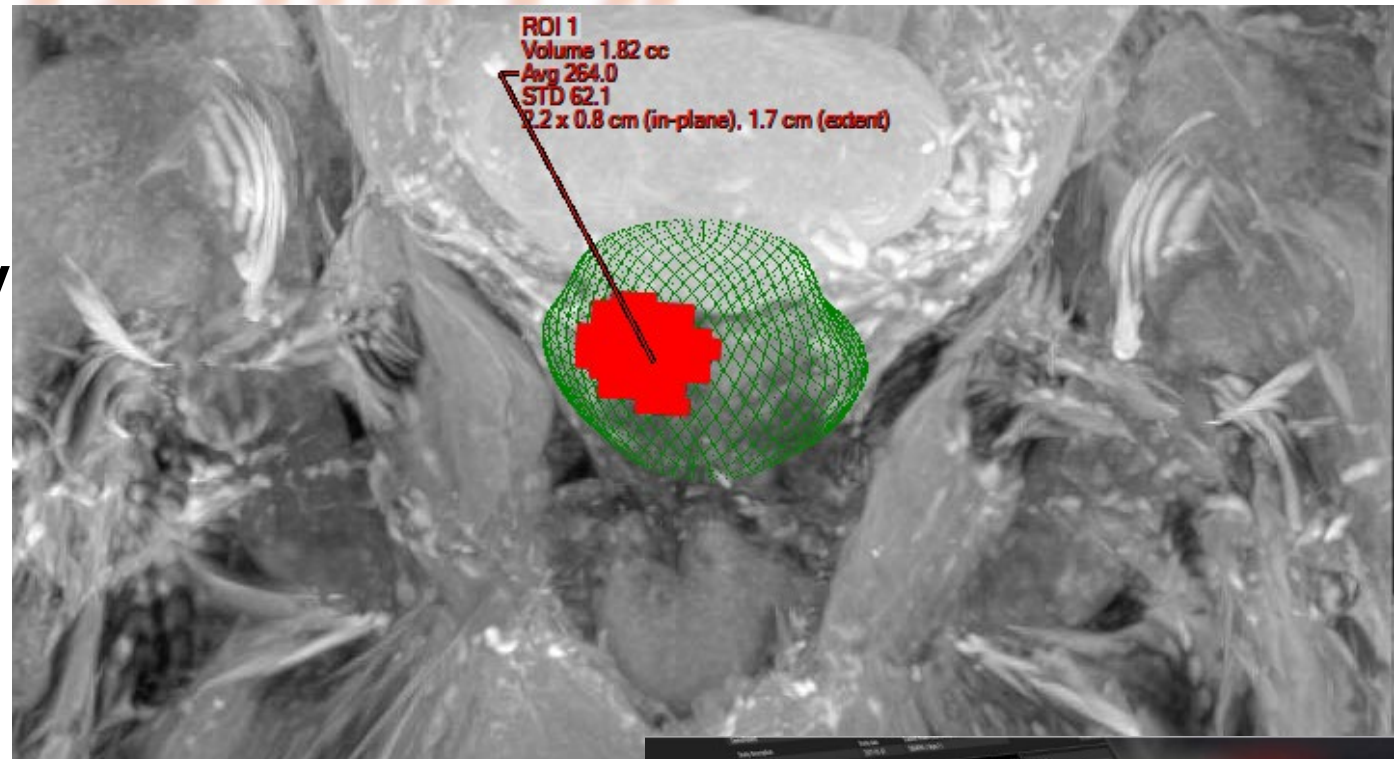


T2-weighted MRI, ADC mapping, and T1 and T2 MR fingerprinting mapping from targeted biopsy-proven prostate cancer.

- For Prostate Imaging Reporting and Data System (PI-RADS) category 3 lesions, noncancers had longer T1 relaxation times than cancers (1630 msec vs 1430 msec respectively;  $P = .006$ ).
- The diagnostic performance of T1 relaxation time at MR fingerprinting for PI-RADS category 3 cancers from noncancers was  $AUC = 0.79$ .
- A combination of MR fingerprinting-based T1 relaxation time and ADC mapping can help differentiate transition zone cancers from noncancers ( $AUC = 0.94$ ).

# Near Term: AI

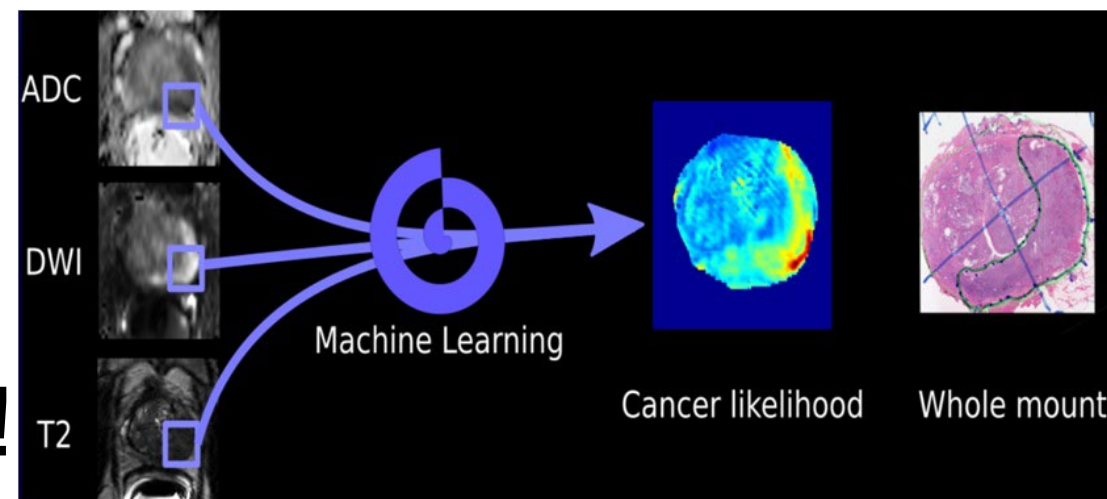
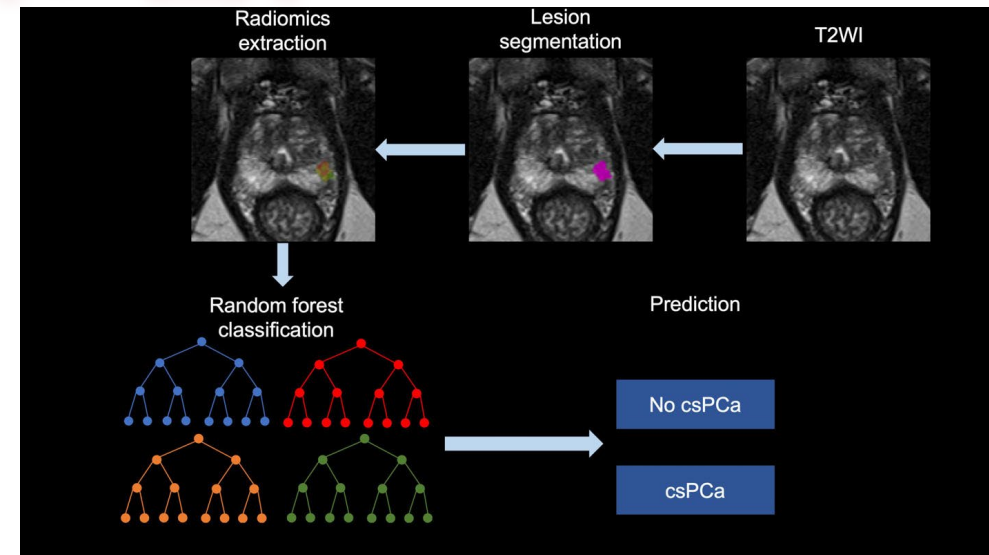
- Prostate segmentation
  - Widely used for UroNav
  - Semi-automatic lesion segmentation
- Multiple companies
  - Promises, promises
  - Results?



Lucida, Ezra, and Quantib

# Long Term: AI

- Suspicion grading
  - Many publications
- Management guidance
  - Replacement for 4Kscore?
- Quality Control
  - During the scan itself
- Profession Society Guidance
  - From the PI-RADS committee!



# Take Home Points

- Quantitative MR and Artificial Intelligence are here
  - ADC and segmentation
- The combination will solve many issues
  - Faster scans (no contrast)
  - More accurate classification (significant vs. not)
  - Compensation for experience
  - Quality control
  - Management guidance

# Acknowledgements

- My chair, Robert J Min, for supporting development
- Manjil Chatterji and the Section of Abdominal Imaging
- Jim Hu and Tim McClure in Urology
- Brian Robinson and Francesca Khani in Pathology
- Our referrers and their patients
- My techs for their expediency

# Thank you. Questions?

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