Finding Needles in Interventional Oncology Images

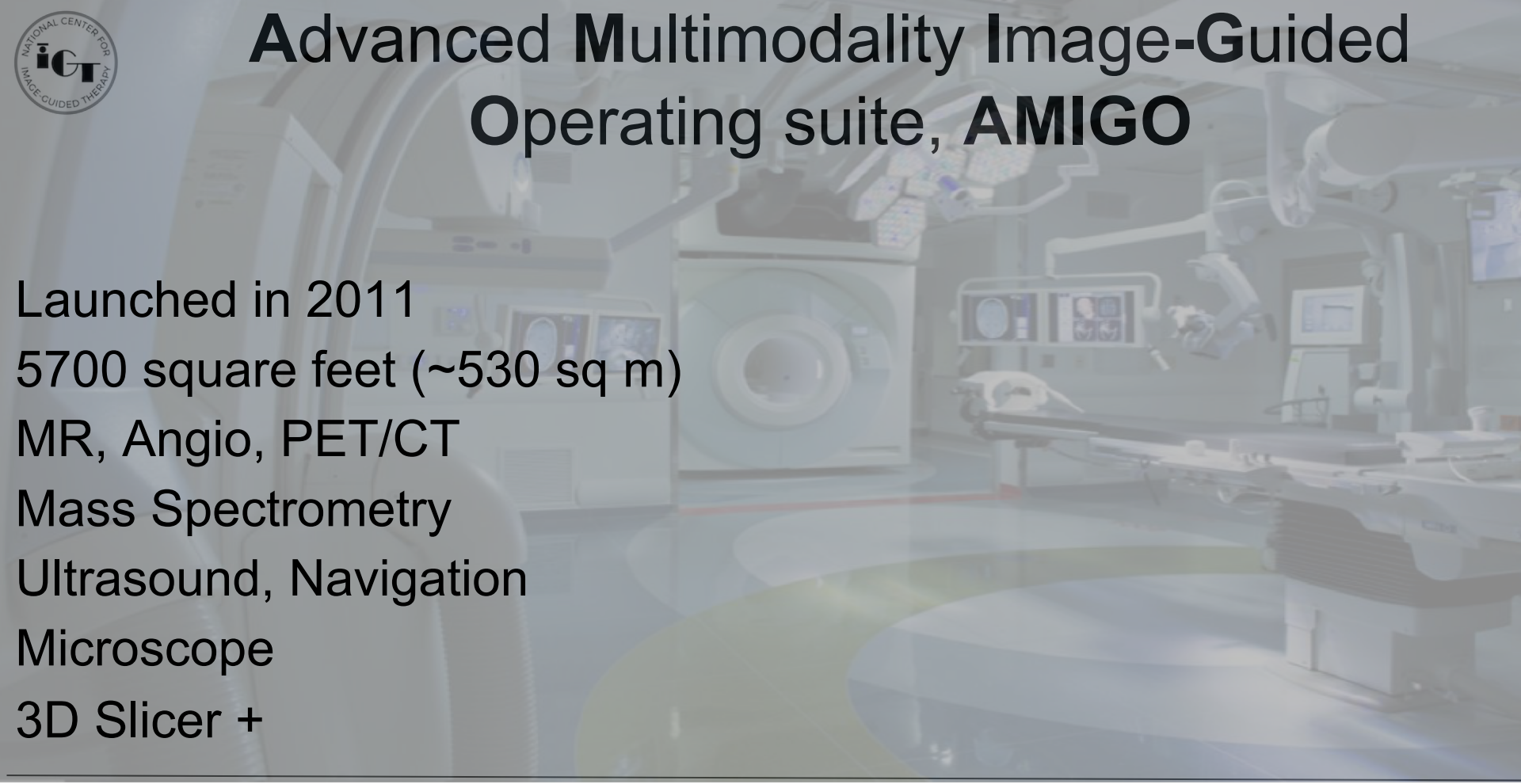
Tina Kapur, PhD
Executive Director, Image-Guided Therapy
Department of Radiology, Brigham and Women's Hospital
Harvard Medical School, Boston

ICERM Computational Imaging Workshop, March 19, 2019

National Center for Image Guided Therapy

NIH Funded Biotechnology Resource Center P41EB015898
PI Clare Tempany, MD
www.ncigt.org

Advanced **M**ultimodality **I**mage-**G**uided **O**perating suite, **AMIGO**



Launched in 2011

5700 square feet (~530 sq m)

MR, Angio, PET/CT

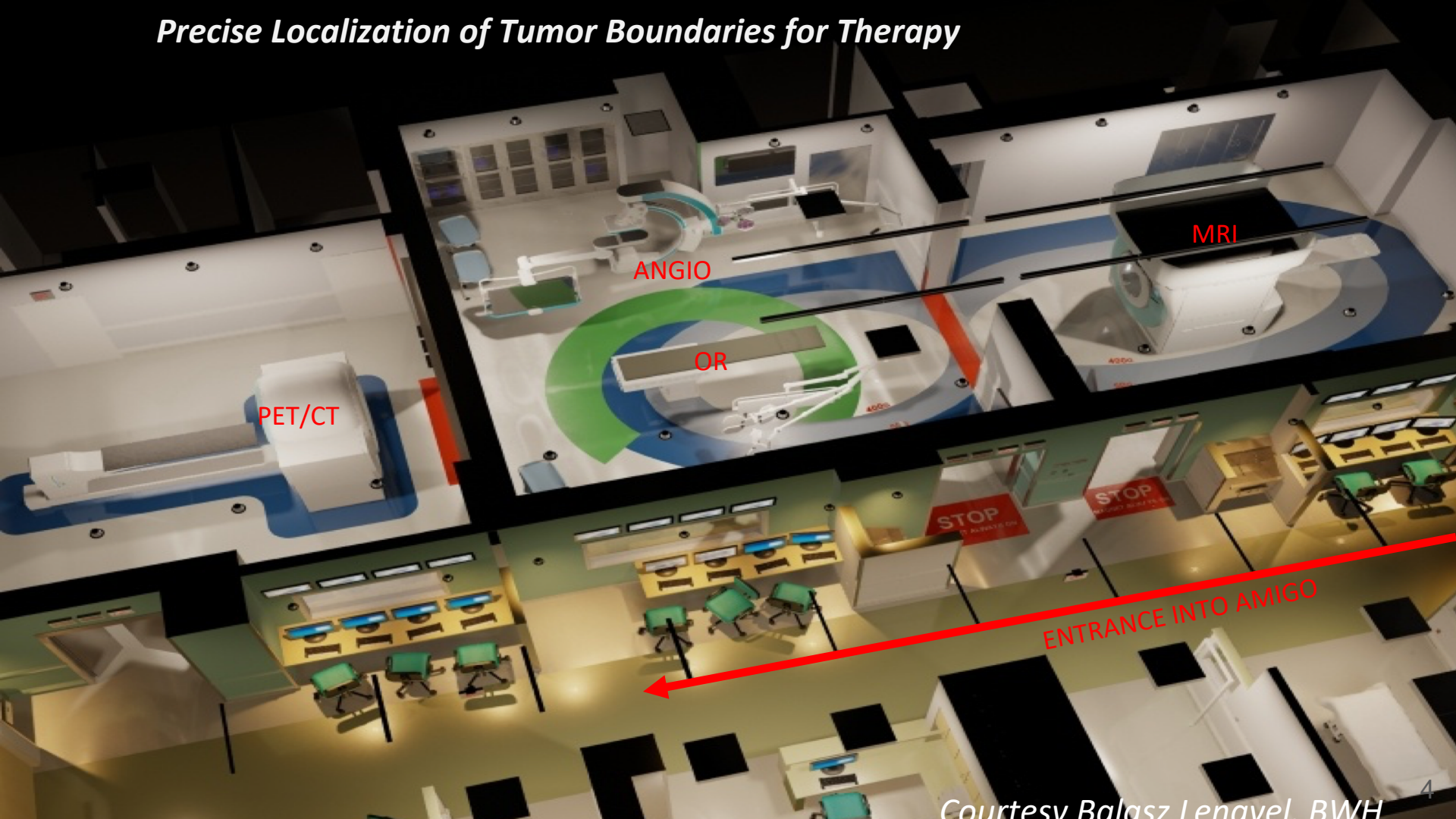
Mass Spectrometry

Ultrasound, Navigation

Microscope

3D Slicer +

Precise Localization of Tumor Boundaries for Therapy



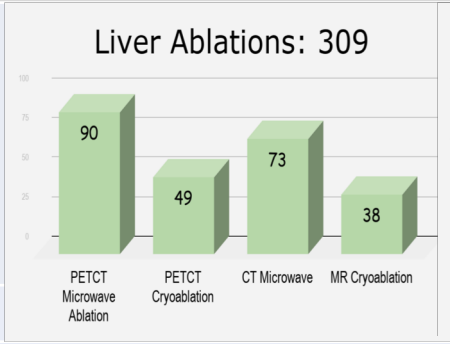
Courtesy Balasz Lengyel, BWH

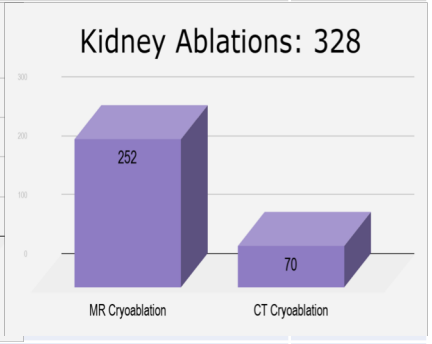
2129 AMIGO Procedures

08/30/2011 – 3/12/2019

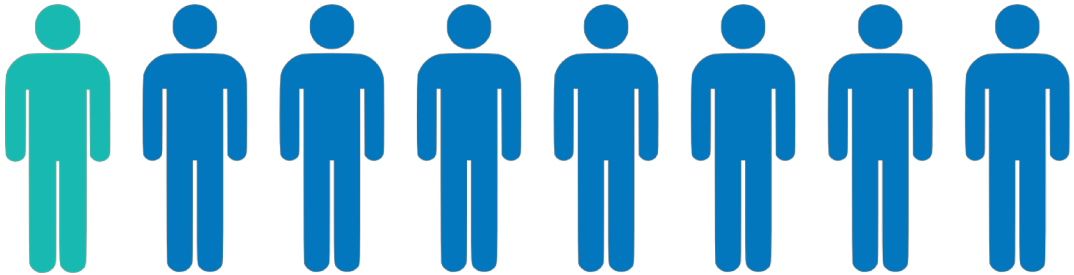
Neurosurgery	462
Brain Tumor Resection	235
Deep Brain Stimulation	109
Brain Tumor Laser Ablation	33
Transsphenoidal Pituitary Tumor Resection	26
Brain Viral Vector	19
Skull Base Surgery	11
Breast Conserving Surgery	**35**
Video-Assisted Thoracoscopic Surgery	**31**
Laparoscopic Intra-abdominal Biopsy	**5**
Endocrine Surgery	**9**
Spine Discectomy and Fusion	**2**
Cardiac EP Ablation	**7**
Radiation Oncology	**144**
Gynecologic HDR Brachytherapy ←	133
Prostate VLDR Brachytherapy	11

Interventional Radiology	1427
ABLATION	867
MR Prostate	36
Lung	42
Spine	42
Head & Neck	30
BIOPSY	554
MR Prostate ←	446
MR, PET CT Lung	27
Transarterial Chemoembolization	**1**





Prostate Cancer



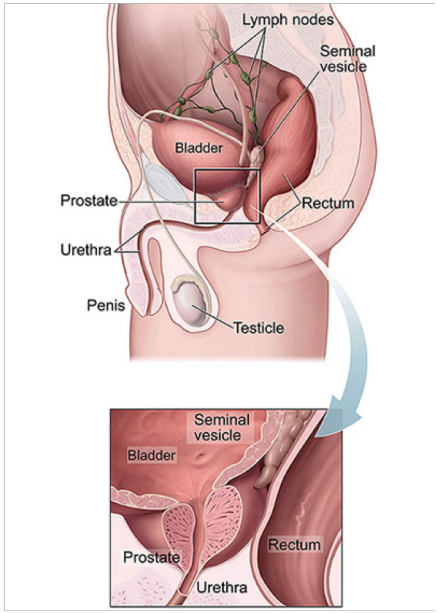
1 in 8 American men will be diagnosed during his lifetime.

174,650

Estimated New Cases in 2019

31,620

Estimated Deaths in 2019



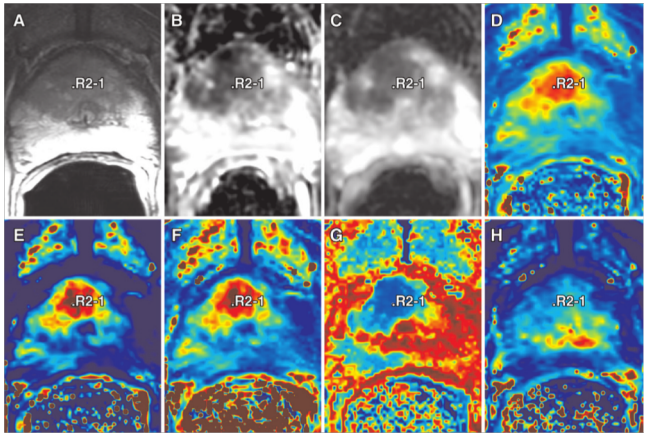
What is the optimal therapy or surveillance for each one?

Increasing Role of Prostate MRI

New England Journal of Medicine (2018)
MRI-targeted or standard biopsy for prostate-cancer diagnosis.
Kasivisvanathan V, Rannikko AS, Borghi M, Panebianco V, Mynderse LA, Vaarala MH, Briganti A, Budäus L, Hellawell G, Hindley RG, Roobol MJ.

The Lancet (2017)
Diagnostic accuracy of multi-parametric MRI and TRUS biopsy in prostate cancer (PROMIS): a paired validating confirmatory study.
Ahmed HU, Bosaily AE, Brown LC, Gabe R, Kaplan R, Parmar MK, Collaco-Moraes Y, Ward K, Hindley RG, Freeman A, Kirkham AP.

MRI-Guided Targeted Biopsy



Penzkofer, et al. (2015). Transperineal in-bore 3-T MR imaging-guided prostate biopsy: a prospective clinical observational study. *Radiology*, *274*(1), 170–80.

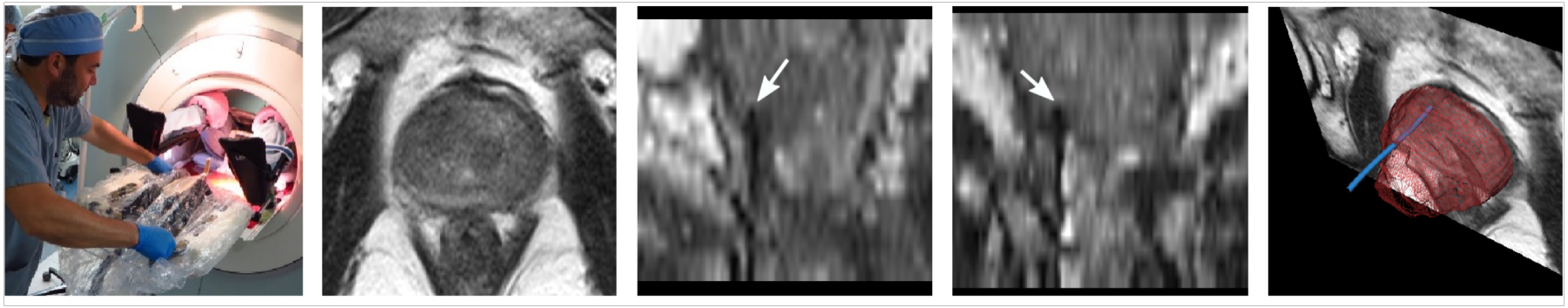

Penzkofer


Fedorov


Tuncali


Tempany

Needle Segmentation



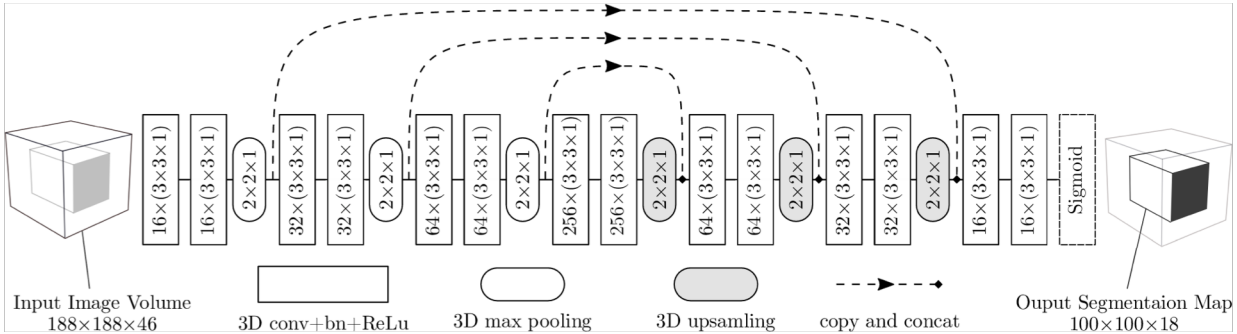
Alireza Mehtrash et al. (IEEE Transactions on Medical Imaging, 2018)

Automatic Needle Segmentation and Localization in MRI with Convolutional Neural Networks:Application to MRI-Guided Prostate Biopsy

Mehrtash

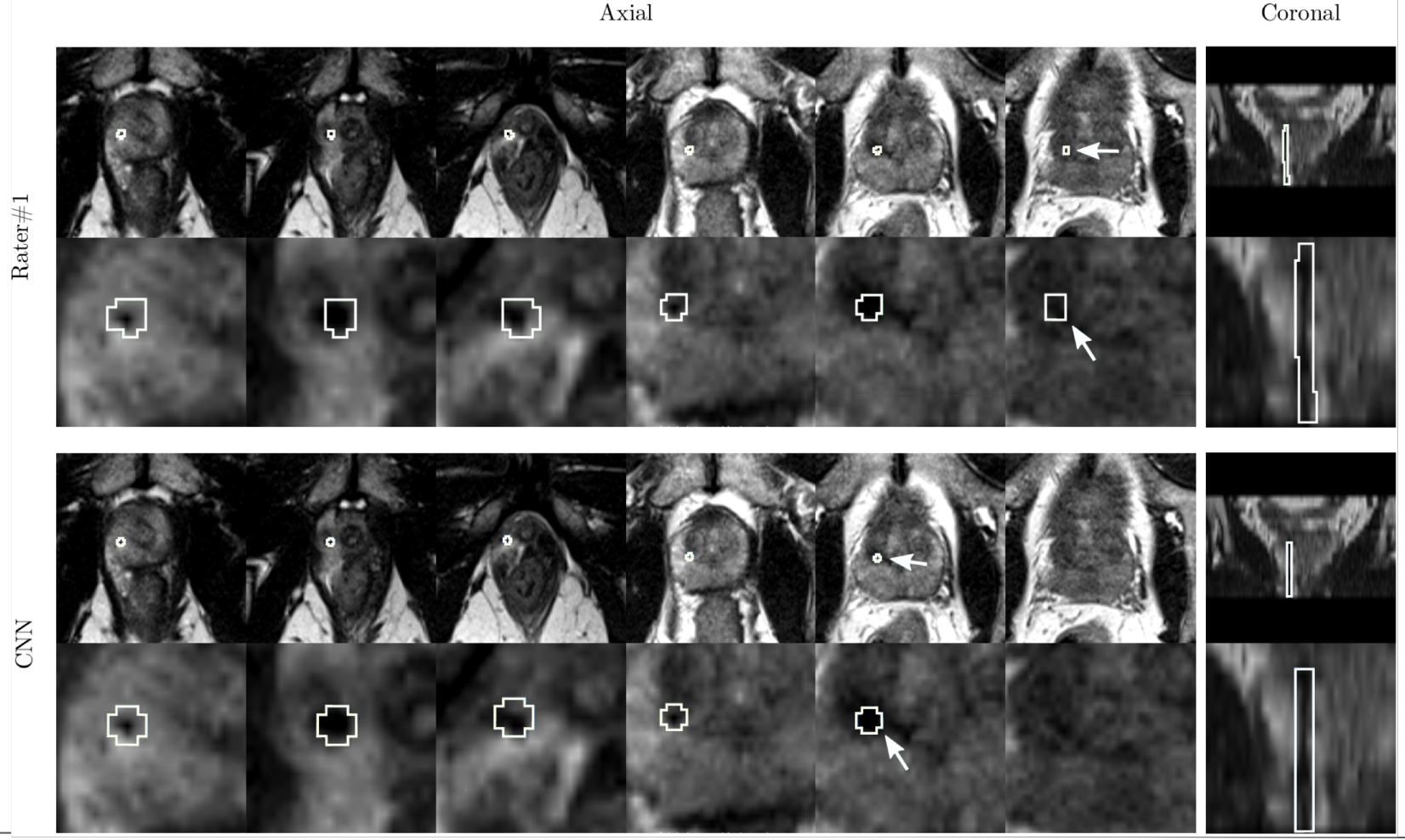
3D Convolutional Neural Network

- 3D Fully Convolutional Neural Network (FCN)
- Training: Data augmentation, 5-fold cross-validation.
- Loss: Negative of Dice.

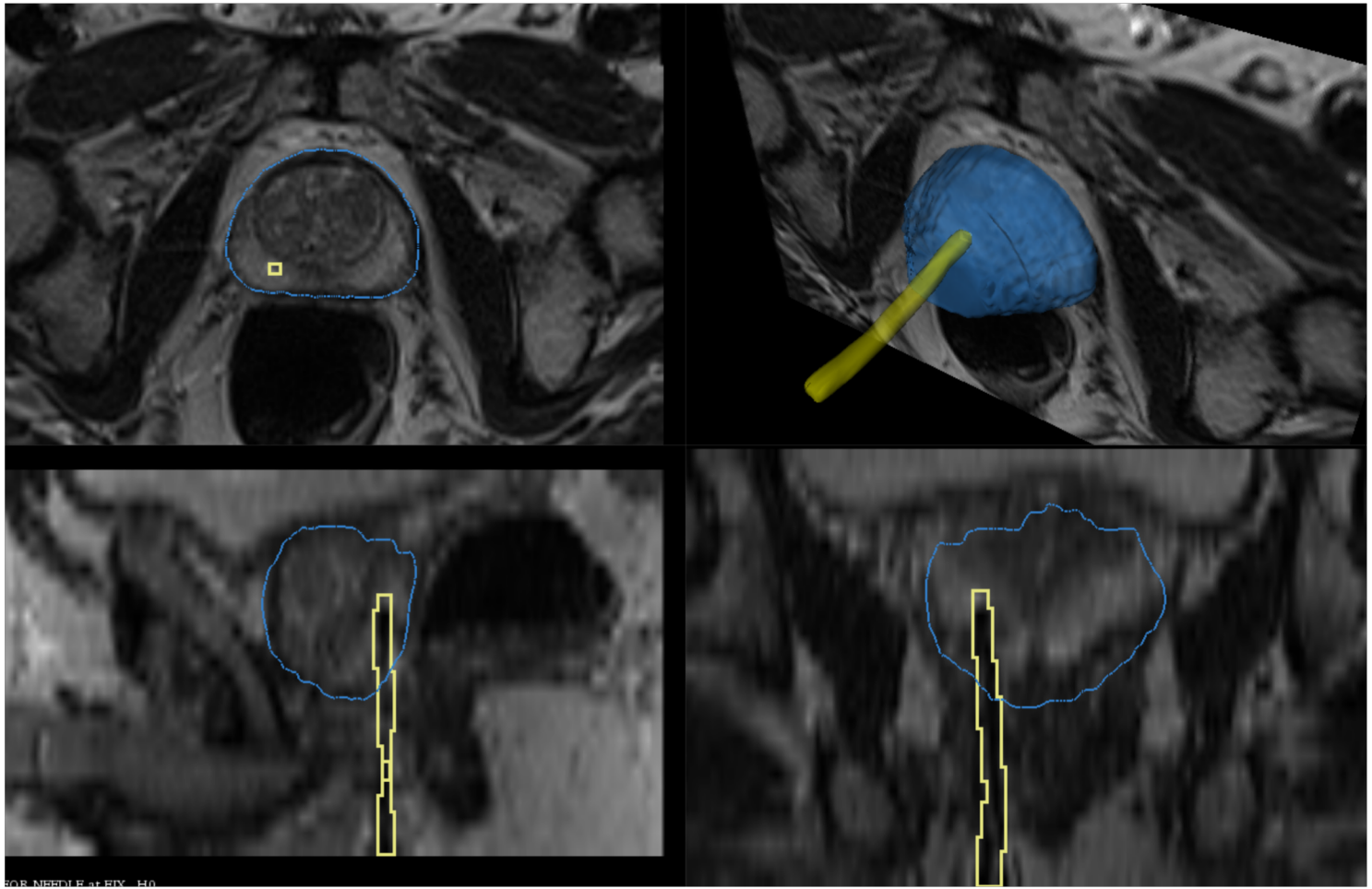


Training Data and Annotations

- Ground Truth: needles marked by rater on 583 MRI (71 patients)
- MRI divided: 50 train-validation, 21 test
- Observer study: second rater blinded to the ground truth


Axial
Coronal
Rater#1
CNN

Case 596



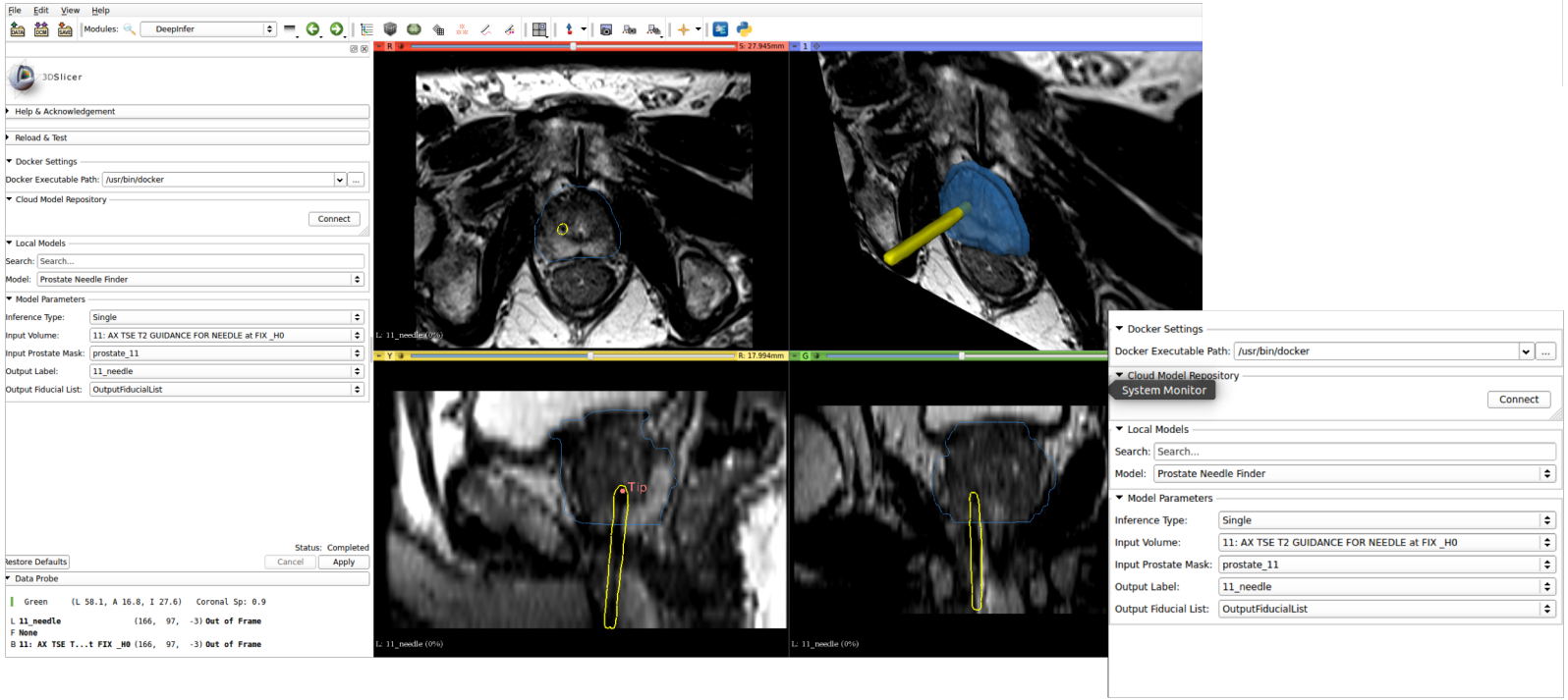
Results Summary

- Less than 3mm localization error in tip and trajectory in axial plane
- Less than 2 slice error in 92% cases along the transaxial plane

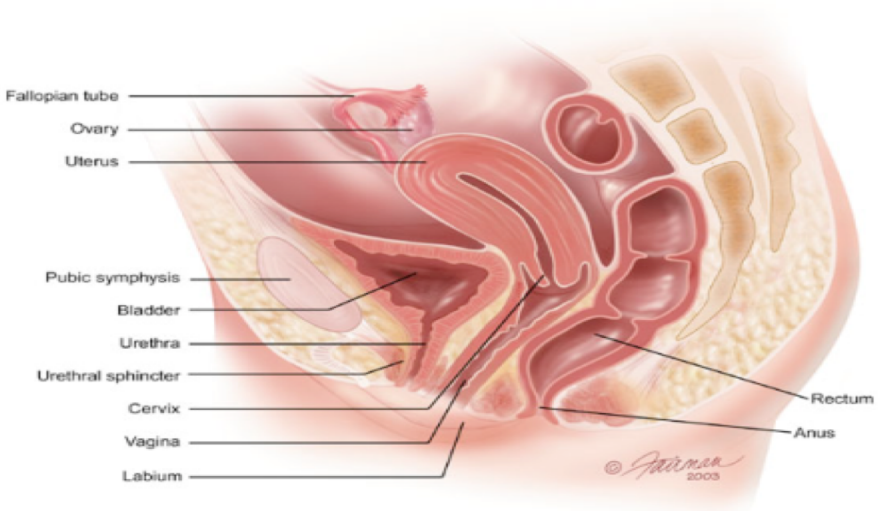
Alireza Mehtrash et al. (IEEE Transactions on Medical Imaging, 2018)
Automatic Needle Segmentation and Localization in MRI with Convolutional Neural Networks:Application to MRI-Guided Prostate Biopsy

Mehrtash

Open Deployment in 3D Slicer DeepInfer



Gynecologic Cancers



Cervical, Uterine, Vaginal, Vulvar, Ovarian

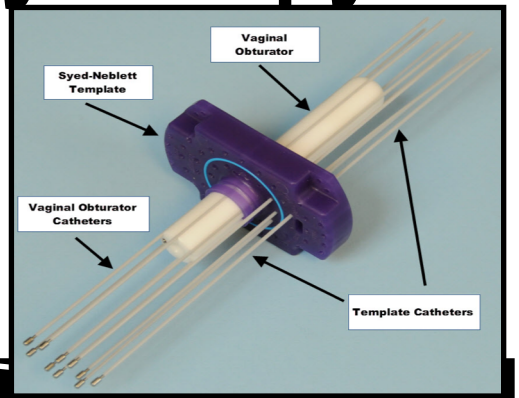
4th leading cause of death in women in the US

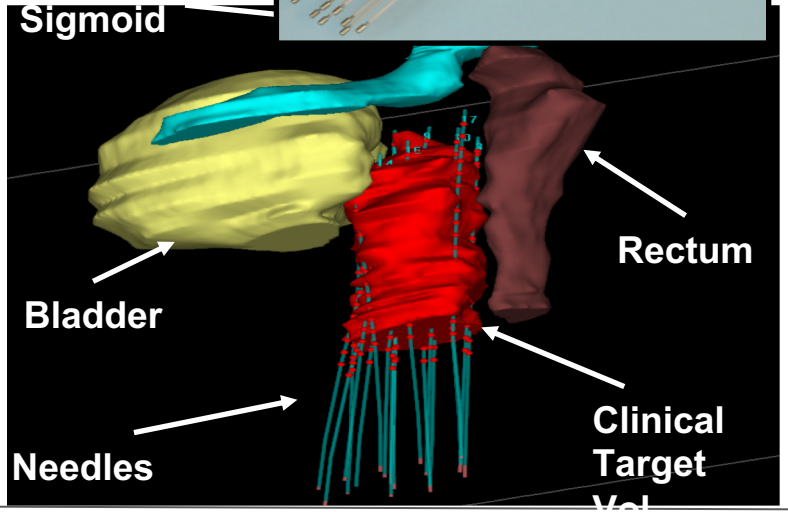
- 109,470 estimated cases in 2019
- 33,100 estimated deaths in 2019

Treated with chemo-radiation, high dose rate brachytherapy

MRI-guided Gyn HDR Brachytherapy

- 30% outcome improvement over chemo-radiation
- MRI preferred





Viswanathan et al. *Comparison of outcomes for MR-guided versus CT-guided high-dose-rate interstitial brachytherapy in women with locally advanced carcinoma of the cervix.* Gynecologic oncology (2017).

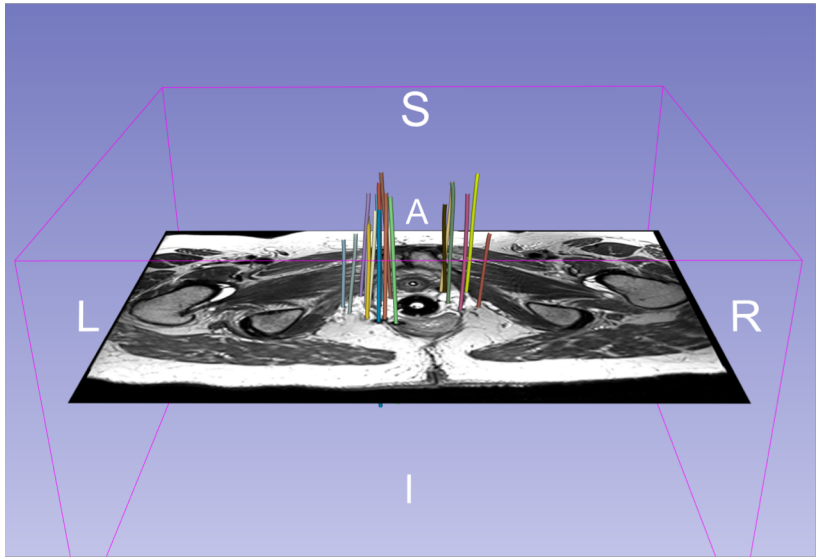
2012-2017

54 Patients

760 Needles

93% accuracy

3 seconds/needle



Mastmeyer

Pernelle

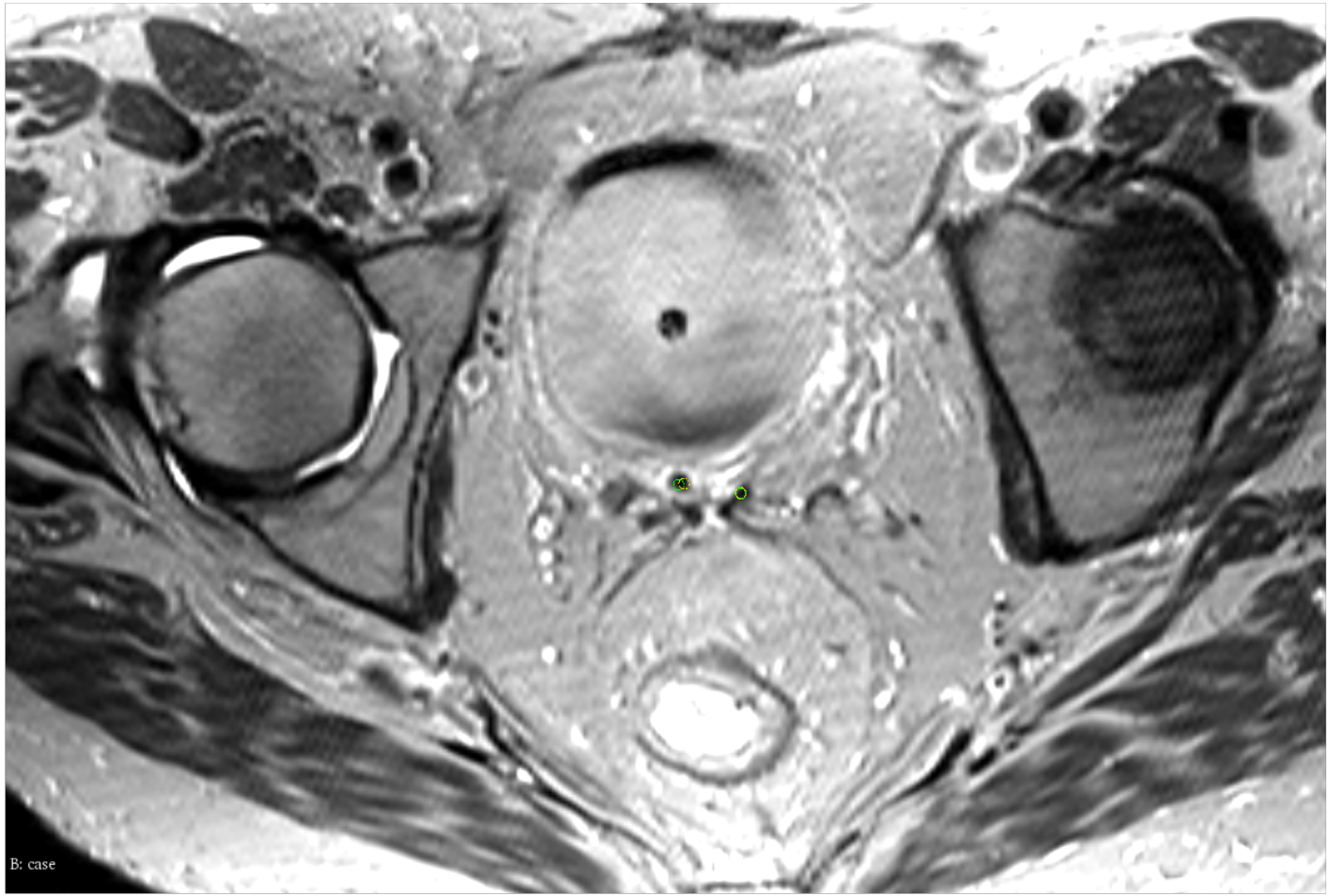
Mastmeyer et al. *Accurate model-based segmentation of gynecologic brachytherapy catheter collections in MRI-images*. Medical Image Analysis. 2017.

Pernelle et al. *Validation of catheter segmentation for MR-guided gynecologic cancer brachytherapy*. MICCAI 2013.

Kapur et al. *3-T MR-guided brachytherapy for gynecologic malignancies.* Magnetic resonance imaging. 2012

2018-2019

Zaffino Spadea Pernelle Mehrtash


B: case

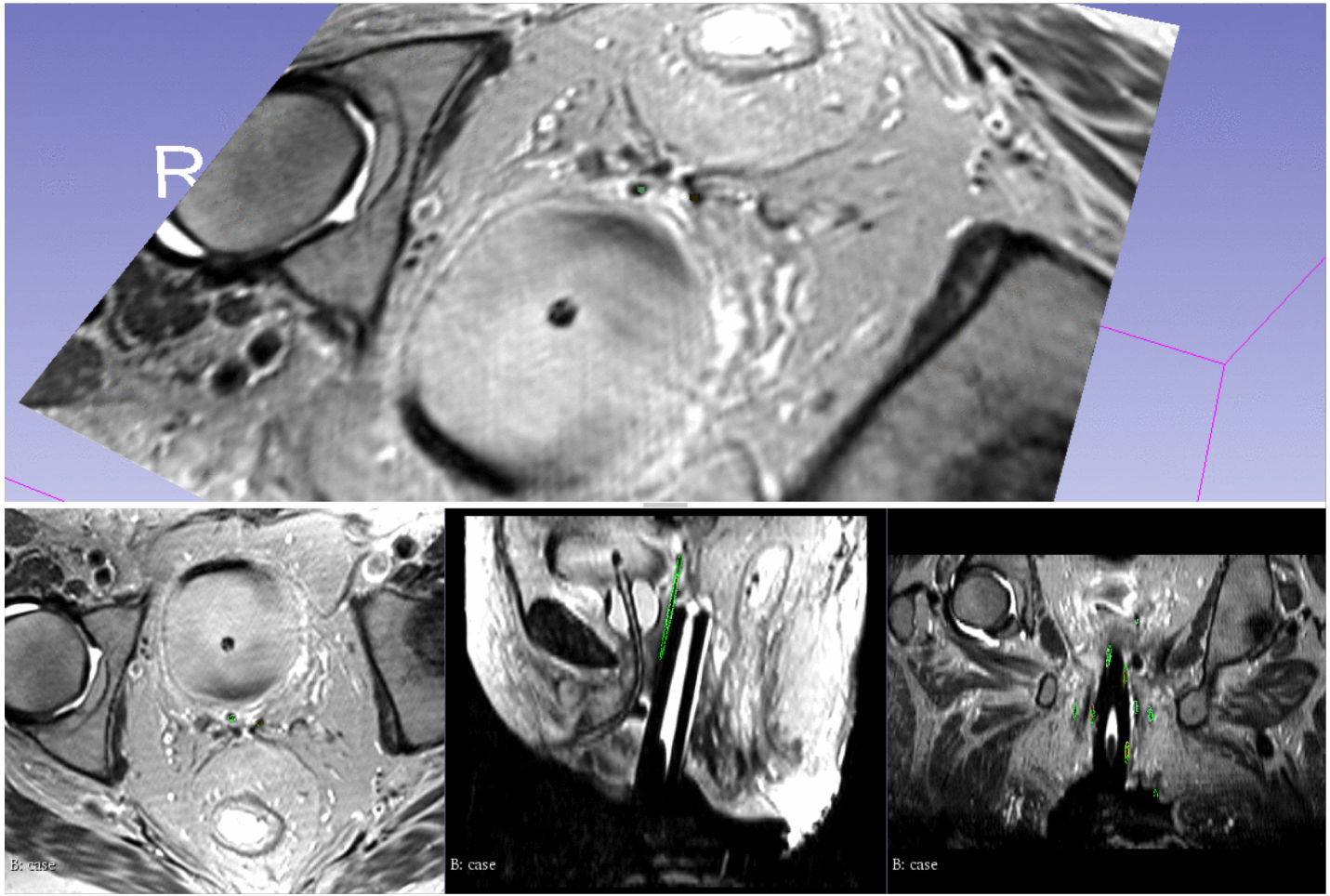

R
B: case
B: case
B: case

Image-Guided Liver Biopsies

Worldwide

1,000,000 annually, 4% growth rate

Brigham and Women's Hospital

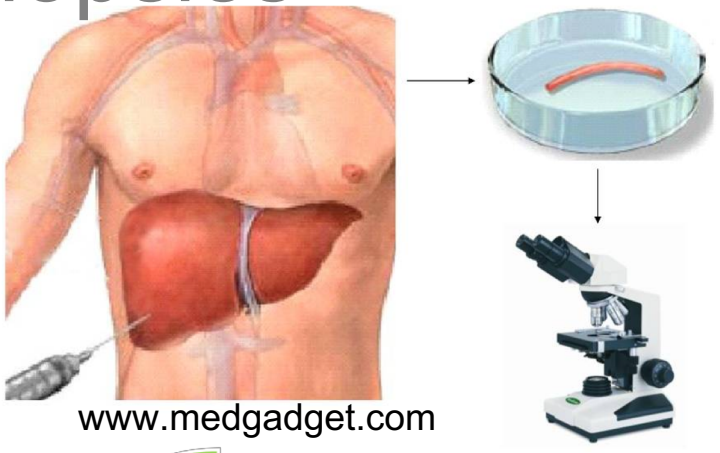
600 liver biopsies annually

30% parenchymal, 70% focal

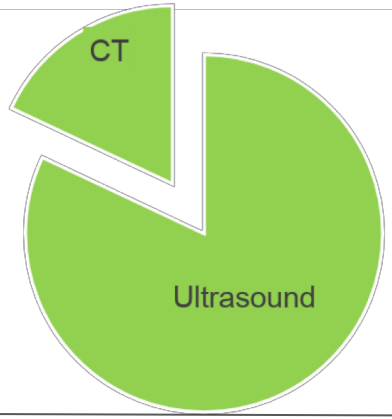
50% focal use ultrasound, 50% CT

For ultrasound guided biopsies

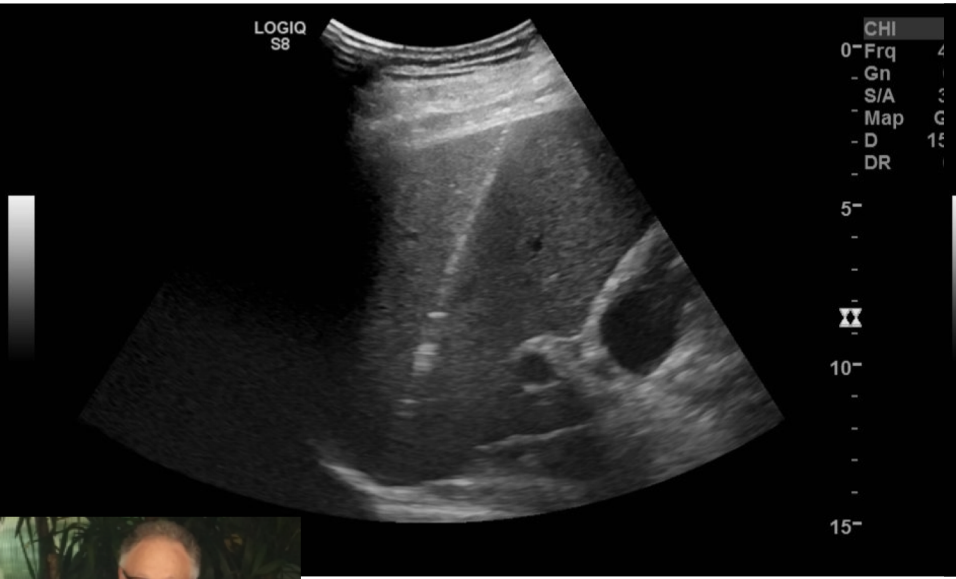
99% freehand

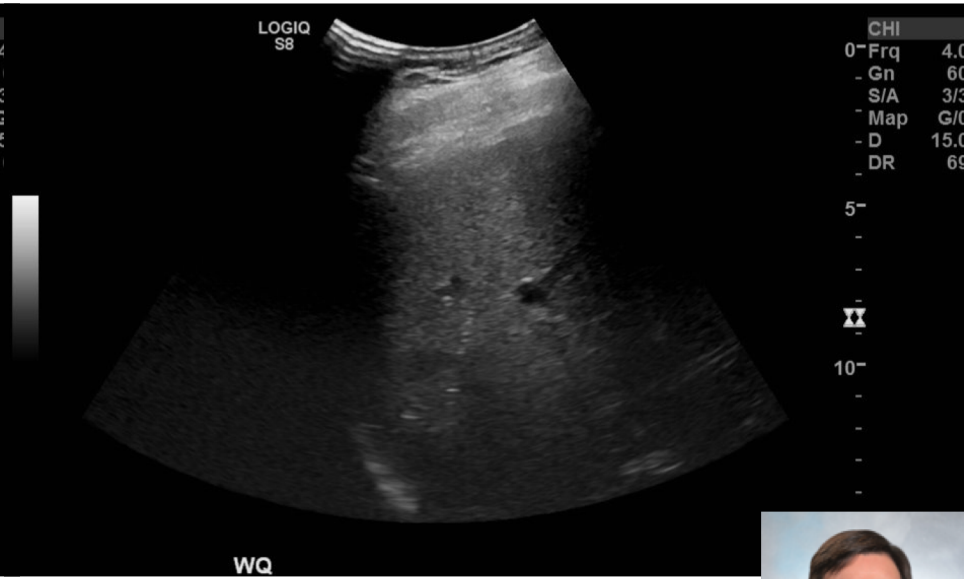


www.medgadget.com



Ultrasound guided Liver Biopsy





Ultrasound guided Liver Biopsy

Needle insertion using real-time ultrasound guidance.

Why should we work on this?

- **Better** accuracy in fewer needle sticks
  - less pain, bleeding and complication risk

- **Shorter** procedure time
- **Shorter** learning curve for physician training

- **Lower cost** modality, no radiation (vs CT)

Challenges

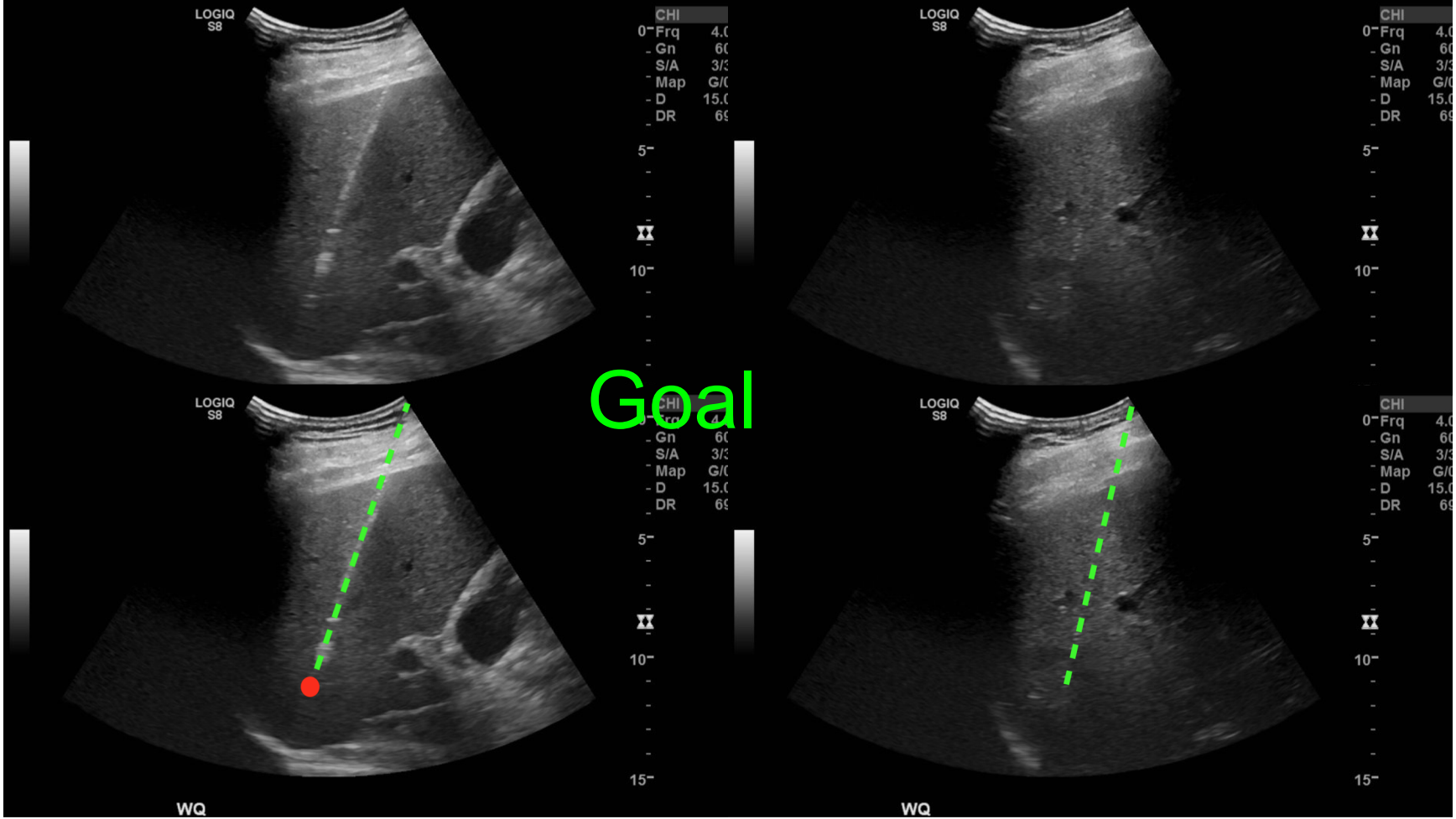
Low reimbursement

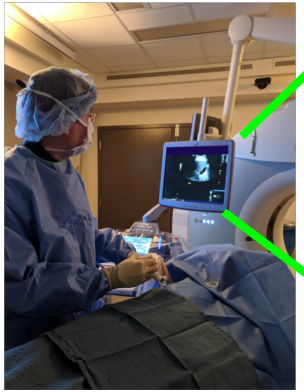
Little room for adding

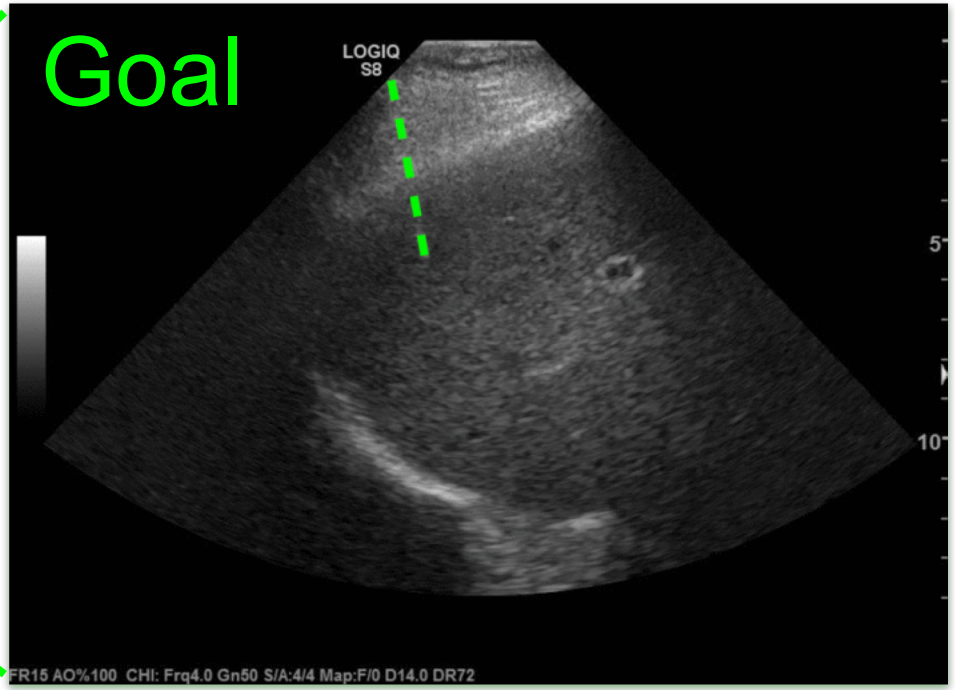
- Time, complexity, incremental cost

Available alternatives not adopted

- navigation with tracking hardware
- needle guides
- needles with echogenic tips


LOGIQ
S8
CHI
Frq
Gn
S/A
Map
D
DR
Goal
WQ




Goal
LOGIQ
S8
5
10
FR15 AO%100 CHI: Frq4.0 Gn50 S/A:4/4 Map:F/0 D14.0 DR72

Join us for Hands-on Projects

31st Project Week, June 24-28, 2019, MIT, Boston

32nd Project Week, July 15-19, 2019, Robarts, London, Canada

33rd Project Week, January 20- 24, 2019, Gran Canaria, Spain

na-mic.github.io/ProjectWeek/