Gynecologic Brachytherapy in AMIGO: A collaboration between Radiology and Radiation Oncology

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P41 EB 015898

National Center for Image Guided Therapy (Jolesz, Tempany)
2005-2015

P41 EB 005149

National Alliance for Medical Image Computing (Kikinis)
2004-2015

R03 EB 013792

Segmentation for Gynecologic Brachytherapy (Kapur)
2011-2013

Today…

Gynecologic Cancer and Treatment

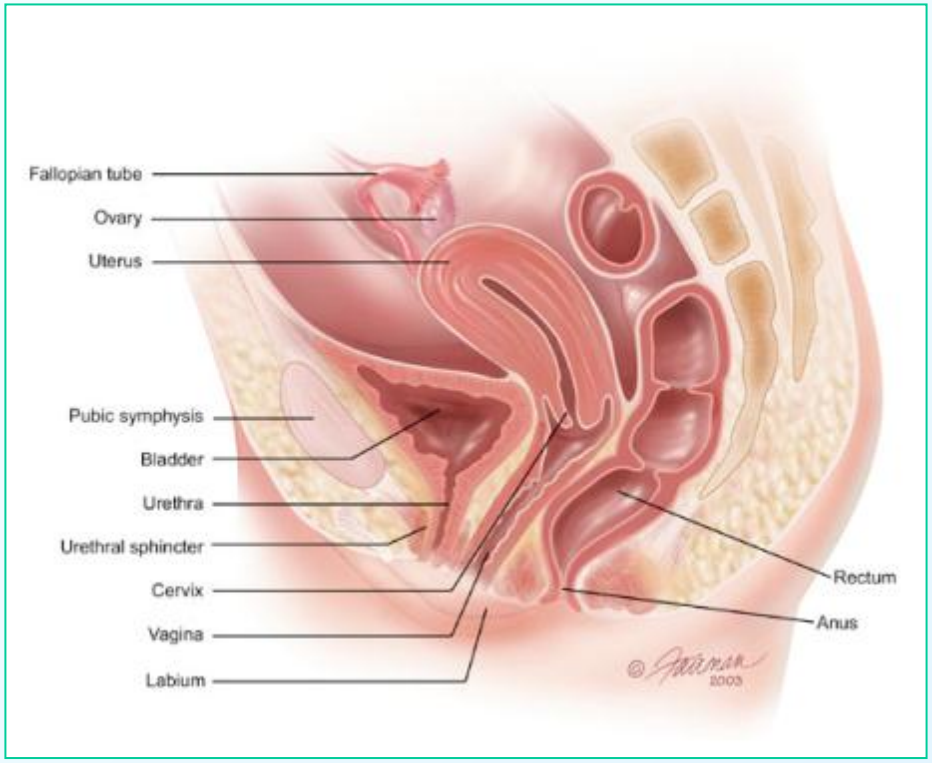
Previous Work in 0.5T MR-Guided Brachytherapy

- Prostate Cancer
- Gynecologic Cancer

Advanced Multimodality Image-Guided Operating (AMIGO) Suite

Gynecologic Brachytherapy in AMIGO

Gynecologic Anatomy and Cancers



- 500,000 cases per year worldwide: Cervical, Uterine, Vaginal, Vulvar, Ovarian
- 4th leading cause of death in women in the US
- External beam radiation, chemo followed by brachytherapy

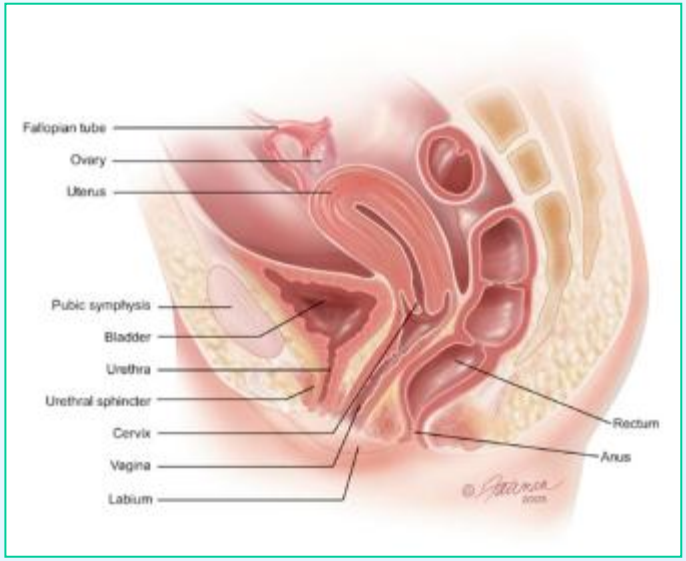
Brachytherapy

Radioactive sources that deliver very high doses of radiation are placed directly inside cancerous tissue.

Gyne Brachytherapy

Step 1: Applicator Placement

Hollow applicators are placed inside the cancerous tissue.



Interstitial **Tandem and Ring** **Tandem and Ovoids**

Gyne Brachytherapy

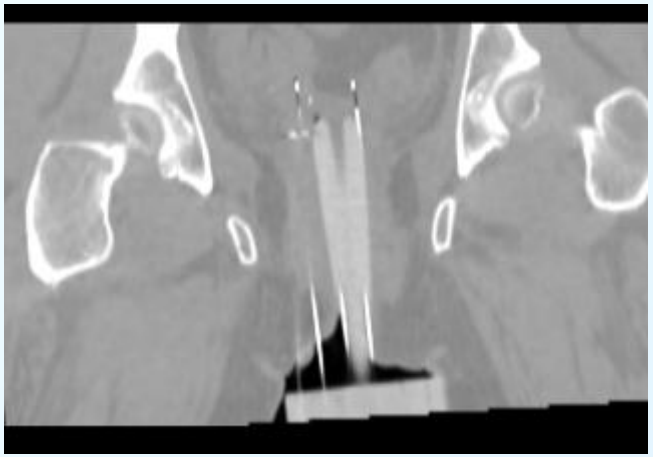
Step 2: Treatment Delivery

- A cable is connected to the applicator through which radiation sources travel
- The radiation source (Iridium-192) is housed in a computer-guided afterloader that directs the source into the treatment catheters
- The source travels through each catheter in discrete steps or "dwell" positions
- The distribution of radiation and dose is determined by the dwell positions and the length of time it dwells there.

Nucletron Microselectron Afterloader

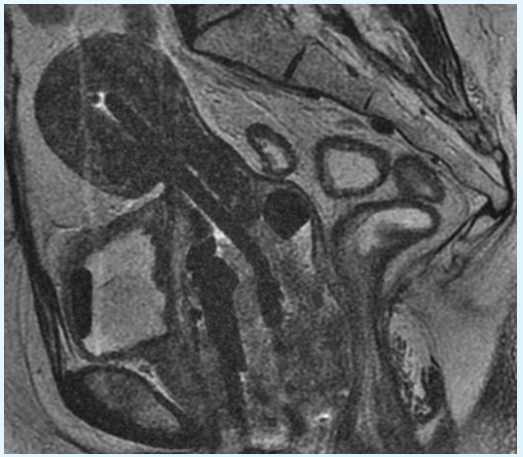
Imaging

Computed Tomography (CT)



2002-2011

Magnetic Resonance Imaging (MRI)



2002-2006 **0.5T**
2011- **3.0T**

Akila Viswanathan, MD, MPH


H
History

0.5T Open Magnet (GE SP Signa) 1997-2006

Clinical Programs

- Neurosurgery
- Abdominal Tumor Ablation
- Prostate Brachytherapy

Pelvic Brachytherapy in 0.5T MRI

- Pioneered MR-guided Pelvic brachytherapy
  - 1997
- Prostate Cancer
  - 1997-2006
  - Clinical Service with 450+ cases
- Gynecologic Cancer
  - 2004-2006
  - Prospective clinical trial with 25 cases

Pelvic Brachytherapy in 0.5T MRI

Clare Tempany, MD
Radiology

Robert Cormack, PhD
Radiation Oncology

Anthony D'Amico, MD
Radiation Oncology

Akila Viswanathan, MD
Radiation Oncology

Pelvic Brachytherapy in 0.5T MRI

D'Amico, A., Cormack, R., Tempany, C., et al. *Real-time magnetic resonance image-guided interstitial brachytherapy in the treatment of select patients with clinically localized **prostate** cancer*. International Journal of Radiation Oncology Biology Physics,42(3), (1998): 507-515.

Viswanathan, Akila N., Robert Cormack, Caroline L. Holloway, Cynthia Tanaka, Desmond O'Farrell, Phillip M. Devlin, and Clare Tempany. "Magnetic resonance–guided interstitial therapy for vaginal recurrence of **endometrial cancer**." International Journal of Radiation Oncology* Biology* Physics 66, no. 1 (2006): 91-99.

Viswanathan AN, Syzmonifka J, Tempany CM, O'Farrell DA, Cormack RA. *A Prospective Trial of Real-Time Magnetic Resonance-Guided Catheter Placement in Interstitial Gynecologic Brachytherapy.* Brachytherapy Epub 2013

2011

Advanced Multimodality Image Guided Operating Suite (AMIGO)

Supported by

National Center for Image Guided Therapy (NCIGT)

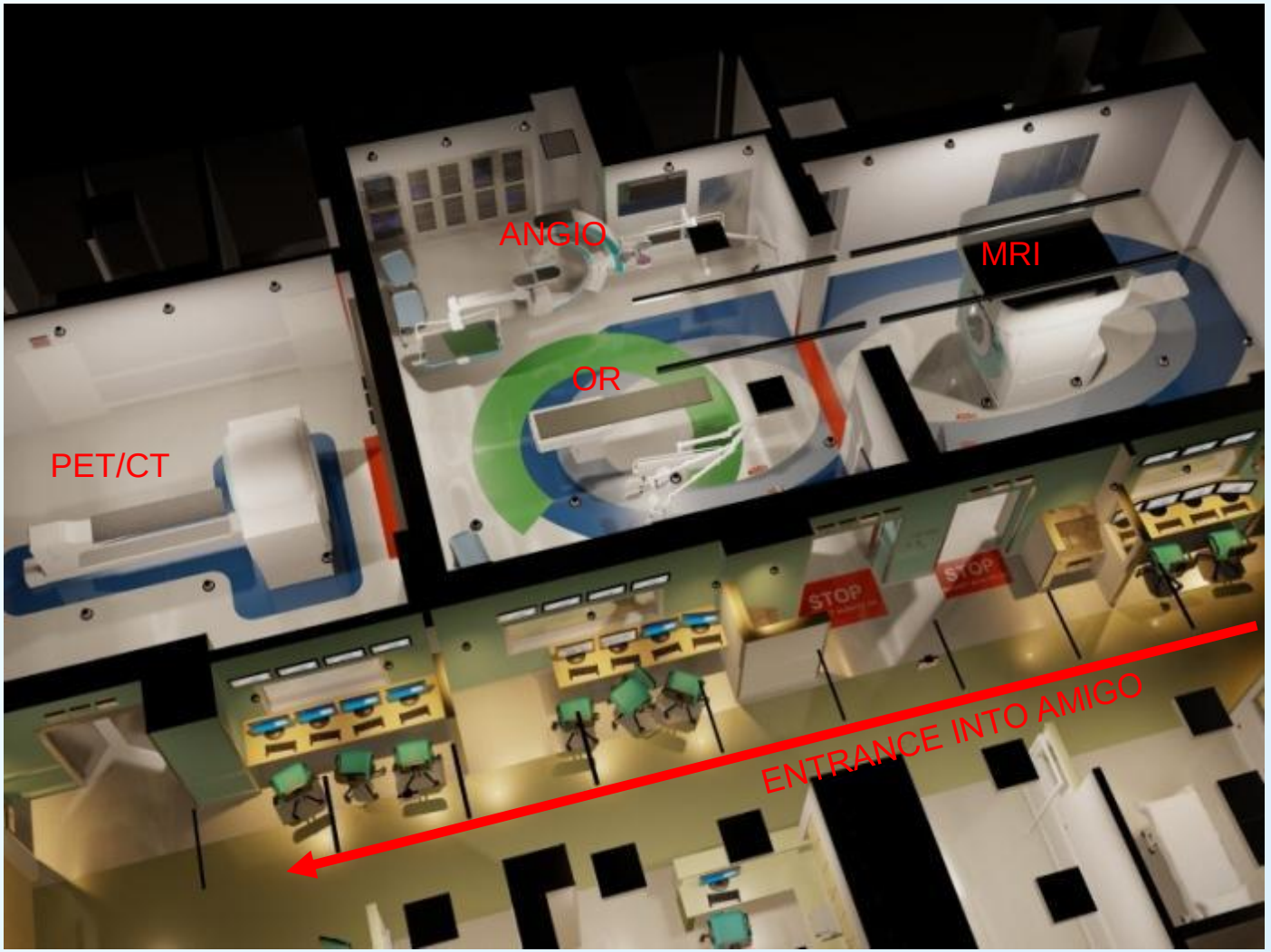
P41EB015898 (Jolesz, Tempany) 2005-2015

Advanced **M**ultimodality **I**mage **G**uided **O**perating Suite

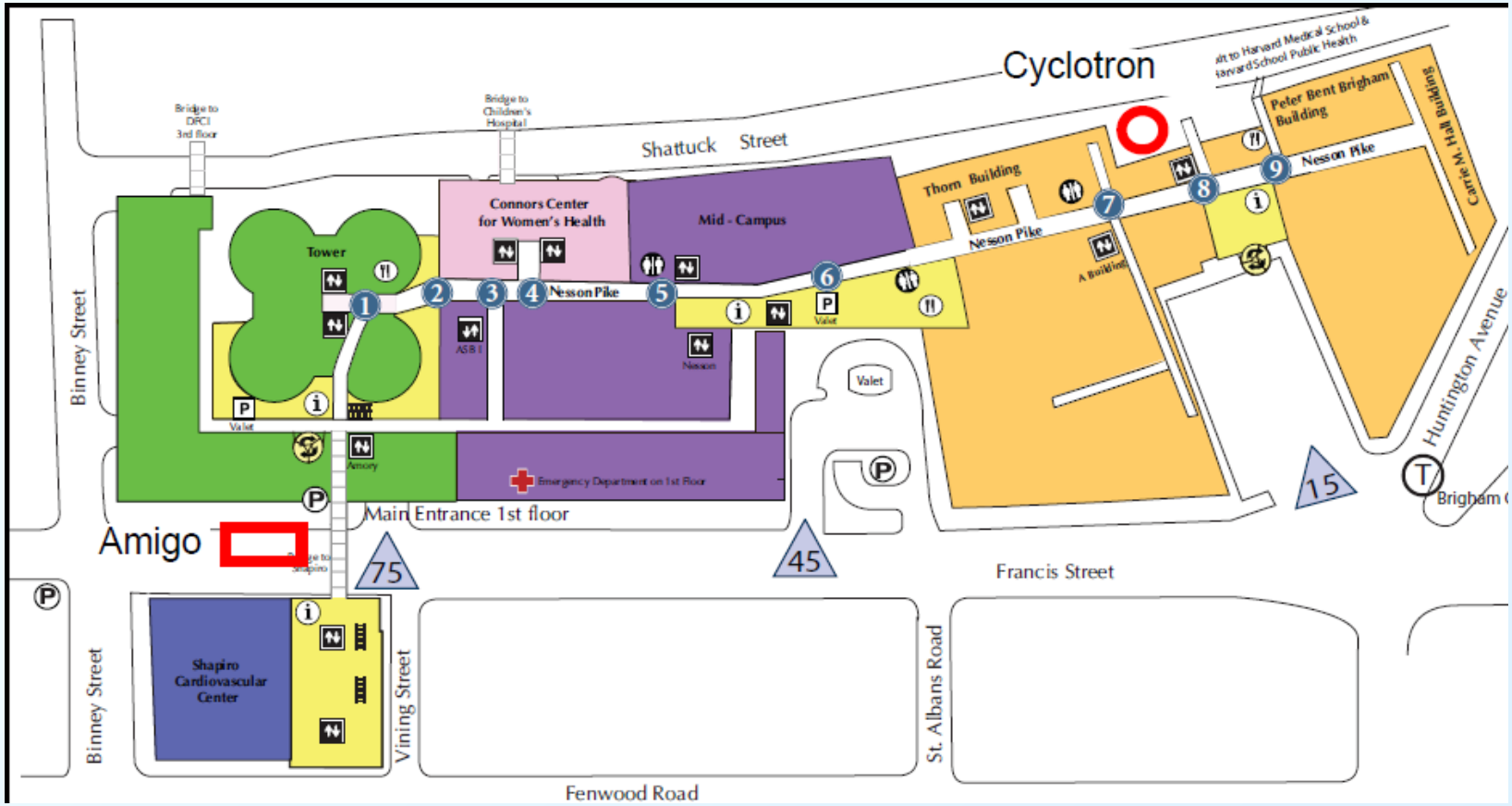
Precise Localization of Tumor Boundaries for Therapy and Biopsy

MRI Room **Operating Room** **PET/CT Room**

With Cardiac Catheterization, Navigation, Ultrasound



Balazs Lengyel, BWH



BWH BRIGHAM AND WOMEN'S HOSPITAL
A Teaching Affiliate of Harvard Medical School

183 AMIGO Procedures Performed (August 30, 2011-September 1, 2011)

58 Cryoablation treatments (liver, kidneys)
- Kemal Tuncali, Servet Tatli

41 Brain surgeries and laser ablations
- Alexandra Golby, Ed Laws, Ferenc Jolesz

32 Prostate treatments and biopsies
- Kemal Tuncali, Paul Nguyen, Clare Tempany

28 Gynecologic Brachytherapy
- Akila Viswanathan, Clare Tempany

10 Soft tissue biopsies
- Kemal Tuncali, Servet Tatli, Paul Shyn

7 Cardiac ablations
- Greg Michaud, Ray Kwong

3 Breast lumpectomies
- Mehra Golshan, Eva Gombos

Investigators

Radiology
Computer Science
MRI Physics
Mechanical Design


Clare Tempany, MD

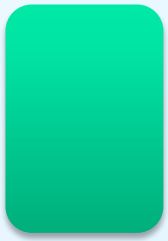

Tina Kapur, PhD


Jan Egger, PhD, PhD


Guillaume Pernelle, BS


Yi Gao, PhD


Xaiojun Chen, PhD


Ehud Schmidt, PhD


Sam Song, PhD


Tobias Penzkofer, MD


Wei Wang, PhD

Radiation Oncology
Radiation Physics


Akila Viswanathan, MD, MPH


Robert Cormack, PhD


Antonio Damato, PhD


Jorgen Hansen, MS

Gyne Brachytherapy in AMIGO

Clinical Workflow and Technologies Developed

- MR and Ultrasound
- MR Imaging and Post-processing centric view

Kapur, T., Egger, J., Damato, A., Schmidt, E. J., & Viswanathan, A. N. (2012). *3-T MR-guided brachytherapy for gynecologic malignancies.* Magnetic Resonance Imaging.

Akila Viswanathan, MD, MPH and Jorgen Hansen, MS

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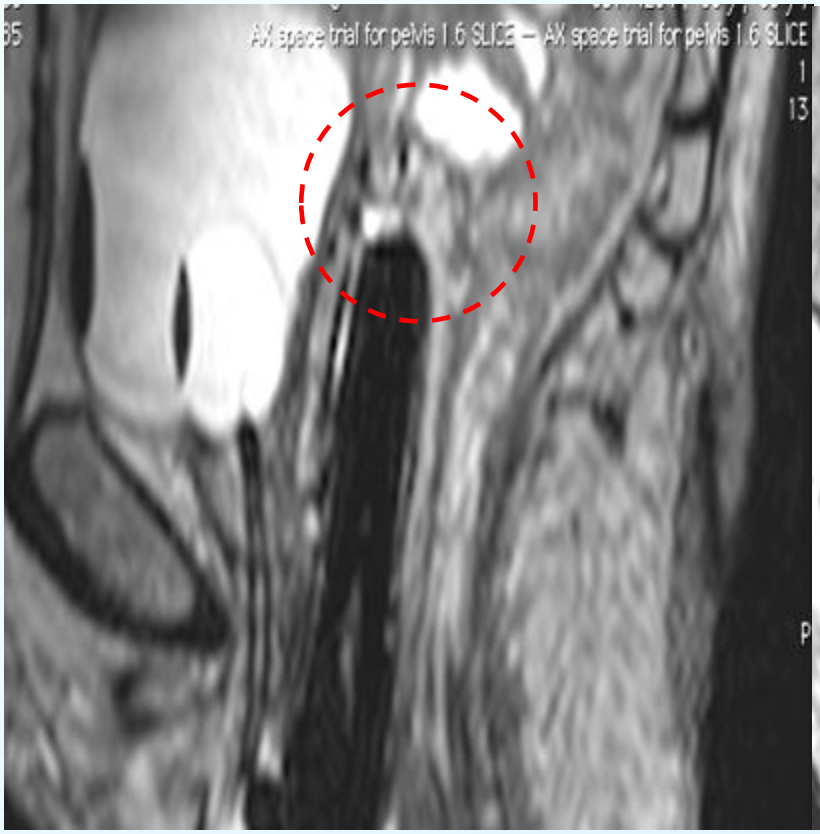
bSFFP MR Images for Needle Tip Localization

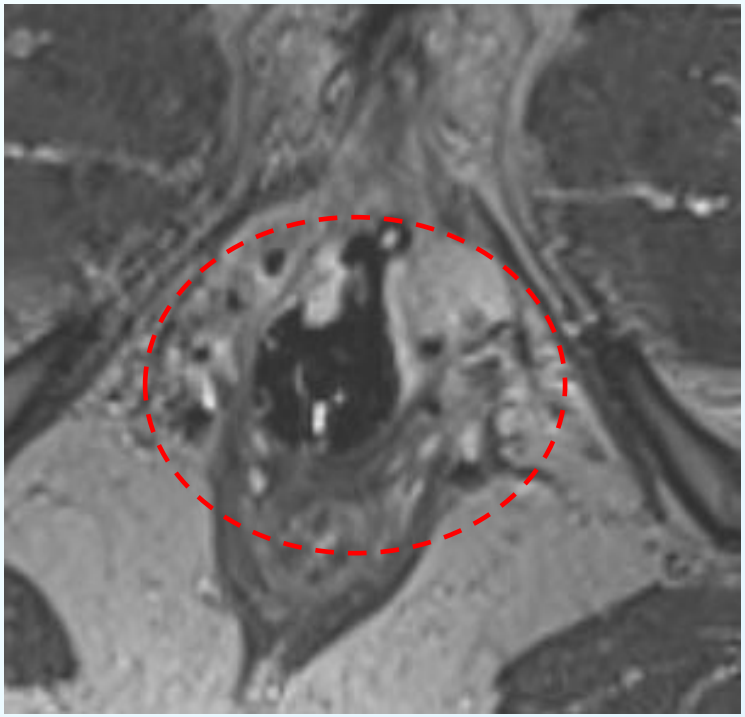


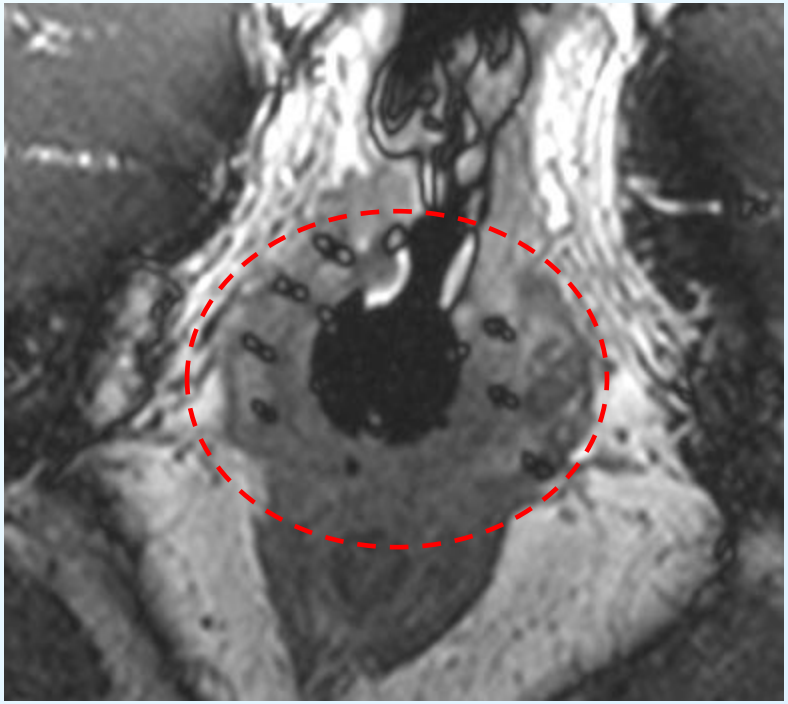
Fat suppressed 3DFSE (SPACE, CUBE, VISTA) 1.2 mm sw, ~5 min

3D fat suppressed balanced SSFP (FISP, FIESTA,bFE) 1.6 mm sw, ~1.2 min

Ehud Schmidt, PhD

bSFFP MR Images for Needle Tip Localization





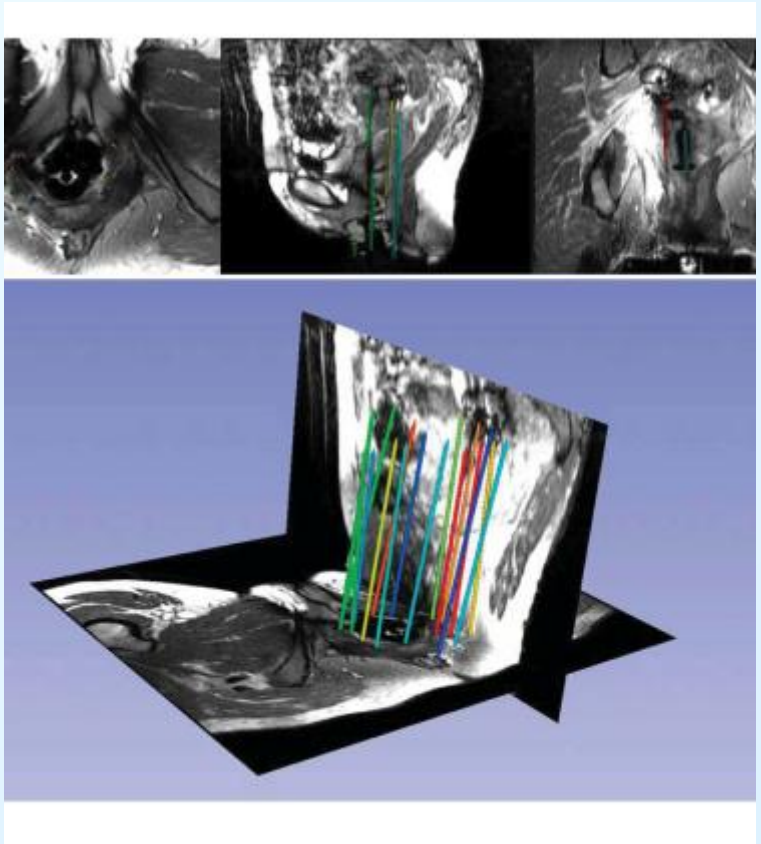
Fat suppressed 3DFSE
(SPACE, CUBE, VISTA)
1.2 mm sw, ~5 min

3D fat suppressed balanced SSFP (FISP, FIESTA,bFE)
1.6 mm sw, ~1.2 min

Ehud Schmidt, PhD

Post-Processing Using 3D Slicer iGyne

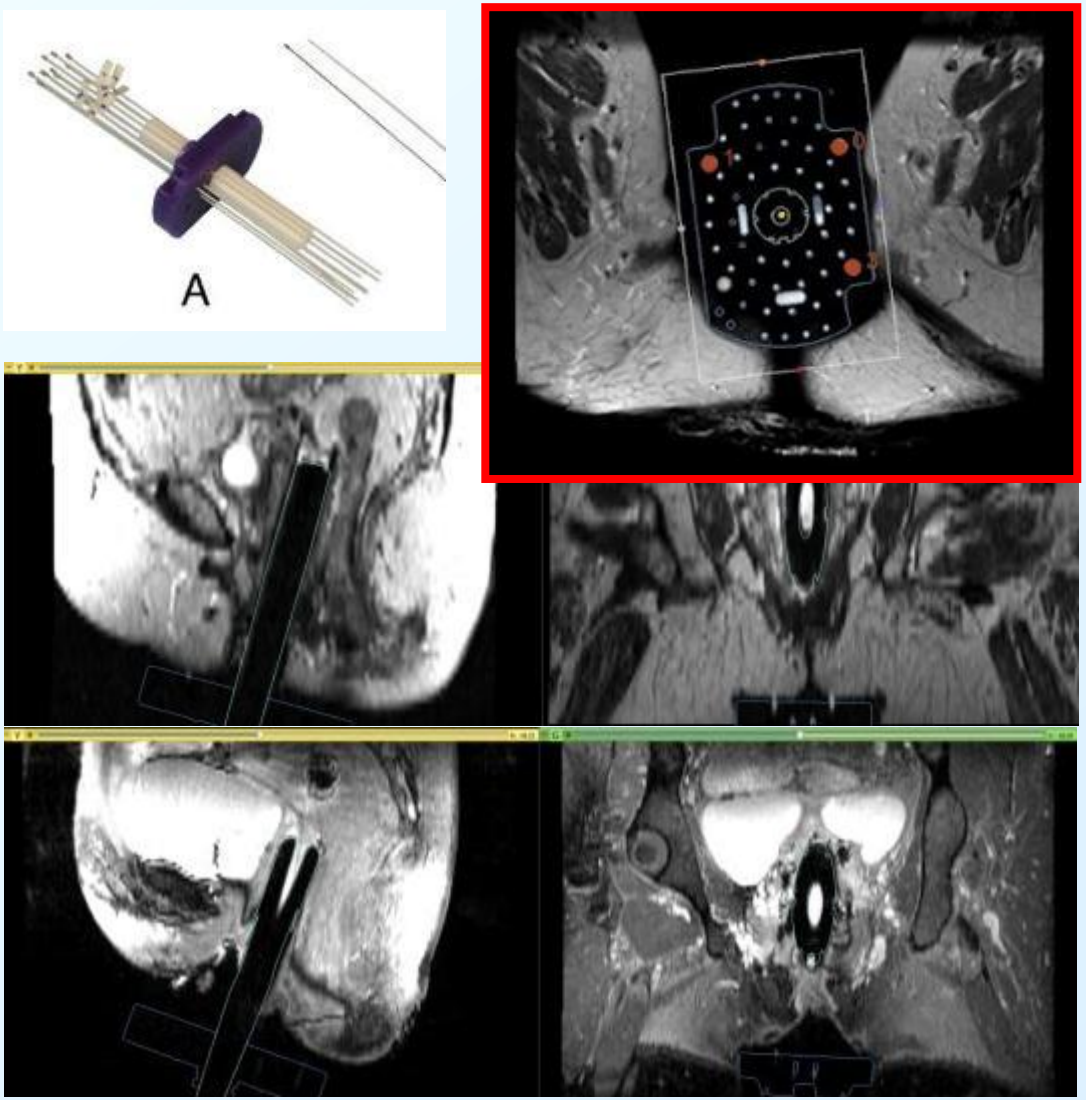
- "Bedside" Project: tight integration of algorithm and software development
- iGyne key features
  - Software workflow that matches clinical workflow
  - (robust) DICOM transfer from MR
  - Model-to-model registration of applicator CAD model to image
  - Simulation of needle trajectories
  - Novel needle detection and labeling
  - Reformatting of MRI along needle trajectory



Applicator Registration

Model-to-Model Registration

- CAD model of Applicator
- Auto detected landmarks
- Surface segmentation using GrowCut
- Iterative Closest Points Algorithm for point cloud registration



Guillaume Pernelle, Technical University Munich and Ecole Centrale Marseille

Needle Planning and Virtual Needle Placement

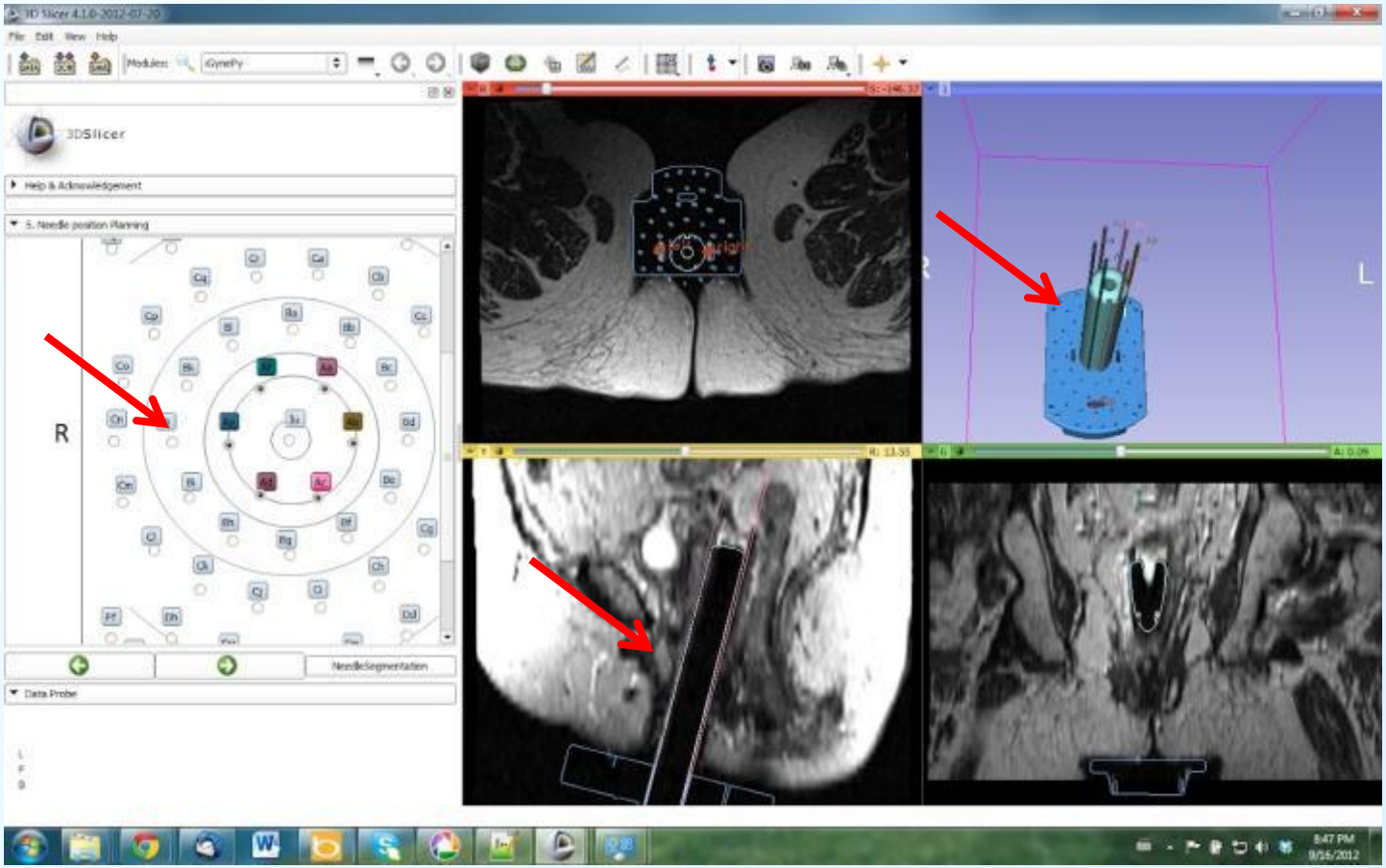
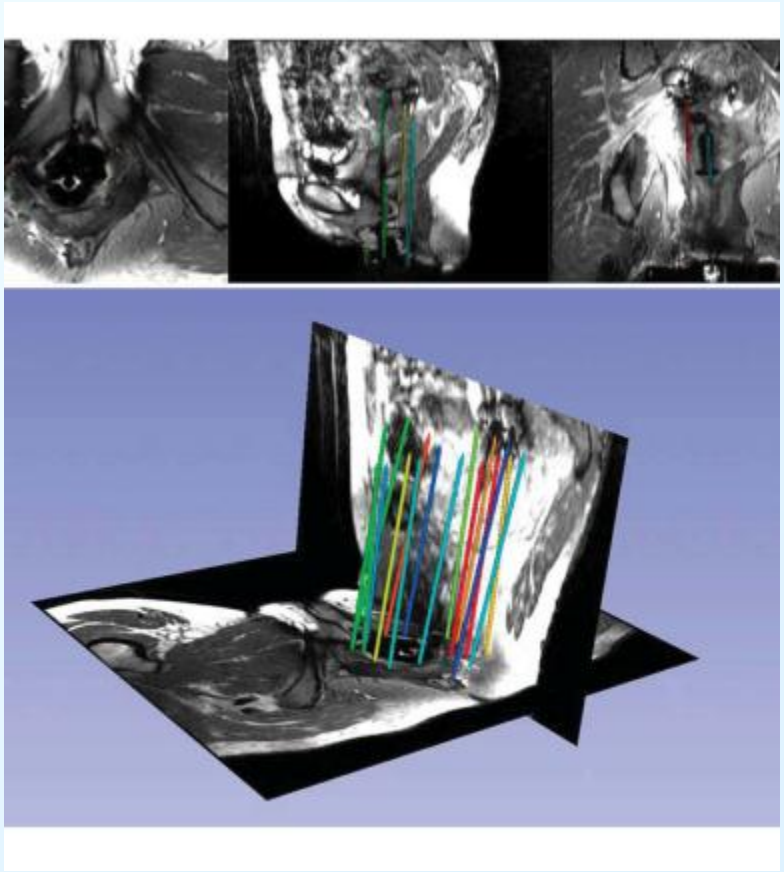


Image Processing for MR-guided Gynecologic Interstitial Brachytherapy in AMIGO
Xiaojun Chen, Jan Egger et al. in Proceedings of 9th International IMRI Symposium, 2012.

Needle Detection

Novel Algorithm

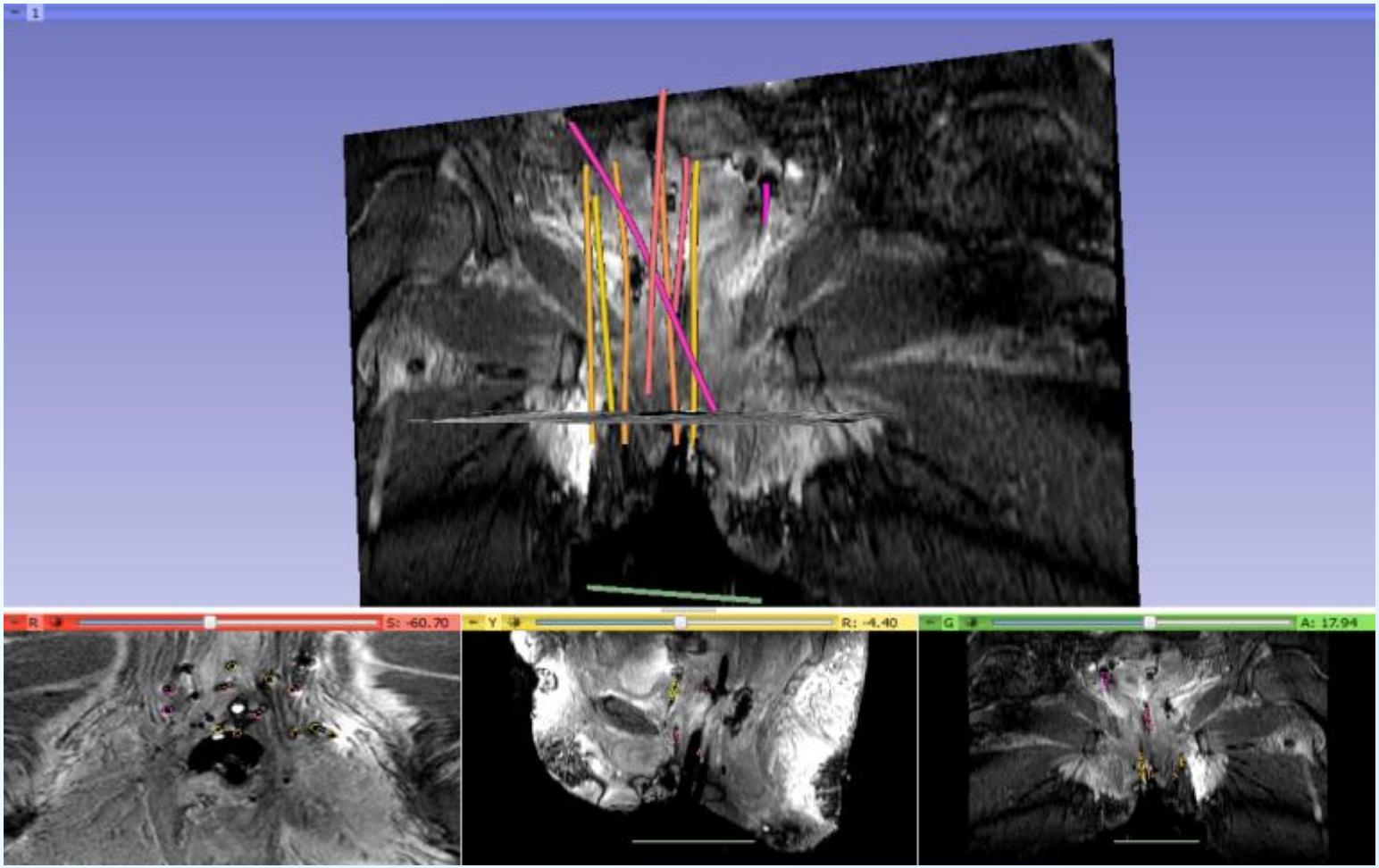
- Relies on needle tips provided by user
- Finds an optimized path in a ‘needleness’ image, computed using a Hessian filter
- Fits a Bézier curve (polynomial regression) to obtain bent needles



Needle Labeling for Interstitial Gynecological Brachytherapy.
Gao, Farhat, Pernelle et al. In Proceedings of Fifth National Image Guided Therapy Workshop, Sept 21, 2012

Needle labeling for Image-Guided Brachytherapy, Masters thesis (in preparation)
Guillaume Pernelle, Technical University Munich and Ecole Centrale Marseille

Deflected Needle Detection



Needle Labeling for Image-Guided Brachytherapy, Masters Thesis (in preparation)
Guillaume Pernelle, Technical University Munich and Ecole Centrale Marseille

Iterative Imaging and Post-Processing

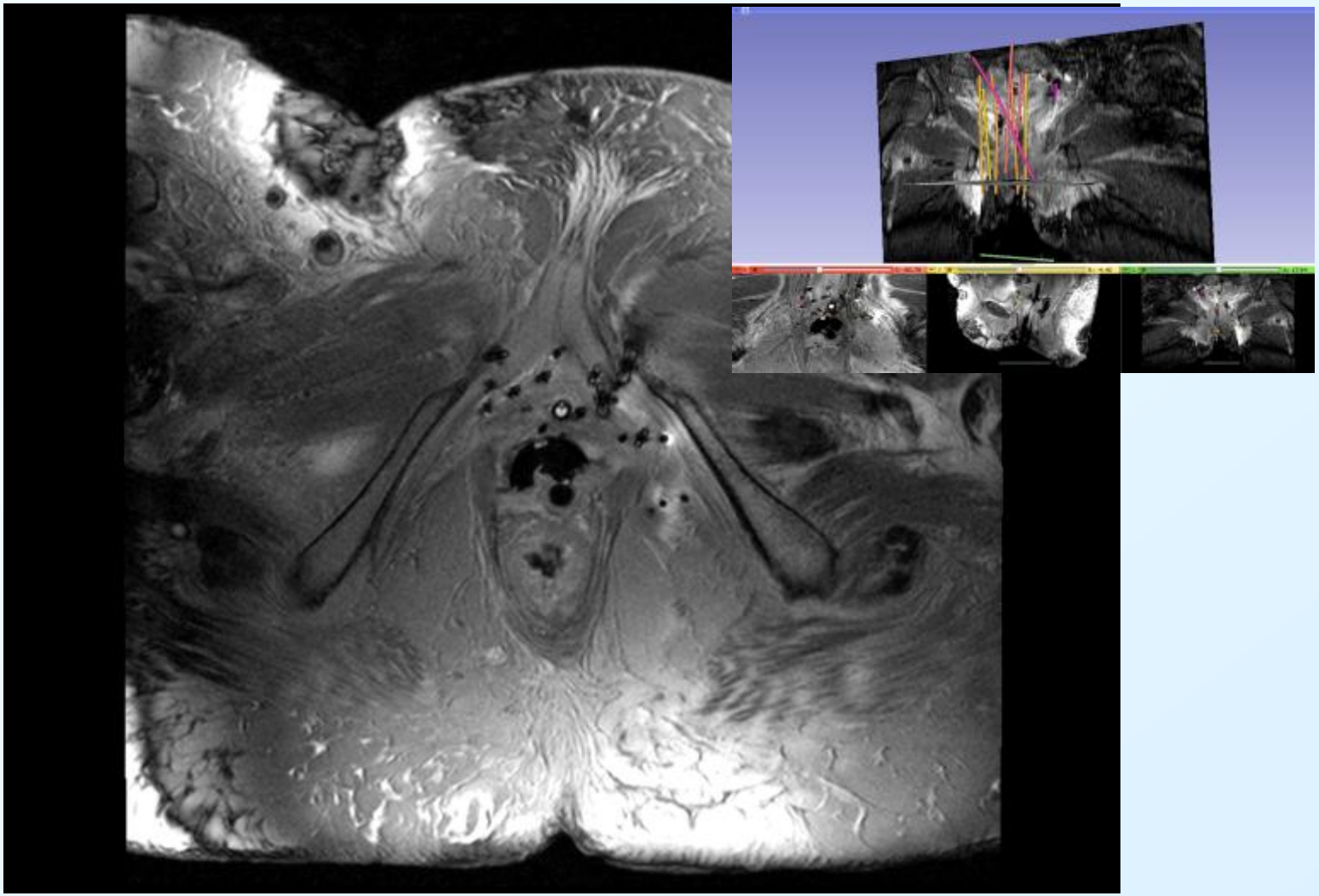
Iterative Needle Placement

Iterative Needle Placement

Iterative Needle Placement

Iterative Needle Placement

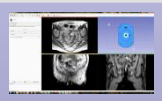
Iterative Needle Placement



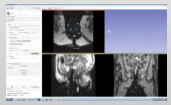
3D Slicer iGyne

DICOM Transfer
From MR Scanner

Applicator Registration



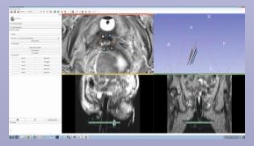
Needle Detection

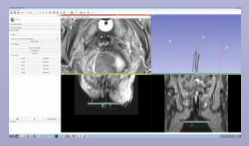

Ex. 1

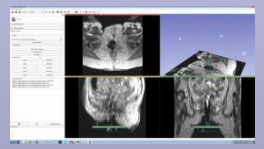

Ex. 2

- **Input**: Needle tips
- **Output**: Needle 3D Models

Exploring the result


Reformating


Detected vs CAD Needles


Distance Transform

Guillaume Pernelle, Technical University Munich and Ecole Centrale Marseille

iGyne Future Directions

Within 6 months

- Validate detected needle geometry (vs. CT)
- Export needle geometry for treatment planning
- Integrate real-time imaging sequence

Within 12 months

- Integrate needle trackers (Endoscout Inc, Symbow Inc, in-house)
- Biopsy needle identification and tracking (with Junichi Tokuda)

1 year+

- Integrate real-time dosimetry (with Robert Cormack)
- MR-Ultrasound registration (with Sandy Wells)