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Sponsored by the Radiosurgery Society (RSS) and
Centro Diagnostico Italiano (CDI)

Section: State-of-the-Art & Emerging Technologies in Radiosurgery

Emerging Technologies of SRS/SBRT: Biology Guided RT / Reflexion PET-linac

Presented by

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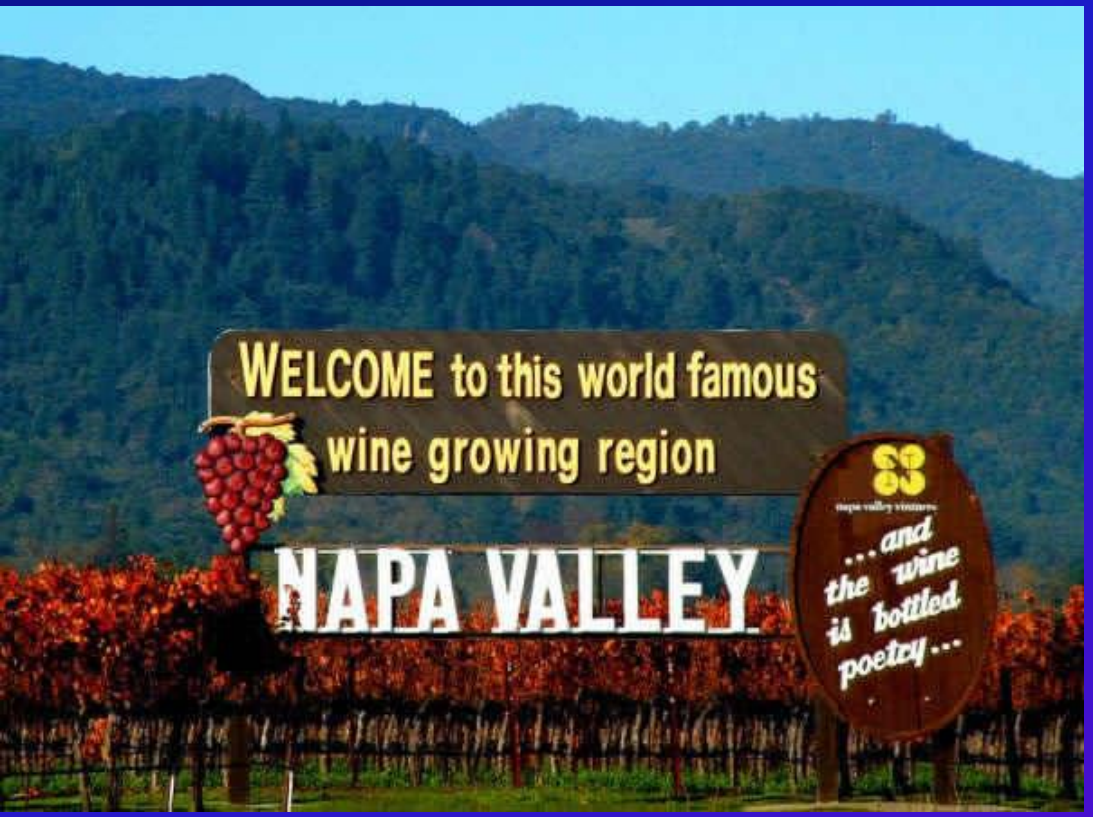
Radiation Oncology

UC Davis, located near Napa and Sonoma is famous for its Winemaking Education Programs



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Wine Executive Program

The UC Davis Wine Executive Program is uniquely designed to teach the fundamentals of winemaking and management skills necessary to be profitable in today's challenging and dynamic wine industry. Sessions are tailored to help industry leaders grow their businesses by expanding on such topics as building one's financial acumen and expanding a company's current marketing and branding strategies. In addition, participants will be exposed to the latest state-of-the-art technologies and processes for making and selling wine as demonstrated in the new LEED platinum winery at the Department of Viticulture and Enology.

Specifically designed to teach the fundamentals of winemaking and management skills necessary to be profitable in the challenging wine trade, the innovative program is tailored for middle and senior managers from wineries and vineyards of all sizes, industry suppliers, distributors, financial institutions, service providers and affiliated businesses. Investors, developers, entrepreneurs and those looking to enter the wine business also benefit greatly from the program. More than 800 wine industry executives have attended this unique and informative program over the past fourteen years.

The next program will be offered on the UC Davis campus. For more information, or to subscribe to our blog, visit the UC Davis Wine Executive Program web site at http://www.wineexecutiveprogram.com.

Participants working on group projects

Students gain advanced knowledge of the genetics, physiology and biochemistry of grapevines; the chemistry, microbiology and sensory science of wines; and the chemical engineering of winemaking necessary for professional careers in the wine industry.

There is a Professional Science Masters Program, and Ph.D. studies are offered through one of the following related Graduate Groups: Agricultural and Environmental Chemistry, Chemical Engineering, Food Science, Genetics, Microbiology, Plant Biology, and Soils and Biogeochemistry.

DISCLOSURES RELEVANT TO THIS PRESENTATION:

- *University of California at Davis does not specifically endorse any of the products in this presentation; rather, it endorses the educational component of the program.*
- *Collaboration with academic medical universities and Reflexion™ on the basic principles of Emission Guided RT (PET) have been published and are on-going.*
- *UC Davis does not have any financial relationship with Reflexion.*

Semin Nucl Med. 2008 Mar;38(2):105-13. doi: 10.1053/j.semnuclmed.2007.12.001.

Tumor biology-guided radiotherapy treatment planning: gross tumor volume versus functional tumor volume.

Guha C[1], Alfieri A, Blaufox MD, Kalnicki S.

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The special edition of *Seminars in Nuclear Medicine* deals with a watershed event in cancer treatment -- the combined use of functional and anatomical information to guide therapeutic interventions. The use of positron emission tomography/computed tomography (PET/CT) in radiation treatment planning and tumor response evaluation brings a paradigm change in the development of image-guided therapies into routine clinical practice.

(Guha, Alfieri, Blaufox, and Kalnicki - 2008)

Semin Nucl Med. 2008 Mar;38(2)

PET/CT in Radiation Oncology /Edited by Shalom Kalnicki

Seminars in Nuclear Medicine

Volume 42, Issue 5,Pages 281-352 (September 2012)

The ultimate goal of the partnership between nuclear medicine physicians and radiation oncologists is to use this information with absolute clarity in target definition for radiation treatment planning and therapy, as well as response evaluation.

POINT/COUNTERPOINT

In the future, emission-guided radiation therapy will play a critical role in clinical radiation oncology

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[https://doi.org/10.1002/mp.13408]

Med. Phys. 46 (4), April 2019

Three Types of Emission Guided Radiotherapy

- PET-guided external beam radiotherapy: Reflexion.
- PET-guided patient dose measurements during particle therapy: *In Development*.
- Emission-guided radionuclide therapy: Using a SPECT and PET, patients for liver cancer radioembolization can be imaged pretreatment to predict the therapeutic dose and be measured posttreatment

Med. Phys. 46 (4), April 2019

PET Guided External Beam Radiation Therapy

- Multiple targets pose a motion management challenge as different targets can be moving independently of each other — PET imaging will naturally be able to show the motion of individual lesions.
- PET-guided external beam radiotherapy will tailor the total dose delivered based on the quantitative biological changes during course of treatment as opposed to having the same dose and fraction size for all patients

Med. Phys. 46 (4), April 2019

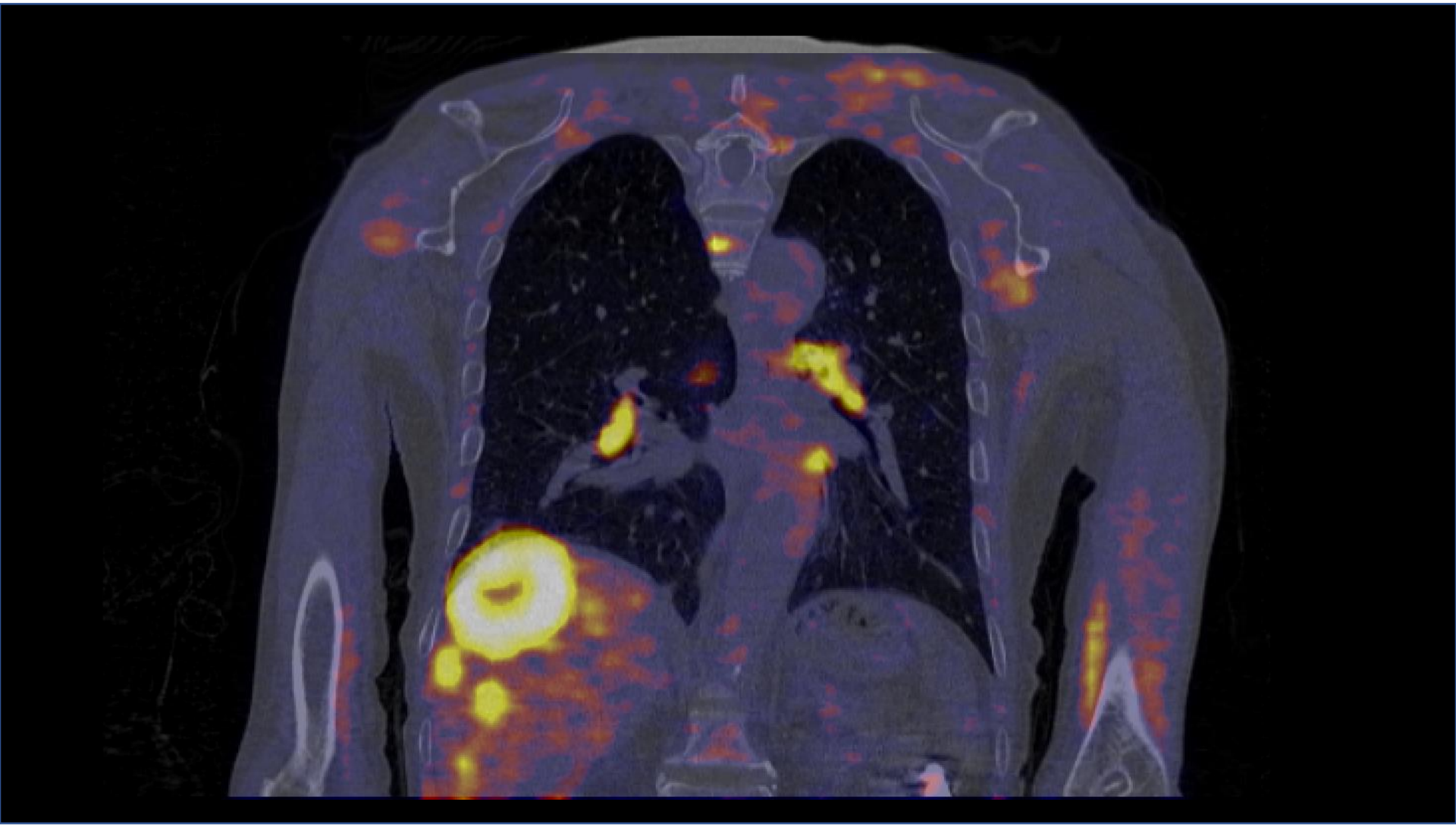
Emerging Treatment **D**elivery Technology:

Hybrid Development of PET IMAGING + LINAC

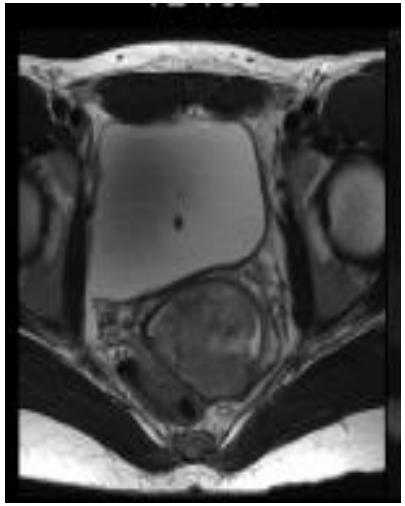
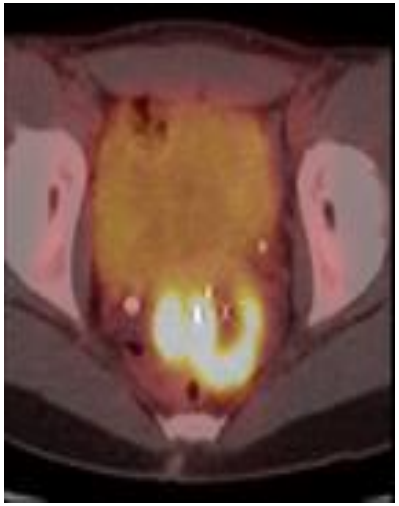
Reflexion, Sunnyvale, CA


Where is human activity?


At night, the activity presents itself.

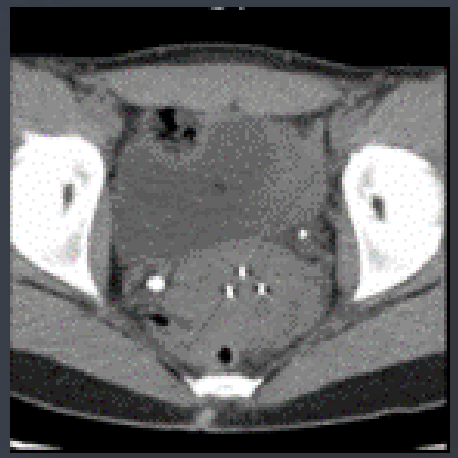


Anatomic vs. Biological imaging

ANATOMICAL		BIOLOGICAL
		
CT	MRI	PET/CT

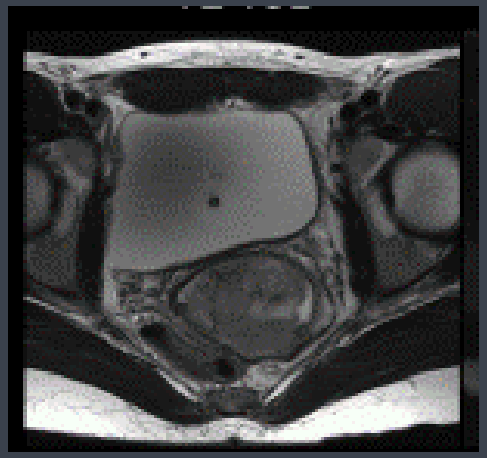
SUPERIORITY OF BIOLOGICAL OVER ANATOMICAL IMAGING

PET PRECISELY LIGHTS UP THE CANCER, WHEREAS CT AND MRI FAIL TO DO SO



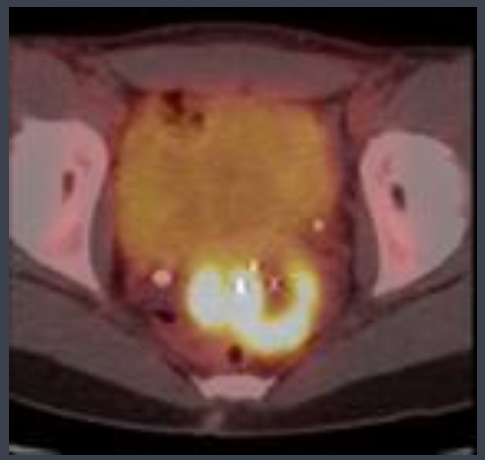
Anatomical: CT

- Images guiding RT are taken hours to days before treatment
- Visualizes bony anatomy, but not biological processes



Anatomical: MRI

- Images guiding RT are taken hours to days before treatment
- Visualizes soft tissue, but not biological processes



Biological: PET/CT

- Each PET image comprised of tens of thousands of emissions
- BgRT uses these emissions to guide radiotherapy from within the body.

The potential of positron emission tomography for intratreatment dynamic lung tumor tracking: A phantom study

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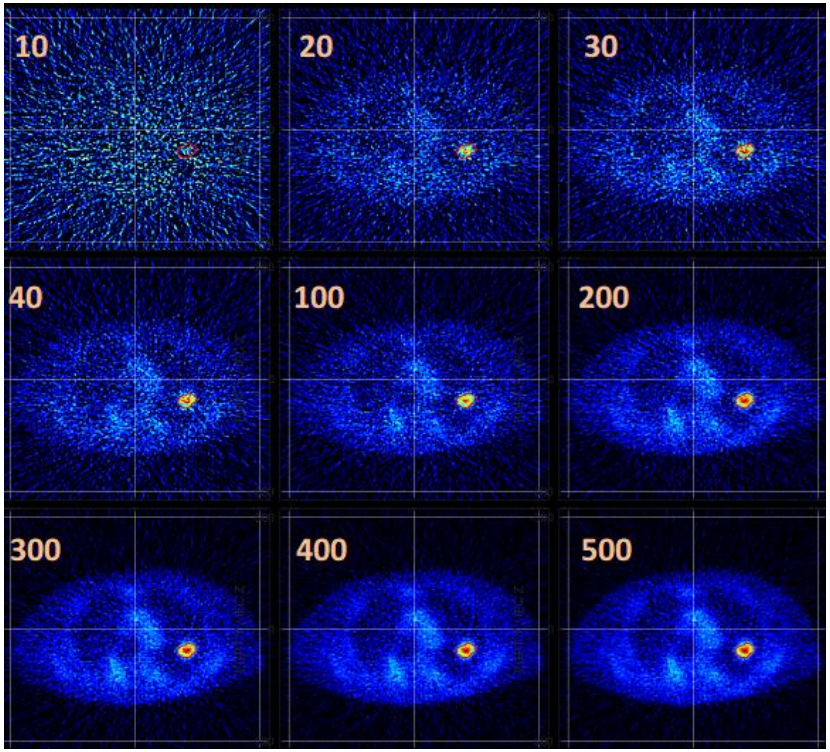
(Received 7 April 2013; revised 17 October 2013; accepted for publication 23 December 2013; published 23 January 2014)

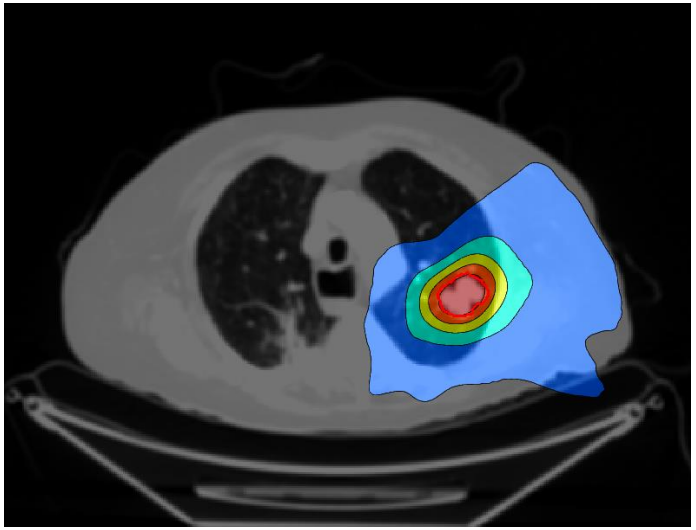
The authors developed an algorithm for dynamic lung tumor tracking using list-mode PET data and a respiratory motion signal, and demonstrated proof-of-principle for PET-guided lung tumor tracking. The overall tracking error in phantom studies is less than 2 mm.

Med. Phys. 41 (2), February 2014

BgRT principle: Just as a PET image can build up over time, BgRT can build the radiation dose over time using a real-time stream of PET emissions



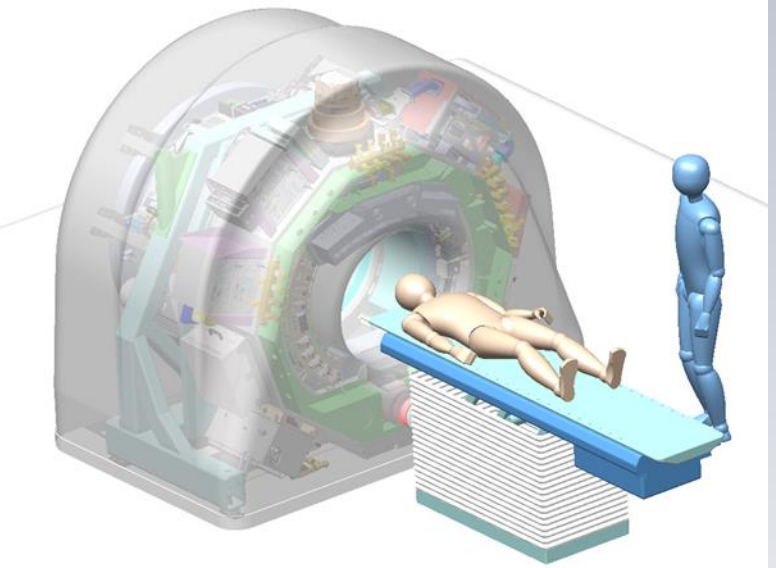
PET emissions collected over time (each frame is 0.5 sec)

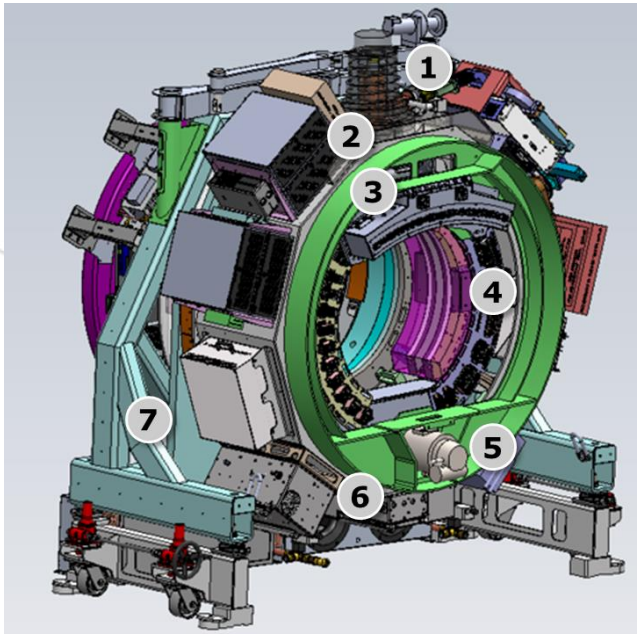


Radiation dose delivered

PET-CT Radiotherapy System

- LINAC, MLC, kVCT, MV detector and two PET detector arrays mounted on a wide bore, closed ring-gantry



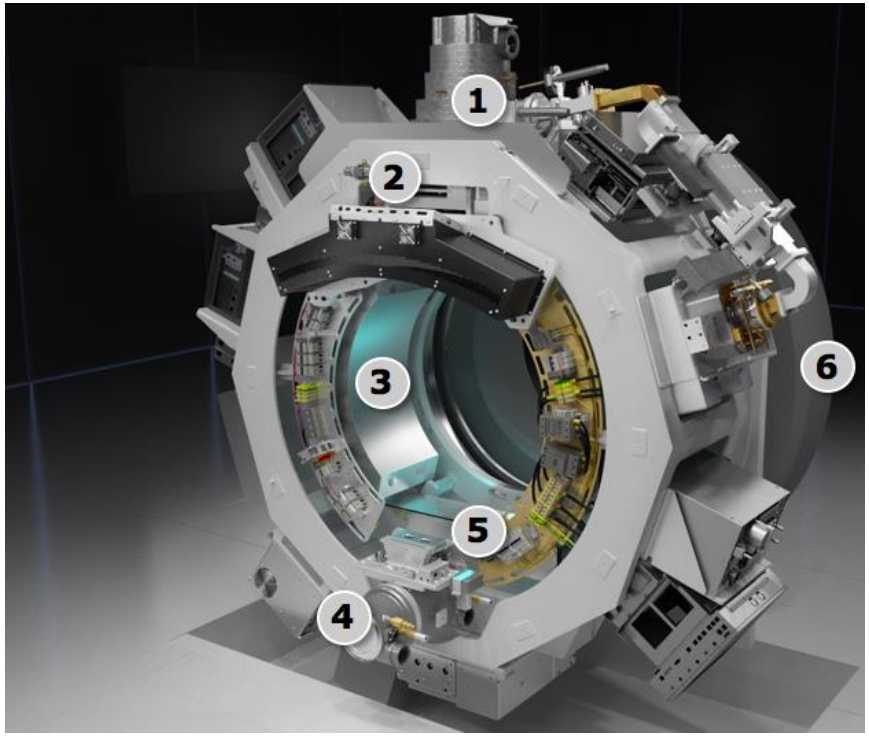


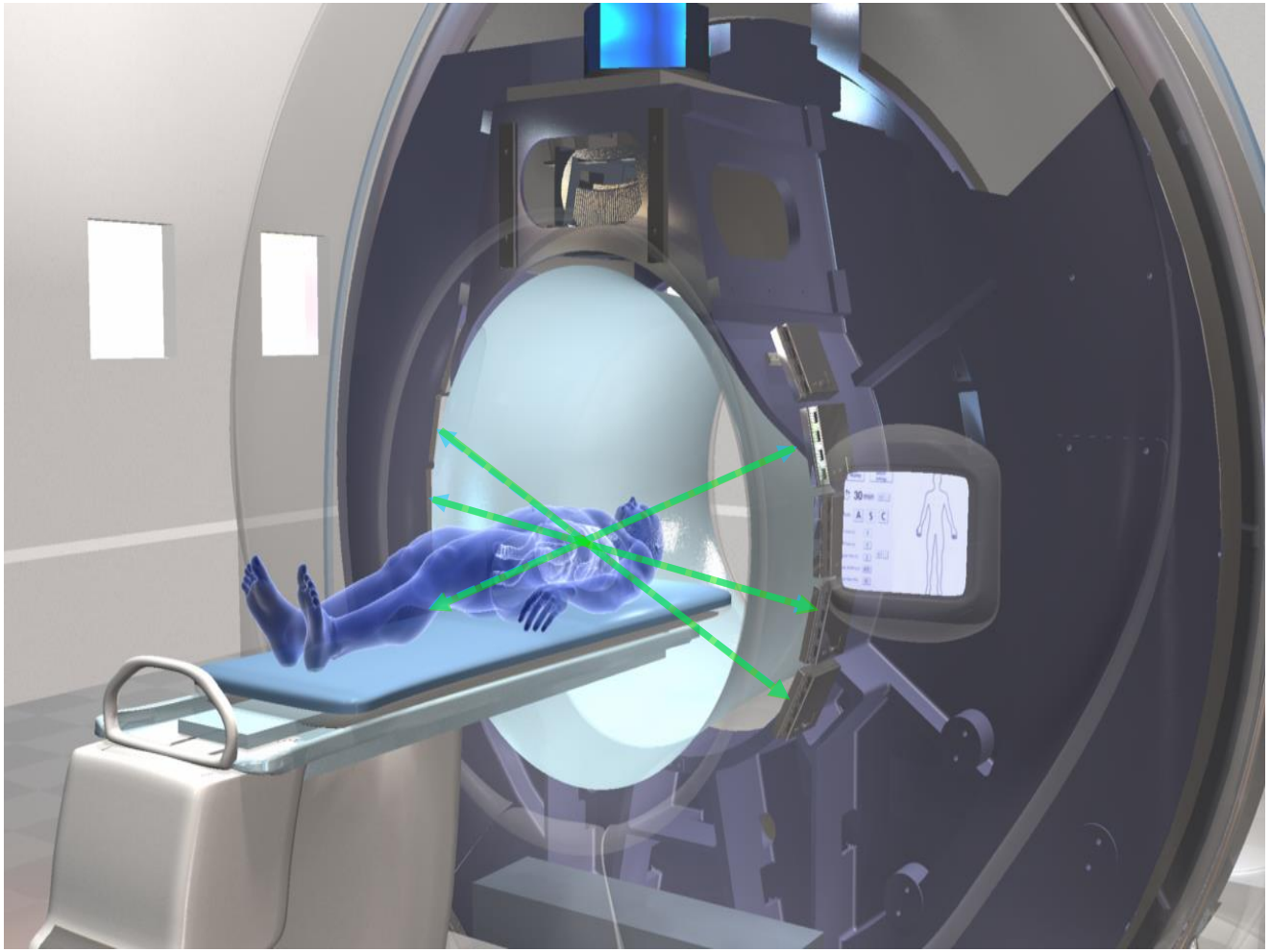
1. Compact Linear Accelerator
2. Primary collimator
3. Binary multi-leaf collimator
4. PET detectors
5. kVCT scanner
6. MV X-Ray detectors
7. Gantry

The RefleXion Machine

5 major subsystems on a wide-bore

1. 6MV LINAC
2. 64-leaf binary MLC
3. Two 90º arcs of state-of-the-art PET detectors
4. 16-slice kV fan-beam CT
5. MV X-ray detector
6. Gantry





Reflexion - A novel radiation therapy system that responds to individual PET emissions in real-time to guide the treatment beam

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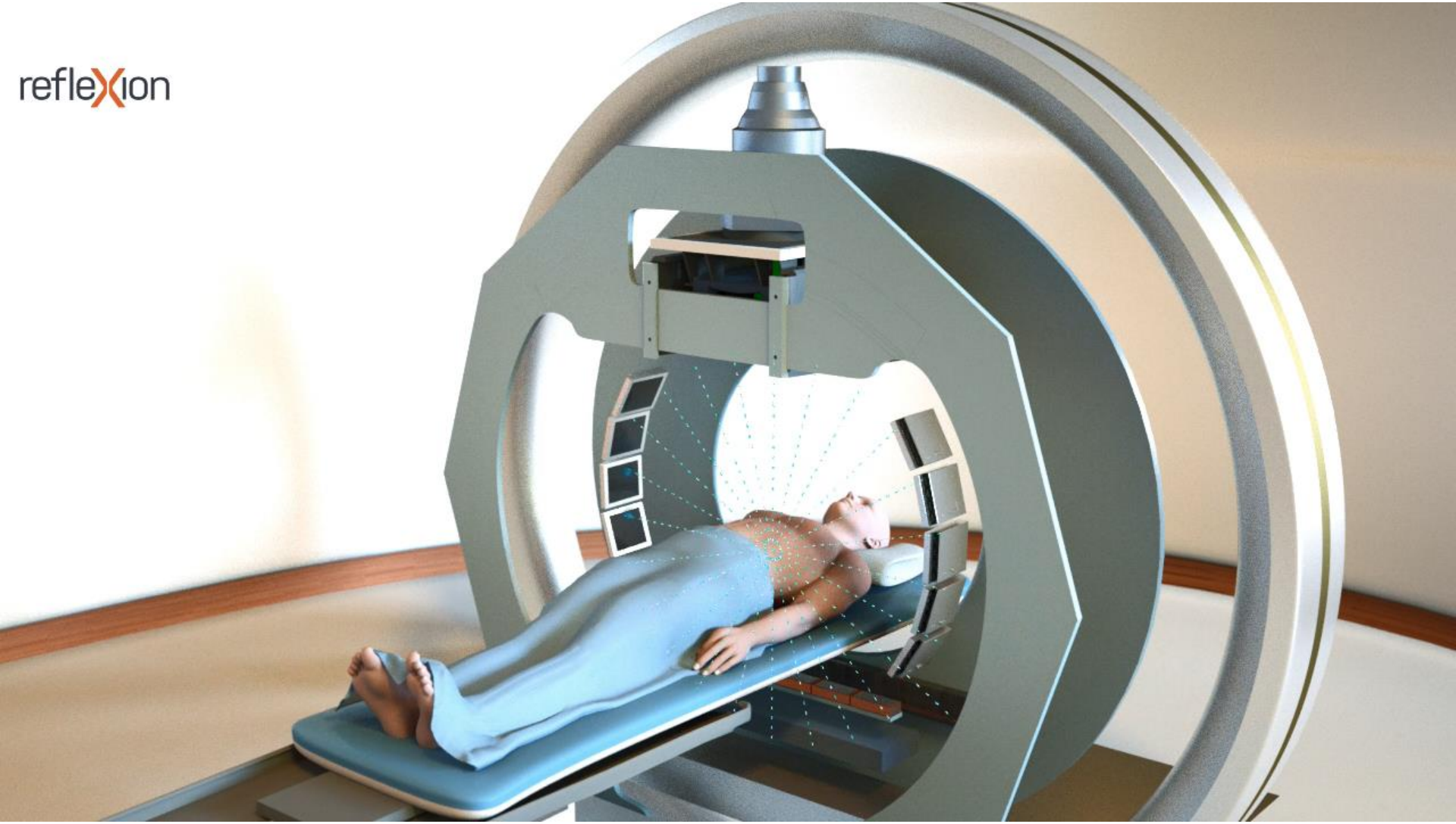
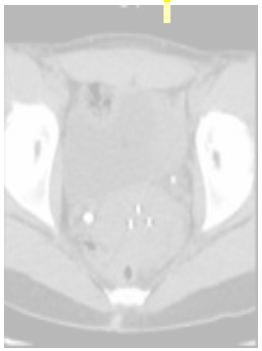
reflexion



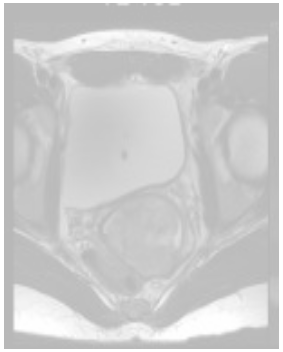
RefleXion Machine

Closed-ring gantry rotates at

60rpm

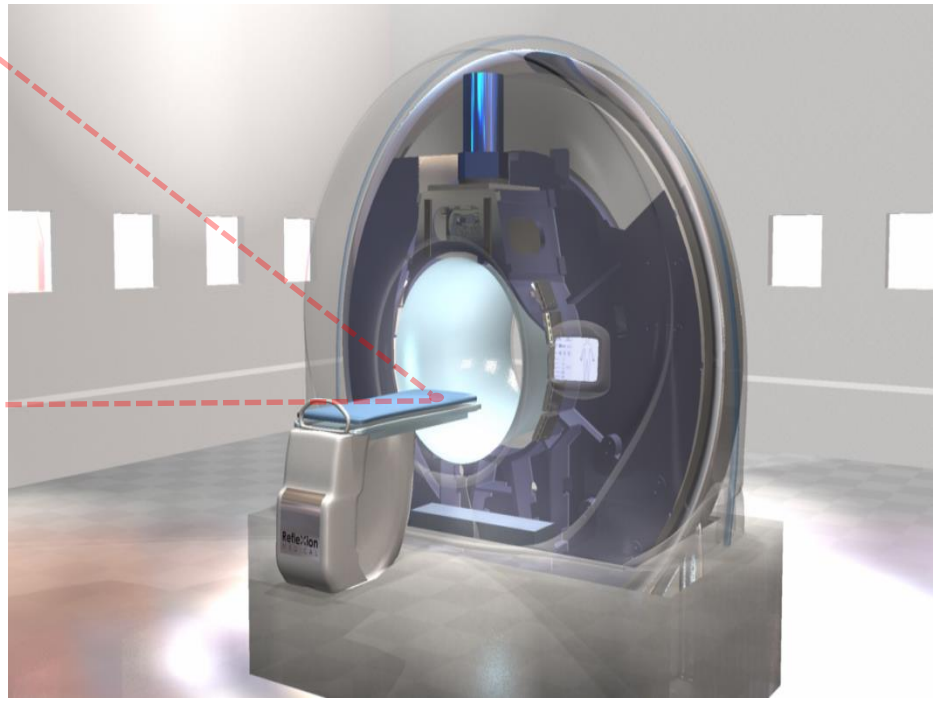


CT



MRI

Biology-guided



Can guiding RT from “biological” signals improve and/or enable new applications?

Toward a planning scheme for emission guided radiation therapy (EGRT): FDG based tumor tracking in a metastatic breast cancer patient

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(Received 17 January 2013; revised 14 May 2013; accepted for publication 7 June 2013; published 17 July 2013)

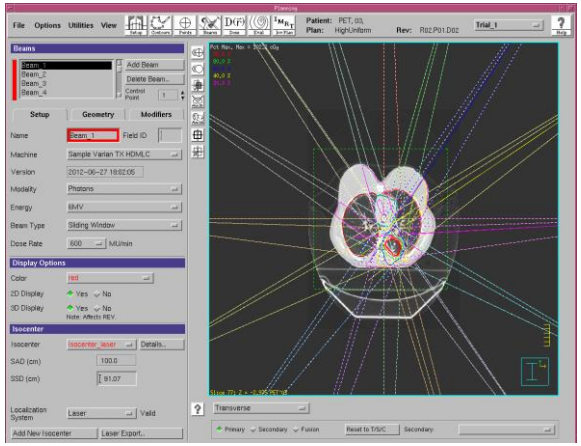
With the capabilities of incorporating planning modulation and accurate tumor tracking, EGRT has the potential to greatly improve targeting in radiation therapy and enable a practical and effective implementation of 4D radiation therapy for planning and delivery

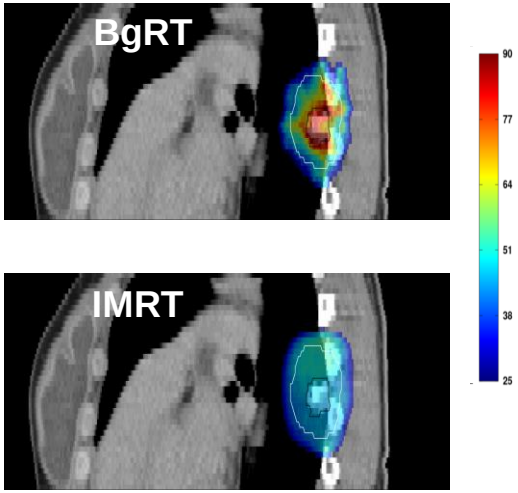
Med. Phys. 40 (8), August 2013

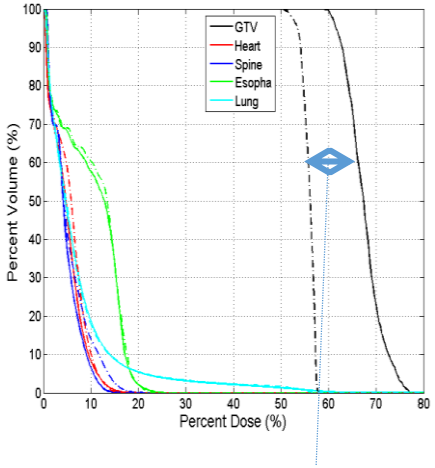
Demonstration Of Biologically Guided RT (BgRT) In A Retrospective Patient Study

Patient data with RT planning → Emulation of BgRT system → Calculate DVH

- ~4cc breast adenocarcinoma
- Planning using Philips Pinnacle workstation

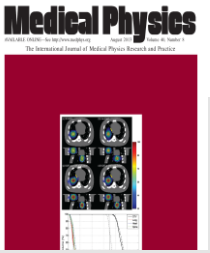






20% more dose to tumor with same dose to OAR's

Q Fan, A Nanduri, J Yang, T Yamamoto, B Loo, E Graves, L Zhu, S Mazin, "Towards a planning scheme for emission guided radiation therapy (EGRT): FDG based tumor tracking in a metastatic breast cancer patient", Med Phys, 2013;40(8):12 pages.



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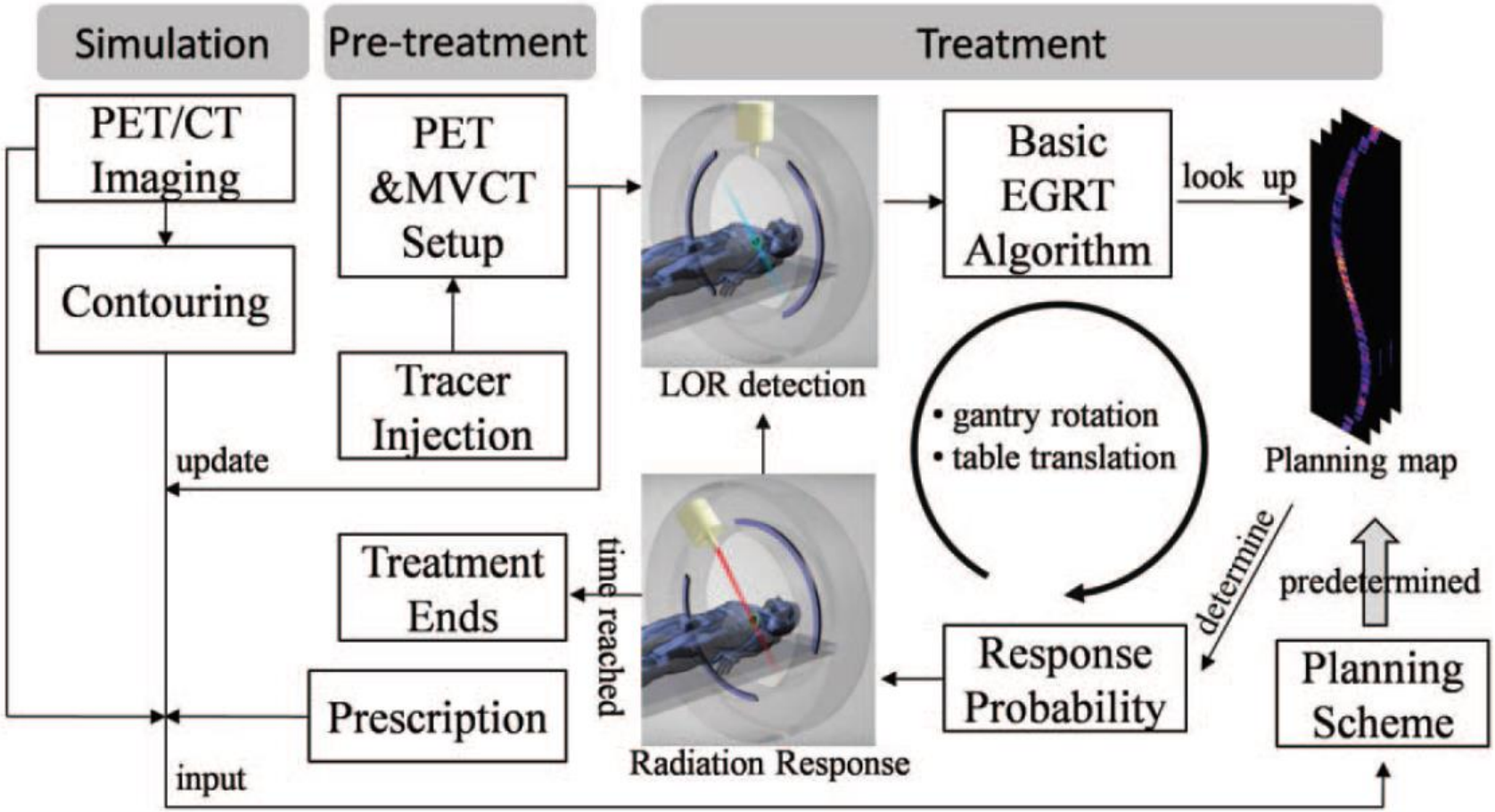

FIG. 2. EGRT treatment scheme consisting of three major components: simulation, pretreatment, and treatment.

Medical Physics, Vol. 40, No. 8, August 2013

INTRODUCTION TO BGRT CLINICAL WORKFLOW

Figure 1. Schematic of BgRT Clinical Workflow

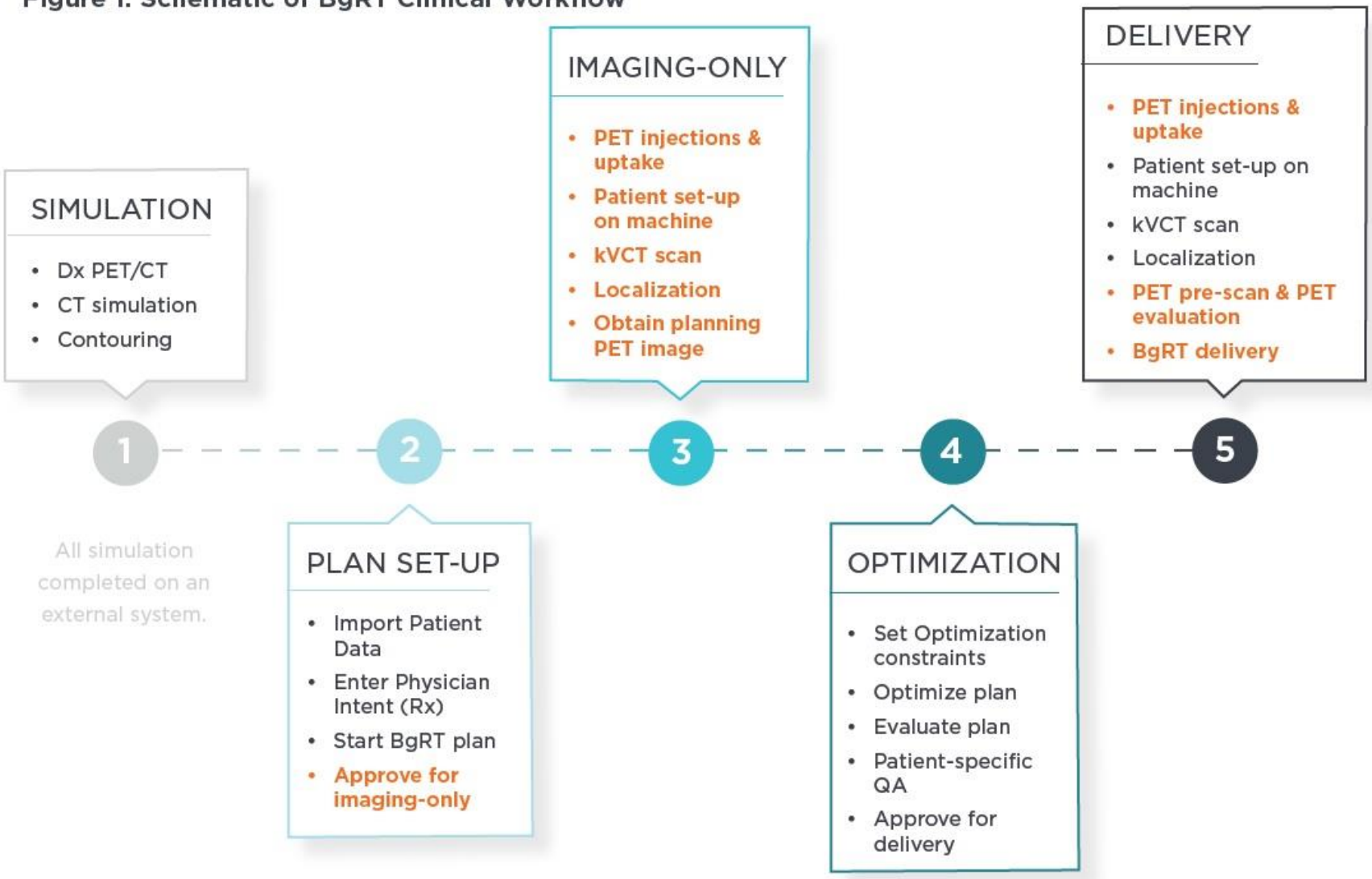

Figure 1 *depicts an overview of the BgRT treatment planning and delivery processes, with steps unique to* ***BgRT highlighted in orange****.*

Summary

- "Because it is a novel science, the future of image-guided functional treatment planning is bright with technologic and biologic innovations, translational research, and new clinical applications…"

(Guha, Alfieri, Blaufox, and Kalnicki - 2008)

Semin Nucl Med. 2008 Mar;38(2)

Grazie