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**Learning Objectives**

1. Understand the steps of a clinical MR-guided ART workflow
2. Appreciate the challenges and risks of online ART

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**Outline**

The ability to adapt a treatment plan online in response to daily anatomic or disease change is a powerful tool in modern radiotherapy. MR guided ART can enable target dose escalation and/or dose reduction to critical structures.

1. Why MRgRT for ART
2. Step of adaptive workflow
3. Day-to-day challenges of on-line ART

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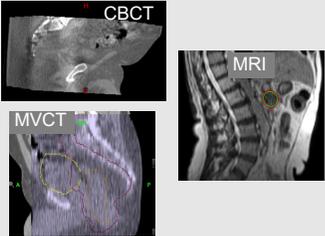
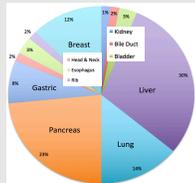
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### Why MRgRT for ART?

- ✓ Superior soft tissue contrast of MR is the (not so secret sauce) to recognize its full potential see targets and avoid OARs.
- ✓ MRgRT is great for abdomen and pelvis- organ filling and positional variability are main sources of uncertainty and dose limitation.

MRgRT @ UW Madison > 400 patients treated since 9/2014

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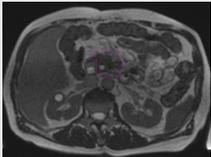
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### Why treat Pancreas with MRg ART?

- ✓ Pancreas is one of the most treated sites for MRgRT.
- ✓ Excellent soft tissue visualization with MRI
- ✓ Surrounded by dose sensitive GI organs
- ✓ Daily anatomic changes due to organ filling and motion
- ✓ Therefore: Ideal candidate for on-line ART
- ✓ The case I will use to illustrate workflow is being treated on a pancreas stereotactic MRI-guided Adaptive RT trial
- ✓ 10 Gy x 5



Prospective phase II Study of Stereotactic MR-guided on-table Adaptive Radiation Therapy (SMART) for Patients with Borderline or Inoperable Locally Advanced Pancreatic Cancer  
 PIs: Parikh, Lee and Low



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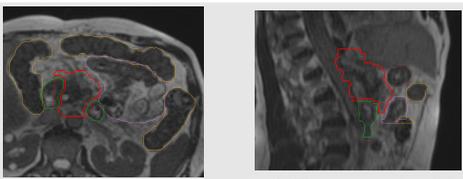
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### Clinical Objectives



	PTVopt	
Ideal, but often violates	$D_{min} = 0.9 \text{ Rx}$	
OAR constrains		
Meet OAR, then:	$V0.95 \text{ Rx} = 60-90\%$	

STRUCTURE	CONSTRAINT
Liver	Mean dose < 20 Gy Keep 700 cm <sup>3</sup> under 15 Gy
Duodenum maximum dose	$V33 < 0.5 \text{ cm}^3$
Stomach maximum dose	$V33 < 0.5 \text{ cm}^3$
Small bowel maximum dose	$V33 < 0.5 \text{ cm}^3$
Large bowel maximum dose	$V33 < 0.5 \text{ cm}^3$
Spinal canal	$V25 < 0.5 \text{ cm}^3$
Kidney (each)	Mean < 12 Gy 2/3 of each kidney < 14 Gy

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**Outline**

What is needed to implement and perform MR guided ART?

1. Why MRgRT for ART
2. Step of adaptive workflow
3. Day-to-day challenges of on-line ART?

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**What is needed to perform MRg ART safely and efficiently?**

- ✓ Daily pre-treatment MRI imaging
- ✓ Deformable Image Registration (DIR)
- ✓ Contouring workflow
- ✓ Accelerated re-planning/optimization/dose computation
- ✓ Patient specific pre-treatment quality assurance
- ✓ Treatment (\*Gated)

All put together with **well thought-out clinical workflow**

\* Not required, but gating or other motion management is key for state of the art abdominal SBRT

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**Dedicated ART Team:**  
 Dosimetrist, RTT, Physicists and MD

...er state of the art SBRT (with tight margins!)

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Positioning → Deformation and electron density → Contouring → Predict dose and plan re-optimization → Plan quality evaluation → Treatment

Short (25 sec) volumetric scan for initial position, manually register, rigid copy contours and send shifts to couch... MD/physics review (1)

(Really small shifts, we are not always that close)

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Positioning → Deformation and electron density → Contouring → Predict dose and plan re-optimization → Plan quality evaluation → Treatment

Process and Plan

- 2 Threshold 55
- Auto-Contour Skin
- Margin 5
- 1 Get Deformation and Auto-Contour
- Advanced Registration
- Rigid Copy Contours
- Edit Contours

Plan image (with deformed but not yet edited contours.)      Electron density view of current image

3. Confirm electron density (just near target) and override as needed using pre-existing empty contours "ToWater" and "ToAir"

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Density override example

Today's MRI

Assigned electron density based on initial CT data.

However today that gas bubble is not there so the contour ToWater was edit to fill in this area.

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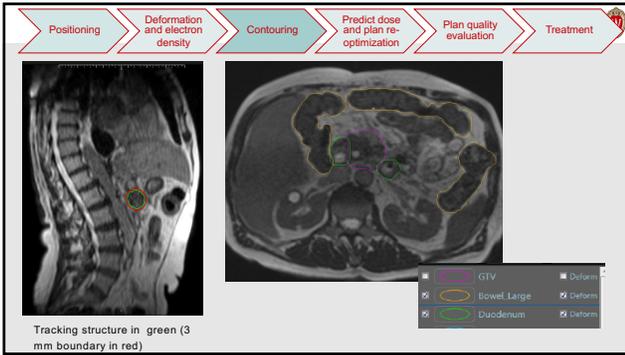
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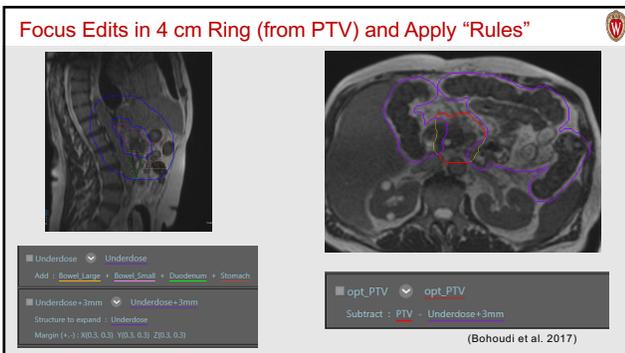
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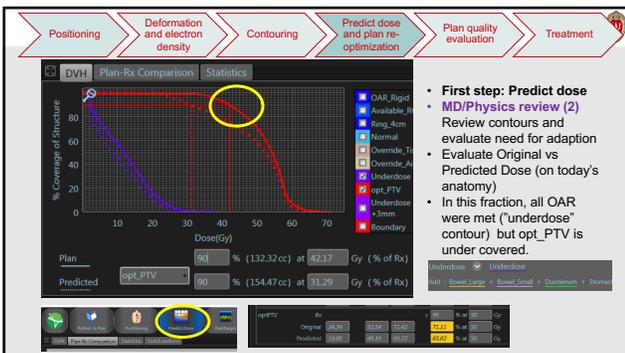
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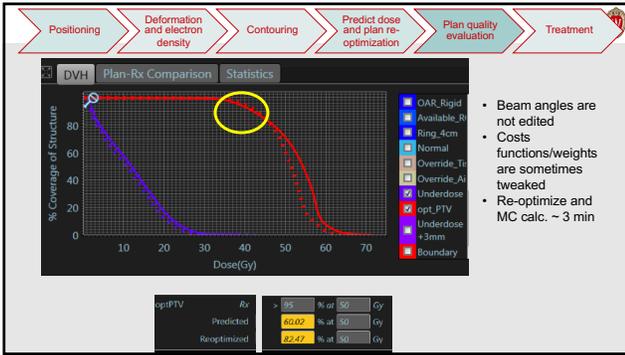
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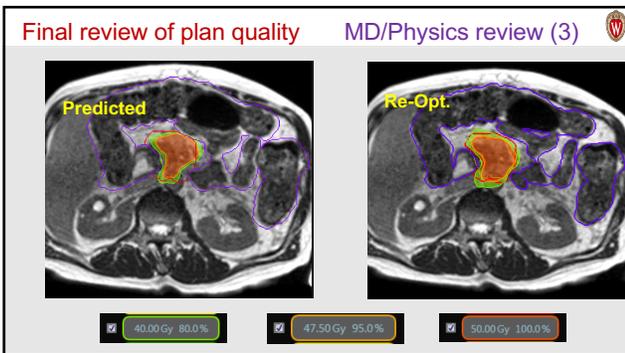
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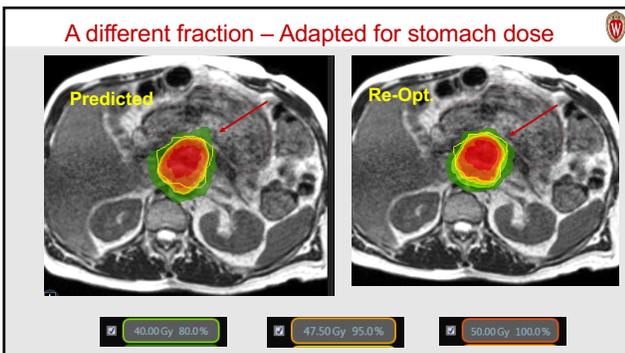
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**Outline**

Sounds swell, when can we start?

1. Why MRgRT for ART
2. Step of adaptive workflow
3. Day-to-day challenges of on-line ART?

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**Day-to-day challenges of on-line ART**

- Patient selection
  - Can be in bore 30 min -2 hrs. (1hr is average)
  - Comfort (claustrophobia, arm position, bladder filling, gated breathing sequence, etc...)
- Internal motion while re-contouring, adapting, evaluating....
- Availability of MD and physics coverage at treatment unit
  - Important roles, random times with short notice
  - Any delay adds to patient time on table
  - Page MD and assign physicist to machine
- Experienced and dedicated therapists are required
  - Very interactive during treatment (compared to other modalities)
  - Trained for OAR contouring and coaching through the gating breathing sequence

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**Day-to-day challenges of on-line ART ...**

- Software limitations
  - Bugs – crash during ART you many loose contours
  - Deformation is less than stellar for abdominal organs
  - Editing contours is time consuming – focus near tumor
  - Optimization and dose computation time
- Finally, not all adaptive plans are acceptable – its important to appreciate the limits of the system and process.

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**All Adaptive Plans Are Not Clinically Acceptable**

Tumor moved A LOT: Initially anterior to liver. Adapted plan was unacceptable.

Initially anterior to liver      Moved with transverse colon into abdomen below inferior tip of liver.

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**The ability to adapt a treatment plan online in response to daily anatomic or disease change is a powerful tool in modern RT.**

- ✓ Slow down
- ✓ Establish clear, well documented workflows with checklists
- ✓ Train and communicate within the ART Team.

With Great POWER comes GREAT Responsibility - Voltaire

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**Thank you**

- Drs. John Bayouth and Poonam Yadav – UW ViewRay Physics leads who developed a darn great ART program on our serial number 2 system!
- Dr. Kate Mittauer – Miami Cancer Institute – teaching me the importance of “getting my reps” for the ART workflow.
- Dr. Laurence Lee - Teaching us all our small bowels from large, and how to find a duodenum in a haystack of bowel loops and vessels.
- The phenomenal UW ViewRay team:
  - RTT: Dan, Dusty, Emilee, Jason, Jess K, Jess S Kailee, Jason and Susie
  - MD: Dr. Bassetti
  - FSE: Nick

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