

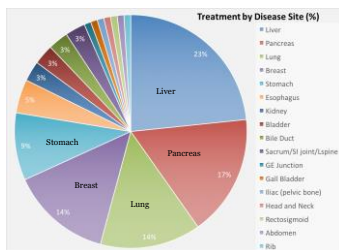
Clinical Indications and Applications of Realtime MRI-Guided Radiotherapy

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Disclosures

Viewray Inc: Travel Reimbursement
Consulting: Thirdbridge

Treatment by Disease Site



Overview



- Patient alignment and setup
 - Inter-fractional changes in target
- Motion Management
 - MRI tracking
- Improving image quality
 - Contrast agents
- Advantages of adaptive treatment
 - Does all this effort matter?
- Treatment response

Patient Alignment and Setup



Consecutive Free Throw Records



Blindfolded

▪ 88



Fred Newman

Not Blindfolded

▪ 5221

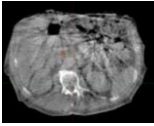


Ted St Martin

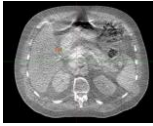
Daily Image Soft Tissue Resolution



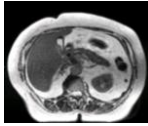
Cone Beam CT
Free Breathing



Cone Beam CT
Breath Hold



0.35T MRI
Breath Hold



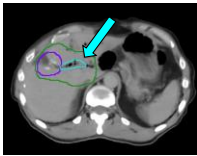
Cholangiocarcinoma at high risk of local recurrence



Targets

Positive Margin Area
Surgical Bed/ 1st LNs
84 Lymph Nodes

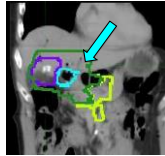
> 60 Gy
= 50.4 Gy
= 45 Gy



Axial View

OAR

Critical Bowel < 54 Gy

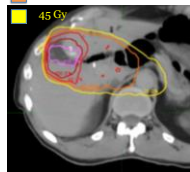


Coronal View

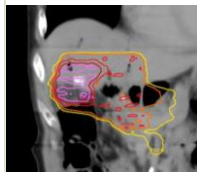
NON-MRI guided VMAT LINAC PLAN



63 Gy
60 Gy
54 Gy
50 Gy
45 Gy



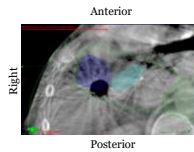
Axial



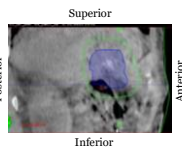
Coronal

Difficult Alignment with Abdominal Cone Beam CT

▪ Axial

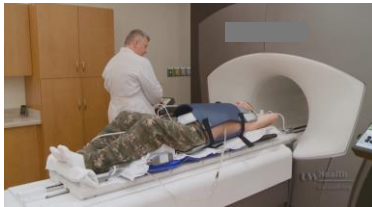


▪ Sagittal

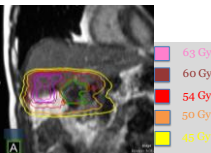
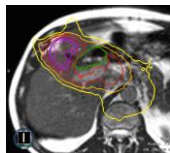


Difficult to resolve soft tissue and align using CBCT
Breathing motion allows bowel to move into high dose region

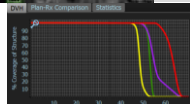
Simulation and treatment



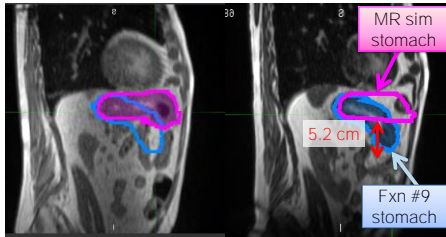
Confidently place high dose adjacent to OARs



- MRI allows confidence placing high dose near organs at risk.
- Breath hold can move OARs away from targets.
- Realtime MRI confirms OAR location during treatments



Inter-fraction Movement



Adaptation: Ensures Tumor Coverage

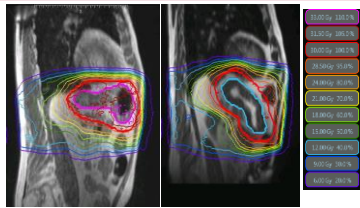


Figure courtesy Kathryn Mittauer PhD

Patients Do the Darndest things

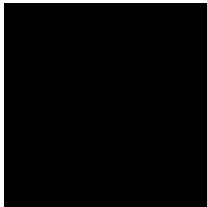


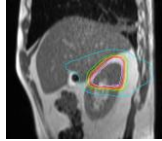
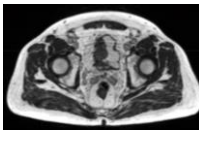
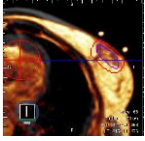
Image Quality for setup at other disease sites



Breast

Pelvis (Bladder, GYN, Rectal, Prostate)

Kidney



Thx Bethany Anderson MD

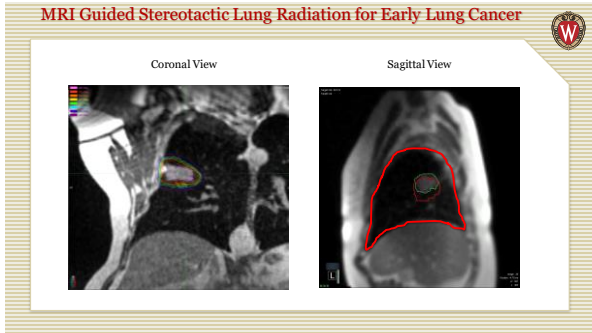
Setup Alignment

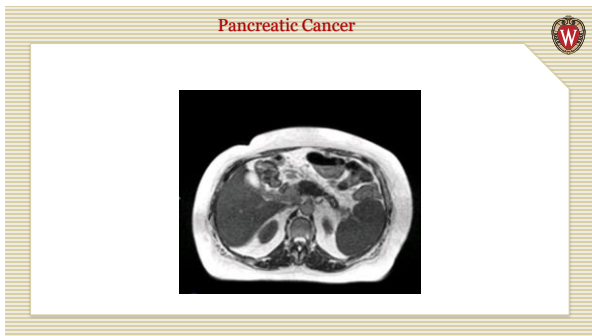


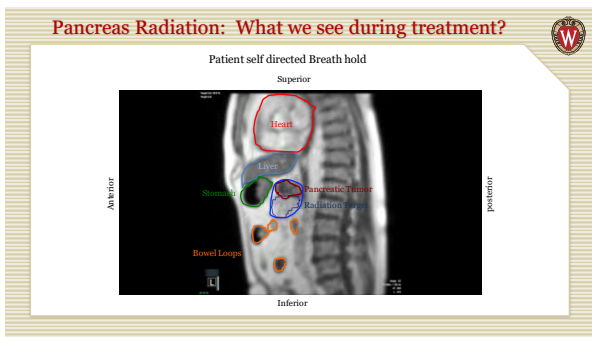
- MRI soft tissue visualization allow accurate setup for a variety of targets.
 - Superior image quality in most areas of the body (exceptions Bone, lung).
- Artifact from motion and bowel gas make accurate soft tissue alignment challenging in the abdomen
 - MRI helps ensure accurate setup alignment
- Abdominal organs (stomach and bowel etc) move and deform
 - MRI helps recognize unexpected interfraction movement

Respiratory Motion Management









Respiratory Motion Management



Advantages of MRI Guided Tracking

- Direct visualization confirms accuracy, not a surrogate (fiducial, chest wall, spirometry etc)
- Non-invasive
- Decreased normal tissue/increase tumor dose
- Improve image quality
- Confidence using high dose near critical organs
- Latency time for MRI and sources are minimal compared to breath hold time.

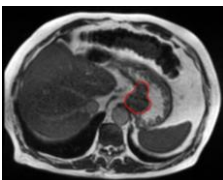
Imaging Contrast Agents



Using Water as Contrast in the Stomach



GTV at Baseline

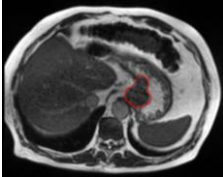


- One 8 oz cup of Water immediately prior to treatment
- Improves contrast between tumor and stomach wall
- Allows software to better track
- Accurate visualization allows small margins
- Breath hold treatment avoids cardiac dose compared to ITV

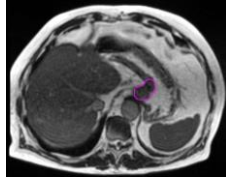
Using Water as Contrast in the Stomach



GTV at Baseline



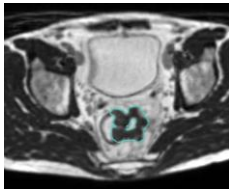
GTV at Fraction 10



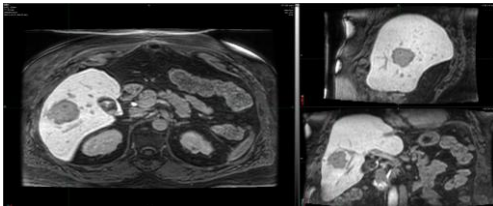
Using Gel as Contrast in the Rectum



T3N1 Locally Advanced Rectal Cancer



Diagnostic T1 weighted Gadoxetate contrast enhanced MRI of Metastatic Colorectal Cancer



Gadoxetate for Stereotactic Ablative Liver Metastasis Radiation



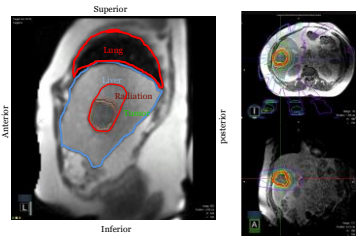
MRI Tracking During Treatment

Radiation is only on when tumor is in proper position

Contrast used to highlight the tumor and allow daily tracking

Unique to be able to see and track actual tumor (not a surrogate) in realtime

Self directed breath hold with RTT "coaching"



Gadoxetate Contrast Remains Stable Throughout Treatment

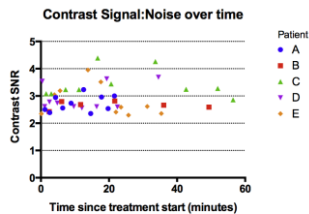


Fig. 3. Contrast signal:noise ratio for five patient fractions.

Wojcieszynski et al, Radiotherapy & Oncology, 2015

Imaging Contrast Agents



- Water is an excellent contrast agent.
 - Bladder
 - Stomach
- Gastric and bladder contents can empty during treatment so this needs to be watched.
- Gel improves visualization of intraluminal component of rectal cancer.
- Rectal gel is invasive and cause tenesmus in some patients
- Gadoxetate contrast in liver allows direct visualization for improved alignment and tracking.
- Gadoxetate lasts for hours so is stable during even extended treatments.

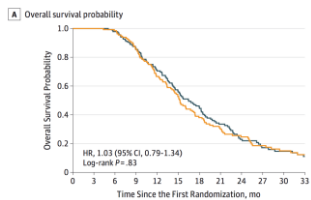
On Table Adaptive Radiation

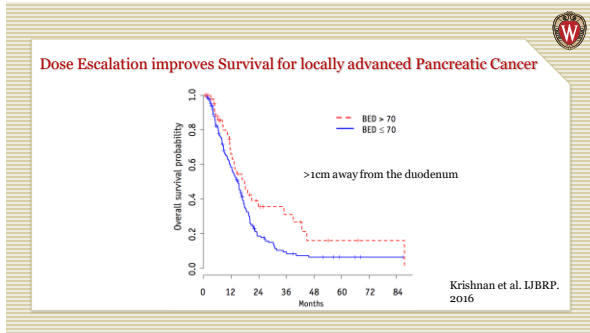
LAP-07

Effect of Chemoradiotherapy vs Chemotherapy on Survival
in Patients With Locally Advanced Pancreatic Cancer Controlled
After 4 Months of Gemcitabine With or Without Erlotinib
The **LAP07** Randomized Clinical Trial

Pascal Hammel, MD, Florence Huguet, MD, Jean-Luc van Laethem, MD, David Goldstein, MD, Bengt Glimelius, MD,
Pascal Artru, MD, Ivan Borbely, MD, Olivier Bouché, MD, Jenny Sharron, MD, Thierry André, MD,
Laurent Mineur, MD, Benoist Chibaudet, MD, Francis Bonnetain, PhD, Christophe Louvet, MD

LAP07: 54Gy Chemoradiation Doesn't Improve Survival Compared to Continued Chemotherapy

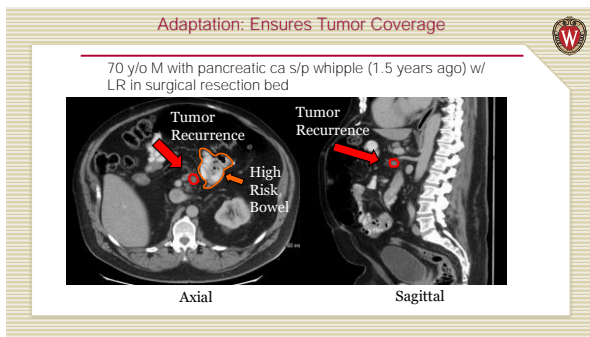


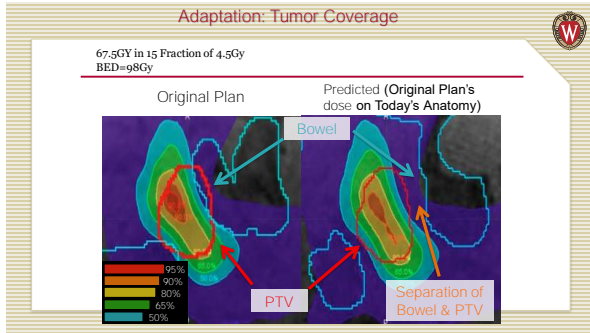


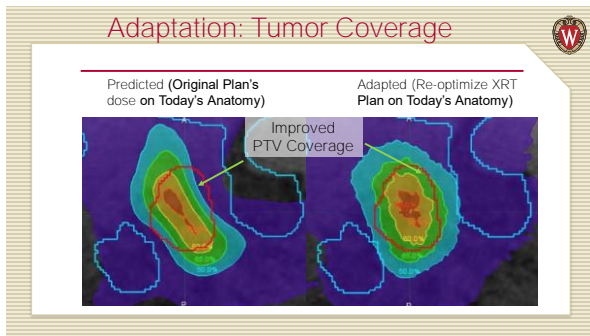
Confidence treating high dose near critical structures

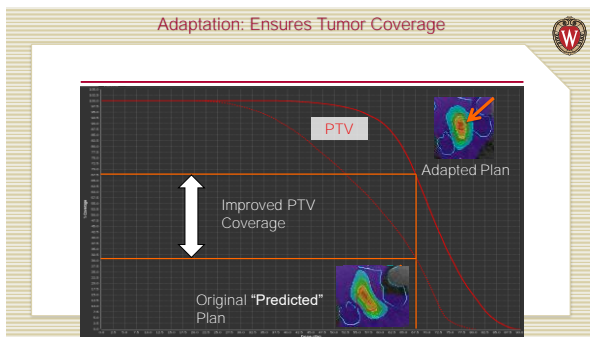
Adapting to inter-fractional changes that:

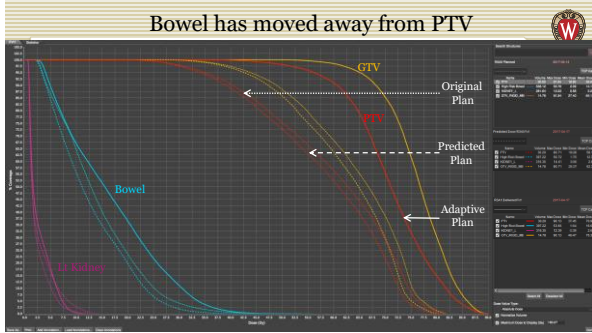
- Decrease PTV coverage
- Increase OAR dose









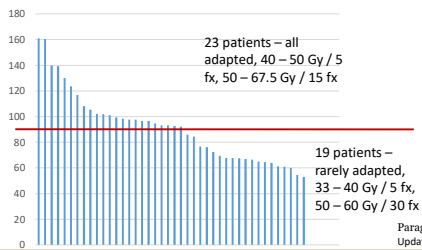


Reviewing MRgRT data to date

- Reviewed five institutions' data for pancreas MRgRT (UCLA, Univ of Miami, VUMC, Washington University, Univ of Wisconsin, Madison)
- Locally advanced, borderline resectable and medically inoperable pancreatic cancer patients
- Practices varied between dose, fractionation, technique between institutions
- Looked at dose as a predictor of survival

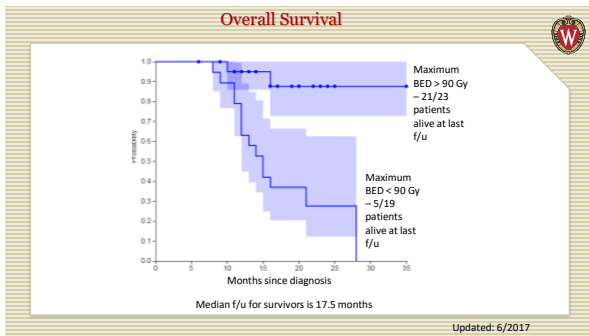
Updated: 6/2017

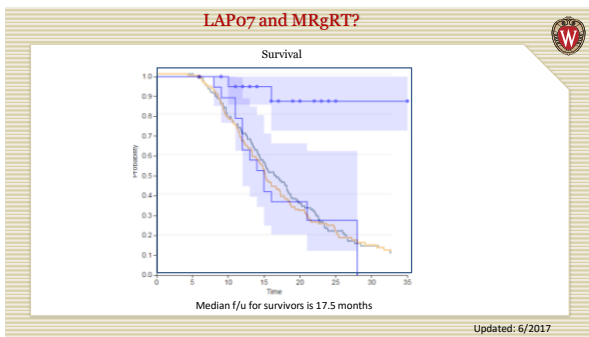
Maximum BED > 90 Gy



Variable	Max BED < 90 (n = 19)	Max BED ≥ 90 (n = 23)	Significance
Age (yrs)	63.4	68.2	0.08
Ct 15-9 (U/mL)	305.9	955.6	0.12
Post-RT Followup (months)	10.3	10	0.84
Node positive disease	4	4	0.7
Resection status BRPC/Inoperable LAPC	6 13	6 17	0.742
RT Type Conventional Hypofractionated SBRT	13 0 6	0 8 15	0.00
Induction Chemo Gem/Abir POL/FAH/CDK Other/none	9 8 2	8 11 4	.66

Updated: 6/2017





Cases which benefit the most from MRI Guidance



- Cases which:
 - Benefit from soft tissue alignment
 - Have significant motion
 - respiratory motion management
 - organ movement
 - Inters vs intra fraction
 - High dose with adjacent organ at risk (OAR)
 - Adaptive treatment
 - Biological Response

Thank You



Physicians

- Paul Harari
- Stephen Rosenberg
- Andrzej Wojcinski
- Andrew Baschnagel
- Bethany Anderson

Physicists

- John Bayouth
- Kathryn Mittauer
- Mark Gaurts
- Patrick Hill
- Bhudatt Paliwal
- Poonam Yadav
- Adam Bayliss
- Zachariah Labby



SAM Question #7



7) In which order of anatomical sites, listed below, has realtime MRI Guided radiotherapy provided the greatest benefit?

- a) Lung, Abdomen, Breast, Pelvis
- b) Abdomen, Lung, Pelvis, Breast
- c) Pelvis, Lung, Breast, Abdomen
- d) Breast, Abdomen, Lung, Pelvis
- e) Lung, Abdomen, Pelvis, Breast

SAM Question #8



8) List the techniques that have been used to improve tumor visualization, from those with the shortest to longest sustainable temporal effect?

- a) Drinking a glass of water, intravenous liver contrast, rectal gel
- b) Drinking a glass of water, rectal gel, intravenous liver contrast
- c) Intravenous liver contrast, rectal gel, drinking a glass of water,
- d) Intravenous liver contrast, drinking a glass of water, rectal gel
- e) Rectal gel, drinking a glass of water, intravenous liver contrast

SAM Question #9



9) What are the most common indications for on-line adaptive radiotherapy observed in clinical practice?

- a) Patient rotation of daily setup alignment
- b) Geometric uncertainty in deformation algorithm
- c) OAR exceeds dose and/or target undercoverage
- d) OAR or target changes in respiratory motion
- e) Patient weight loss

SAM Question #10



10) What unique strategies are being used to increase the duty cycle and targeting accuracy for MRI Guided motion management?

- a) Visual display seen by the patient in real time
- b) Meditation training to improve stability of respiratory pattern
- c) Medication to normalize respiration
- d) MRI compatible ventilators to program breathing amplitude and frequency
- e) Patient self-directed / RTT assisted breath hold
