

## Working On MRI Guided Machines for Medical Physicists Who Are Trained in MRI

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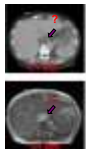
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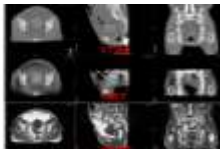


### What MR guided RT (MRgRT) can give us?

- Better target/OAR delineation for planning
- Reduce patient setup uncertainty
- Adaptive treatment planning
- Motion assessment and management - Accurate gating



Better target localization



Better patient setup



Soft tissue based gating



Elekta MRI-Linac Unity™ (1.5T)



ViewRay MRIdian (0.35T)



The Australian MRI-Linac program (1.0T)



MagenTx Aurora-RT™ (0.5T)

### Outline

- Introduction to MRI guided radiotherapy system (MRgRT)
  - RT system and MRI system configuration
  - Special treatments enabled by on-board MRI
- Special MR considerations
  - MR safety consideration
  - Development of QA programs for "MR in RT"
- MRI sequence developments in response to different clinical RT applications




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### Introduction to the ViewRay system

- RT components:
  - 3 headed cobalt system, each 15,000Ci, dose rate around 500cGy/min at 105cm SAD
  - 3 independent MLC systems (1cm leaf width, double focus, field size 27.3cm x 27.3cm)
- MRI components:
  - Split superconducting MRI (0.345 T)
  - 50cm FOV with 70cm bore size
  - Imaging isocenter matches with RT system
  - High resolution 3D MRI images in 15s-172s
  - Real time cine MRI image (4 frames/s)




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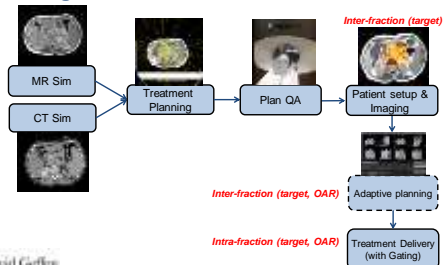
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### UCLA MRgRT Clinical workflow




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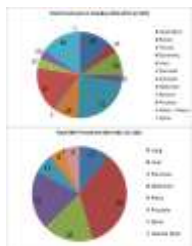
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### Personalized treatments on MRgRT

- Challenges:
  - Mobile and easily deformed
  - Packed with soft tissue organs
- Advantages with MRgRT:
  - Adaptive radiation therapy
  - Inter-fraction motion / change
  - Soft tissue based gated treatment
    - Intra-fraction motion




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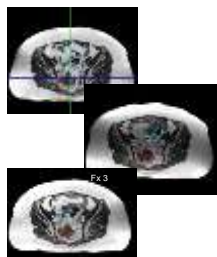
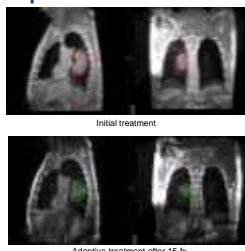
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### Adaptive RT – Tumor or OAR?




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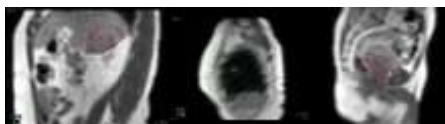
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### Intra-fractional Motion Management

- Free-breathing with monitoring
- Free-breathing with gating
- Breath-hold treatment
  - Inhale
  - Exhale
  - Free breathing




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**Special MR considerations on MRgRT system**

- MR safety consideration
- Development of QA programs for "MR in RT"




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**MR safety consideration**

- MR Safety – Proj
- **MR SAFE** – pos
- **MR CONDITION** – environment will displacement for
- **MR UNSAFE** – environment




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**Emergency Procedures**

- Medical emergency
  - Remove patient, no paramedic team should enter without proper screening
- Firefighting emergency
  - MR-safe actions
- Quench – stopping of the super conduction which rapidly removes the magnetic field
  - Spontaneous magnet quenches
  - Quench in emergency: life or death situation, fire




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## Emergency Quench Procedure

1. Push the Magnet Emergency Stoppage Button:
  - There will be loud nearby alarming, analogous to the alarm built into the magnet's field will shut down to approximately half within 60 seconds.
2. Rescue the patient, or, whichever has been trapped by an object and the loss of the magnetic field.
3. Stay out there until the quench vent:
  - The liquid helium boils off during a quench and a combination will occur on the quench vent pipe and can slip down and cause fires.
4. Leave the Quench Room:
  - The helium is vented outside through the quench vent during a quench. One year, it is possible for helium to escape and fill the room causing oxygen deficiency and the danger of asphyxiation.
5. Call the fire service. It is important to service a quenched magnet immediately.

Confirmation of an oxygen alarm during the process of the cold helium gas and increase the rate of flow. Make sure there is no smoking or use of equipment that releases electrical sparks in the room.

FIGURE

Even though the magnet returns to a superconducting state after 60 seconds after pressing the EMERGENCY STOPPAGE BUTTON, it will be five minutes before the magnet field is completely extinguished.




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## MRI QA on MRgRT

1. Magnet Field Homogeneity
2. Eddy Current Compensation
3. SNR/Uniformity
4. ACR phantom tests
  - 1) Slice Position
  - 2) Slice Accuracy
  - 3) High contrast
  - 4) Low Contrast
  - 5) Percentage Ghost
5. Spatial Integrity
6. Coincidence of MRI and Radiation Field



- Working Group on Magnetic Resonance Testing and Quality Assurance (WGMRTQA)
- Working Group on Magnetic Resonance Safety (WGMRS)




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## MRI sequence development on MRgRT system

- Current imaging protocols (3D and 2D Cine)
- Motion artifact free MRI
  - Breath hold MRI
  - Free breathing MRI
- 4DMR
- Treatment response with DWI




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### Current imaging protocols on ViewRay MRIdian® system

- Two basic acquisition modes:
  - 3D volume scan (static)
  - 2D sagittal cine imaging (dynamic): 4fps
- 3D volume scan:
  - 18 protocols with different image fields of view
  - Spatial resolution: 0.15x0.15cm or 0.15x0.3cm
  - Acquisition time: 17 -175 seconds




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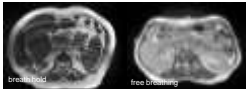
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### Limitations with current imaging protocol on ViewRay

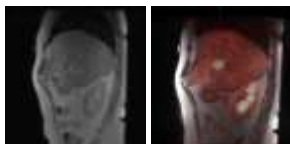
#### 3D sequence

- Breath hold MRI
  - Long acquisition time for breath hold MRI (17s – 25s)
- Free breathing MRI
  - Large motion artifact with free breathing



#### 2D CINE

- Tracking motion through a slice in one plane
- sub-optimal tumor contrast/conspicuity
- Inadequate spatial coverage for retro. dose calculation




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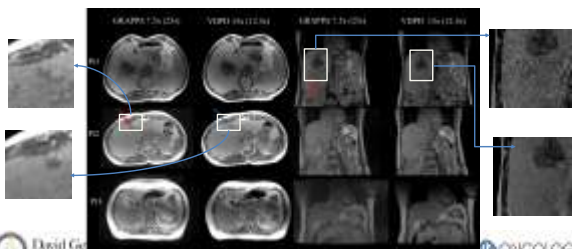
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### Improved breath hold MRI:

#### Accelerated 3D Balanced SSFP Imaging




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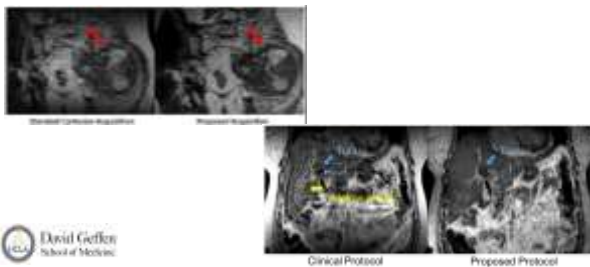
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**Improved free breathing MRI:  
Compensated free breathing 3D MRI for MRgRT**




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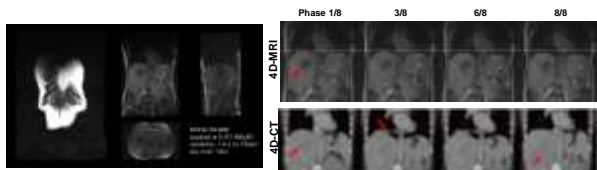
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**4DMRI on Viewray**

- 3D encoding has SNR advantages
- Higher slice resolution
- More flexible sampling design
- Established theories to retrieve missing k-space lines




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**Treatment response assessment:  
Diffusion MRI**

- **Measures tissue cellularity**
  - tumors -> higher cellular density -> lower ADC (Apparent Diffusion Coefficient)
- **Extensively studied at high field (>=1.5T)**
  - may be an early imaging biomarker for tumor response to treatment




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## Summary

- MRgRT brings new possibilities for improved radiation treatments
  - MRI offers superior soft-tissue contrast for MRgRT
  - Real-time MRI provides effective methods for motion management for RT
  - MRI-guided adaptive: a new RT paradigm?
- Calls for special considerations from both expertise
  - MR safety program and QA program
- Comprehensive MRI acquisition: different MRI pulse sequences

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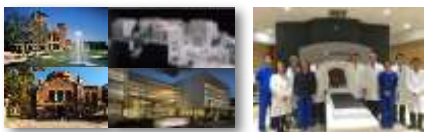
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**Thank you!**



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