Starting an MRgRT Program: installation, safety considerations, and commissioning

O. L. Green, Ph.D.

SITEMAN CANCER CENTER | BARNES-JEWISH Hospital | Washington University in St. Louis School of Medicine | NCCN National Comprehensive Cancer Network | NCI CCC

siteman.wustl.edu 800-600-3606

SITEMAN CANCER CENTER

Disclosure

- Honoraria and travel grants from ViewRay, Inc.

SITEMAN CANCER CENTER

Outline

- Current status of MRgRT systems
- Site Planning
- Staff Training and Patient Safety
- Commissioning

SITEMAN CANCER CENTER

Outline

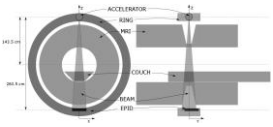
- Current status of MRgRT systems
- Site Planning
- Staff Training and Patient Safety
- Commissioning

SITEMAN CANCER CENTER

Current status of MRgRT systems

- Basic characteristics of commercially-available systems

Elekta Unity



-7FFF linac
-EPID
-55x22 cm^2 field size
-160-leaf MLC
-1.5 Tesla

SITEMAN CANCER CENTER

Current status of MRgRT systems

- Basic characteristics of commercially-available systems

-Three Co-60 sources
-555 cGy/min
-Single-stack MLCs
-105 SAD

-Split-doughnut 0.35-T MRI
-4 fps sagittal plane imaging
-real-time gating

ViewRay MRIdian

-6FFF linac
-600 MU/min
-Doubly-stacked MLC
-90 SAD
-24x27 cm^2 field size

SITEMAN CANCER CENTER

Current status of MRgRT systems

- Proliferation of 0.35-T MRLinac units:

https://viewray.com/clinical-affairs/

SITEMAN CANCER CENTER

Current status of MRgRT systems

- Proliferation of 1.5-T units:

Both 0.35T & 1.5T: 21 clinical units worldwide

Compare with 27 proton centers in USA, 73 worldwide

https://www.elekta.com/radiotherapy/treatment-delivery-systems/unity.html

SITEMAN CANCER CENTER

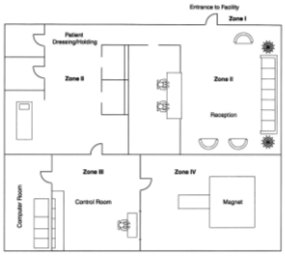
Outline

- Current status of MRgRT systems
- Site Planning
- Staff Training and Patient Safety
- Commissioning

SITEMAN CANCER CENTER

Site Planning – Access Control Requirements

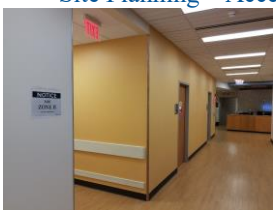
- ACR guidance on MRI Zone Delineation
  - Zone I: general public
  - Zone II: unscreened patients under supervision of MRI personnel
  - Zone III: screened patients under supervision of MR personnel only, restricted from general public access, visitors must also be screened
  - Zone IV: MR scanning room itself

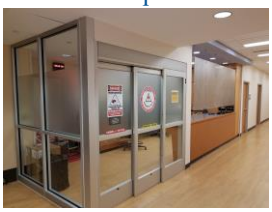


Kanal, Emanuel, et al. "American College of Radiology white paper on MR safety." *American Journal of Roentgenology* 178.6 (2002): 1335-1347.

SITEMAN CANCER CENTER

Site Planning – Access Control Requirements





SITEMAN CANCER CENTER

Site Planning – Access Control Requirements

SITEMAN CANCER CENTER

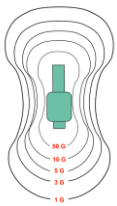
Site Planning – Quench Pipe & Other Ducts

- Both commercially-available systems utilize superconducting magnets filled with helium at 4K
  - The gases must have an escape path in case of instability
  - The quench pipe often cannot have the necessary bends to reduce shielding requirements (as with HVAC) due to maximum pressure limitations to ensure gases escape quickly and harmlessly
- Especially tricky for radiotherapy departments due to their commonly underground locations
- There will be other vault penetrations for cables coming from auxiliary equipment rooms
  - Majority of electronics and cooling equipment located outside the vault
  - These penetrations must be both RF and radiation-shielded

SITEMAN CANCER CENTER

Site Planning – Fringe Magnetic Fields

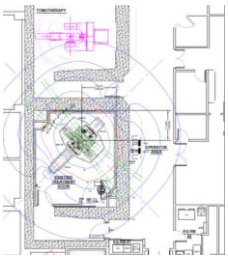
- Manufacturer should provide map of fringe fields
- Must identify and mark the 5-Gauss line
  - The region beyond which magnetic fields can become harmful
- Must consider equipment adjacent to MRgRT vault



SITEMAN CANCER CENTER

Site Planning – Fringe Magnetic Fields

- Example of fringe field interference: ViewRay & Tomotherapy
  - Steel plate installed in the wall between the two vaults, taking the fringe field down to the level of the Earth (0.5 Gauss)



SITEMAN CANCER CENTER

Site Planning – Fringe Magnetic Fields

- Example of fringe field interference: Elekta and Elekta
  - A weak field at the standard linear accelerator resulted in a significant change to flatness and output that was not able to be fully corrected by the linac's servos.
  - After the 1.5-T magnet was stabilized, the adjacent linacs were recalibrated

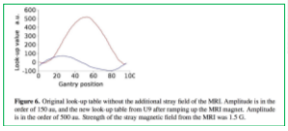
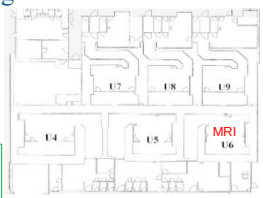


Figure 6. Original look-up table without the additional stray field of the MRI. Amplitude is in the order of 150 au, and the new look-up table from U9 after ramping up the MRI magnet. Amplitude is in the order of 500 au. Strength of the stray magnetic field from the MRI was 1.5 G.



Kok, J. G. M., et al. "Installation of the 1.5 T MRI accelerator next to clinical accelerators: impact of the fringe field." *Physics in Medicine & Biology* 54.18 (2009): N409.

SITEMAN CANCER CENTER

SAM Question

The 5-Gauss line is:

A. A pixel line in the matrix

B. The magnetic field line territory within which the magnetic field can become harmful

C. A catheter inserted into the femoral artery

D. A geometric theorem

SITEMAN CANCER CENTER

SAM Question

The 5-Gauss line is:

A. A pixel line in the matrix

B. The magnetic field line territory within which the magnetic field can become harmful

C. A catheter inserted into the femoral artery

D. A geometric theorem

Reference: E Kanal, JP Borgstede, AJ Barkovich, C Bell, WG. Bradley, JP Felmlee, JW Froelich, EM Kaminski, EK Keeler, JW Lester, EA Scoumis, LA Zaremba and MD Zinninge, American College of Radiology White Paper on MR Safety, American Journal of Roentgenology. 2002;178: 1335-1347. doi:10.2214/ajr.178.6.1781335

SITEMAN CANCER CENTER

Outline

- Current status of MRgRT systems
- Site Planning
- Staff Training and Patient Safety
- Commissioning

SITEMAN CANCER CENTER

Staff Training and Patient Safety

- Staff training – adhere to ACR guidelines
  - MRI director
    - Physician responsible for establishment and adherence to MRI safety guidelines by all staff
  - Level I training – general MRI safety, does not grant unescorted access
    - Should be required of all clinical and engineering staff in radiotherapy as well as all cleaning staff
  - Level II training – unescorted access
    - Should be required of all physicians, physicists, residents, nurses, therapists
    - Anyone who may screen patients and visitors

SITEMAN CANCER CENTER

Staff Training and Patient Safety

- Patient Safety
  - The patient must be screened more than once for MRgRT specifically:
    1. At time of initial consultation
    2. At time of simulation (even if not using MRI or MRgRT for sim)
    3. At time of first fraction
    4. At time of every subsequent fraction (at least an abbreviated version

Never assume that just because a patient had a prior MRI scan that they are safe!

SITEMAN CANCER CENTER

Staff Training and Patient Safety

- Patient Safety – emergency procedures
  - Emergency response personnel must be aware of MRI field
  - An MR-compatible stretcher may be used to transfer patient from MRgRT vault to maze or just outside, where the emergency response team may treat them without fear of ferromagnetic equipment entering the main vault

Kanal, Emanuel, et al. "American College of Radiology white paper on MR safety." *American Journal of Roentgenology* 178.6 (2002): 1335-1347.

SITEMAN CANCER CENTER

Outline

- Current status of MRgRT systems
- Site Planning
- Staff Training and Patient Safety
- Commissioning

SITEMAN CANCER CENTER

Commissioning - Simulation

- Immobilization and positioning device selection
  - Check with manufacturer regarding MRI compatibility of existing products
    - E.g., Vacloc bags, Alpha cradles already MR-compatible
  - Solutions starting to appear for head and neck immobilization
    - Cannot use the standard HN board as it is typically carbon fiber
- Must evaluate the effect on image quality if immobilization/positioning device increases distance between patient and receiver coils

SITEMAN CANCER CENTER

Commissioning - Simulation

- Patient hearing protection
  - May be too large to be comfortably worn in the arms-up position
  - May be impossible to combine with head immobilization

SITEMAN CANCER CENTER

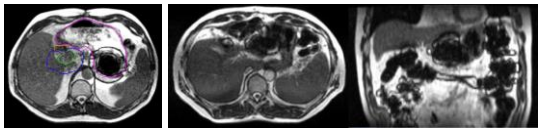
Commissioning - Simulation

- Patient hearing protection
  - Ear plugs are a potential solution
  - Must educate patient to alert staff if they fall out

SITEMAN CANCER CENTER

Commissioning – Considerations for Daily Treatments

- Patient preparation for radiotherapy, especially adaptive
  - Maximize efficiency by minimizing amount of variation in internal anatomy
    - NPO for 2 hours prior to treatment
    - Avoid iron fortified foods and vitamins for duration of treatment



Green, Olga, et al. "Practical Implications of Ferromagnetic Artifacts in Low-field MRI-guided Radiotherapy." *Cureus* 10.3 (2018).

SITEMAN CANCER CENTER

Commissioning – Considerations for Daily Treatments

- Patient monitoring devices (interaction with image quality)
  - It is possible to use anaesthesia and patient monitoring, but care must be taken to evaluate impact on image quality
    - There are no windows in MRgRT vaults! Must have additional cameras
  - Devices are typically tested in diagnostic MRI scanners, there may be RF noise interfering with MRgRT systems specifically
  - Consult with radiology department for more complicated cases

Henke, Lauren E., et al. "First reported case of pediatric radiation treatment with magnetic resonance image guided radiation therapy." *Advances in radiation oncology* 4.2 (2019): 233.

Gach, H. Michael, et al. "Lessons Learned From the First Human Low-Field MRI Guided Radiation Therapy of the Heart in the Presence of an Implantable Cardiac Defibrillator." *Practical radiation oncology* (2019).

SITEMAN CANCER CENTER

Summary

- The proliferation of MRgRT units allows for sharing of experience with installation and implementation
  - Task groups and working groups are actively being organized and guidance is forthcoming
- There is established guidance regarding MRI safety from ACR, but care must be taken as MRgRT patients will be receiving multiple scans and encountering multiple personnel
- It is beneficial to align with a neighboring radiology department but do not assume their procedures are sufficient

SITEMAN CANCER CENTER

siteman.wustl.edu