Integrating the MR-Linac into Radiation Therapy Practice

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MR-Linac: From Prototype to Clinical
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Objectives

- To review the benefits, challenges and clinical implications of the MR-Linac on radiation therapy practice

- To discuss what scope of practice changes will emerge from the implementation of the MR-Linac and the impact it will have on education and regulation

MRGRT - SWOT

Strength

- Improved image quality
- Beam-on images
- On-board functional imaging
- Avoid exposure to imaging dose

Opportunities

- Newly developed workflows
- Ultrahypofractionation
- Research

Weaknesses

- Health economics
- Fraction times
- Deformable registration accuracy
- Magnetic field
- Bore size
- Geometric deformation & MRL calibration

Threats

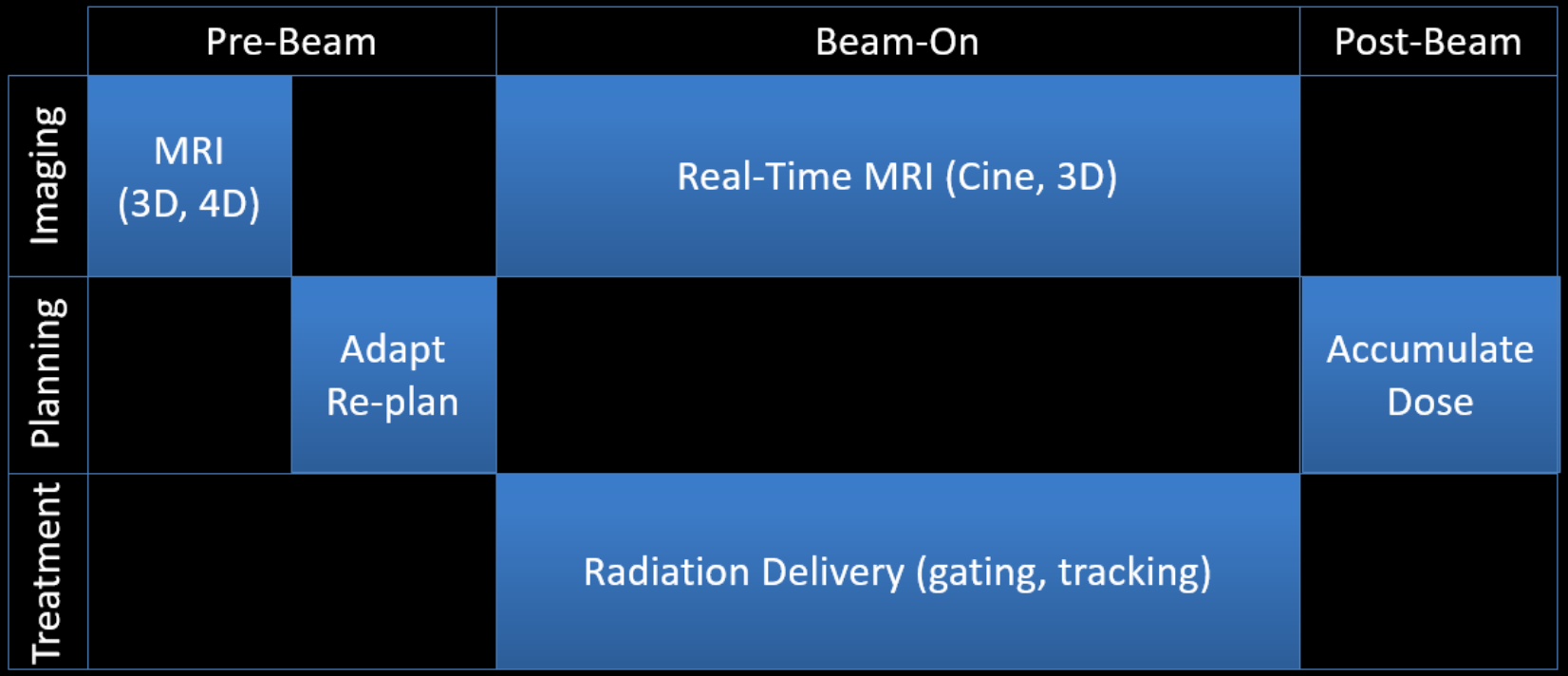
- Workflow & software development
- Intrafraction motion
- Suboptimal patient selection
- Staffing
- Evidence of clinical benefit

EDITORIAL

Magnetic Resonance Imaging—Guided Radiation Therapy: A Short Strengths, Weaknesses, Opportunities, and Threats Analysis

Marcel van Herk, PhD,*,† Alan McWilliam, PhD,*,† Michael Dubec, MSc,† Corinne Faivre-Finn, PhD,*,† and Ananya Choudhury, PhD*,†

MR-Linac Workflow



Courtesy Dr. Allen Li, MCW

Clinical & Technical Considerations

Simulation/ Planning

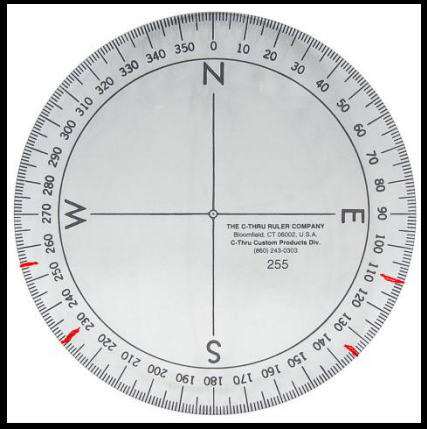
- MRI planning (sequence optimization)
  - MRI eligibility (initial)
- Patient positioning/ immobilization devices
- Motion management
- CT planning
  - Back-up plan for CBCT Linac
- Monaco templates for reference planning

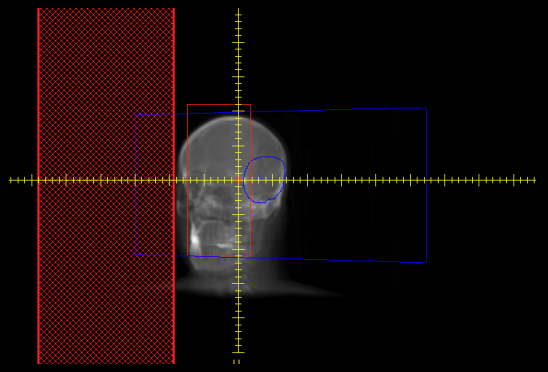
Patient Positioning & Immobilization

- Position of the patient and size of accessories are limited by the size of the bore (arms up vs. arms down)
- All accessories must be MRI compatible and indexed
- Coil indexed

Monaco Planning Considerations

- 57 cm (W) x *22 cm (L)* max field size (fixed collimator)
- Avoid gantry angles through couch/coil mechanics
- Avoid gantry angles through cryostat
- IMRT/ 3D Conformal Only (no VMAT)





Monaco Templates

Templates store beam geometries, calculation parameters, calculation settings, physician's intent, IMRT constraints, etc.

- Plans = more heterogenous

Beams

Beam	Description
1	20
2	140
3	165
4	195
5	225
6	260
7	290
8	320
9	350

RT Sided

Beams

Beam	Description
1	20
2	60
3	100
4	140
5	180
6	220
7	260
8	300
9	340

Midline

Beams

Beam	Description
1	340
2	220
3	195
4	165
5	140
6	100
7	70
8	40
9	5

LT Sided

Structure	Cost Function	Enabled	Status	Manual	Weight	Reference Dose (cGy)	Multicriterial	Isoconstraint	Isoeffect
PTV1	Target Penalty	☑	On	☐	1.00			6000.0	5922.5
	Quadratic Overdose	☑	On	☐	4.56	6100.0		120.0	117.8
	Target Penalty	☑	On	☐	1.00			5000.0	5027.9
LENS_Rorig	Serial	☑	On	☐	0.01		☐	975.0	830.3
LENS_Lorig	Serial	☑	On	☐	0.01		☐	975.0	916.3
BRAINSTEMorig	Serial	☑	On	☐	0.01		☐	5300.0	3614.2
OPTICCHIASMorig	Serial	☑	On	☐	0.02		☐	5000.0	4884.3
OPTICNERVE_Rorig	Serial	☑	On	☐	0.01		☐	5000.0	4793.5
OPTICNERVE_Lorig	Serial	☑	On	☐	0.01		☐	4500.0	2415.1
Eye_Lorig	Serial	☑	On	☐	0.01		☐	2800.0	1445.9
Eye_Rorig	Serial	☑	On	☐	0.02		☐	3000.0	2141.1
External	Quadratic Overdose	☑	On	☐	0.01	6000.0	☐	15.0	9.1
	Quadratic Overdose	☑	On	☐	0.01	5600.0	☐	20.0	18.3
	Quadratic Overdose	☑	On	☐	0.01	5200.0	☐	50.0	23.5
	Quadratic Overdose	☑	On	☐	0.01	4500.0	☐	50.0	24.6
	Quadratic Overdose	☑	On	☐	0.01	3500.0	☐	40.0	22.9
	Quadratic Overdose	☑	On	☐	0.01	2000.0	☐	105.0	62.0

Clinical & Technical Considerations

Treatment Delivery

- Anatomic sites
- Pre-beam, Beam-on & post-treatment imaging
- Daily MR eligibility
- ATP vs. ATS
- *No* laser system
- *No* MLC tracking, automatic gating, multi-structure motion monitoring, dose accumulation

- Other Considerations:
  - Patient/ staff scheduling
  - Partial treatment workflow
  - Patient communication

Imaging Workflow

Pre-Treatment
- 3D image acquired from treatment console
- Pre-sets provided
- Drives adaptive plan

Motion Monitoring
- Optional 2D cine
- Can select anatomical plane

Verification
- Re-acquisition of pre-treatment preset before adapted plan approved
- Register image of the day with verification as a visual check to ensure patient hasn't changed significantly

Intra-fractional
- Optional 3D intrafractional intended for beam-on imaging
- Only able to have one beam-on imaging activity (i.e. motion monitoring OR intrafraction imaging)*

Post-Delivery
- Customized pre-sets available
- Potential to use in offline Monaco
- Novel research sequences

Protocols for Adaptation

Anatomical

- Ex. Contour change, bladder filling, rectum filling, seminal vesicles outside PTV

Dosimetric

- Adaptive plan better than reference?
- Adaptive plan is different, but within limits?
- Adaptive plan is worse, not within limits?

Physics

- MU check
- Segment check
- Largest aperture

Training Considerations

- New treatment planning system
- MR safety, patient screening
- MR-based anatomy
  - Image assessment on MRI vs CBCT vs CT
- MR image quality, scan optimization & interpretation
- Daily/weekly QA requirements

Team Development - Sunnybrook

Clinical Specialist Radiation Therapist (CSRT)

Monaco Super User (experienced therapist with minimal Pinnacle experience)

- Responsible for preparing the Monaco treatment planning platform for clinical use

Imaging Super User (RTT/RTMRI)

- Responsible for preparing the imaging platform for clinical use

MR-Linac Rotational Positions (x4)

- Responsible for all aspects of planning and treatment for patients scheduled to the MR-Linac
- Two of the staff selected were certified RTT/RTMRI

Team Development - PM

- Super Users with combination expertise:
  - Monaco
  - MR imaging
  - Clinical implementation
  - Treatment planning
  - Image guidance (online and adaptive)

MRL Workflow Models

- *MRL workflows will be very different*
- 3-4 RTs staffed on MRL (± RO, MP)
  - RT(T) vs RT(MR) vs RT(T, MR)
- Pt in and out of room in 26 min is possible
  - ~45-60 min typical/reported for actual patients
- Some sites looking into MD-independent workflows
  - MD vs RT vs computer for contours / plans / approval

Final Thoughts

1. How will the integration of MRI further expand radiation therapy practice?
2. With integrated MR-Linac systems and adaptive RT, what does this mean for our workflows and our patients?
3. What scope of practice changes will emerge?
4. What impact will integration have on entry level certification, on accreditation, on regulation?