2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

MR-Simulation Motion Emulation Versus Measured Gating Performance for Ultra-Central Lung Adaptive Treatments on 1.5T MR-Linac

Justin Visak, PhD[1], Ruiqi Li,[1], Fan-Chi Su, PhD[1], Jie Deng, PhD[1], Sean J. Domal, PhD[1], Christopher Kabat, PhD[1], Shahed Badiyan, MD[1], Yuanyuan Zhang, MD, PhD[1], Kenneth Westover, MD, PhD[1] and Mu-Han Lin, PhD[2]
[1]UT Southwestern Medical Center, Dallas, TX, USA

UT Southwestern Simmons Cancer Center Radiation Oncology

INTRODUCTION

- Respiratory gating on a **1.5T MR-linac** aids in delivering adaptive treatments for **ultra-central lung tumors**, where target motion must be tightly controlled near critical structures.
- For challenging lung cases, tracking performance may be influenced by respiratory motion amplitude, breathing regularity, and the quality of the selected tracking surrogate.
- Gating performance for complex cases is often evaluated with an additional patient visit to optimize tracking surrogate selection.
- Emulation of gating performance is possible with additional sequence acquisition during MR-simulation.

OBJECTIVE

- ***Compare MR-simulation motion emulation with measured respiratory gating performance for ultra-central lung treatments on a 1.5T MR-linac.***

METHODS AND MATERIALS

- **Five ultra-central lung PULSAR patients** treated on a 1.5T MR-linac were analyzed.
- Respiratory motion was characterized at MR-simulation using cine imaging and used to emulate expected gating duty cycle with carefully selected, **case-specific tracking surrogates**.
- Surrogates were defined to maximize tumor visibility while explicitly cropping adjacent structures that introduce competing motion signals.
- During treatment, **real-time MR tracking** recorded delivered duty cycle, tracking success, and 95th-percentile motion amplitudes in the left-right (LR), superior-inferior (SI), and anterior-posterior (AP) directions.
- Emulator predictions were compared with patient-averaged treatment metrics.

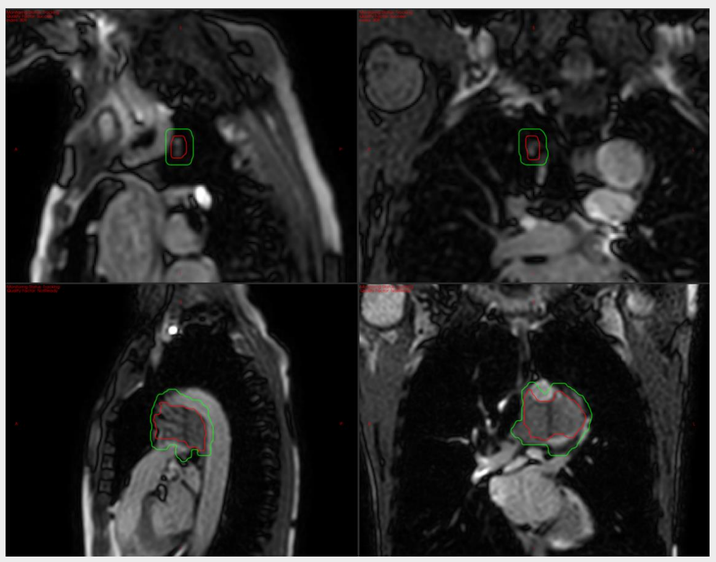

Figure 1. Representative cine MR images from two example patients emulated for tracking surrogate selection, showing the surrogate regions of interest (green) used to maximize tumor visibility (red) while excluding adjacent structures with independent motion.

RESULTS

- Emulated duty cycle agreed with delivery **within 2 percentage points** in two patients (P1: 82.6% vs 82.95%; P5: 55.7% vs 54.3%).
- In the remaining three patients, delivered duty cycles exceeded emulation by **10–32 percentage points**, with treatment duty cycles consistently **above 90%**, despite one patient with values as low as 56%.
- Motion amplitudes varied across patients, with SI or AP excursions exceeding 4–6 mm in several cases, but larger motion **did not correspond to lower duty cycle**.
- Tracking success remained high across all treatments, indicating stable tracking once an appropriate surrogate was defined.

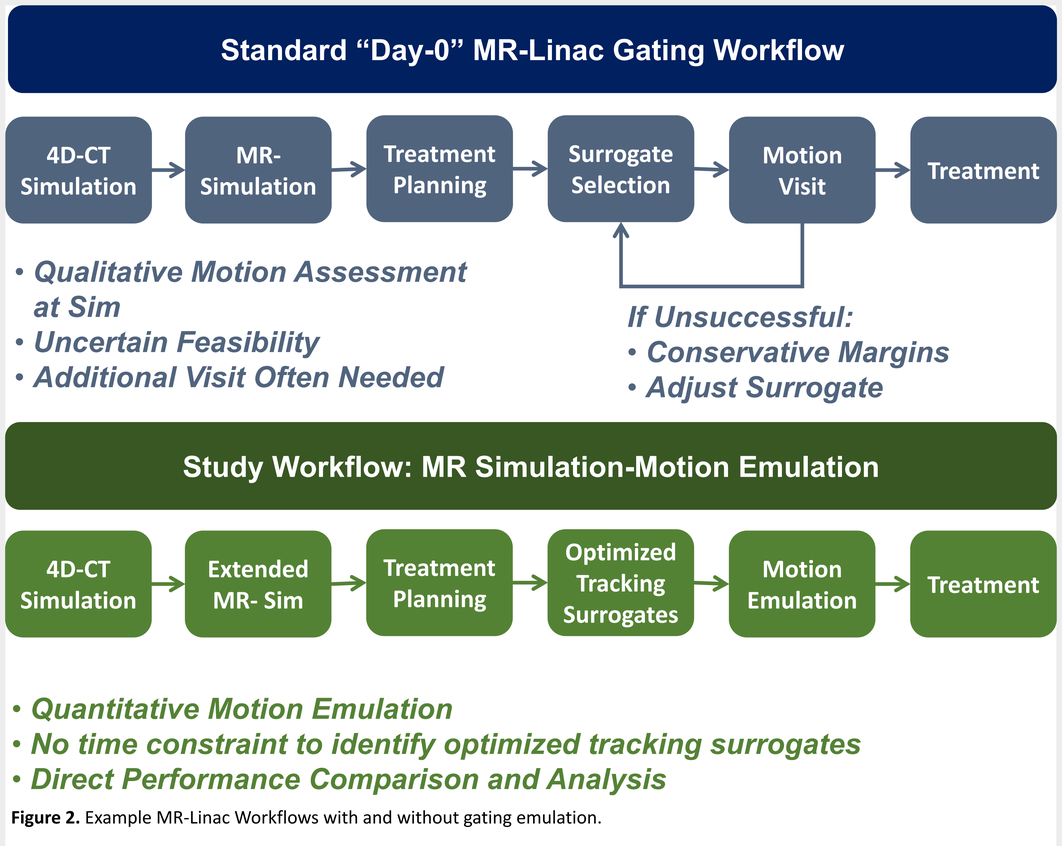

Figure 2. Example MR-Linac Workflows with and without gating emulation.

MR Simulation - Emulation					
Pt. No	Duty Cycle (%)	APM OK (%)	95th LR (mm)	95th SI (mm)	95th AP (mm)
Pt 1	82.6	94.9	2.87	3.08	3.41
Pt 2	71	97.4	3.91	6.25	2.09
Pt 3	86.7	99.2	1.34	2.16	1.87
Pt 4	64.8	99.2	1.28	4.26	4.30
Pt 5	55.7	99.6	5.65	4.28	2.47
Average Treatment Delivery					
Pt 1	83.0	93.5	2.32	3.36	4.97
Pt 2	93.0	96.4	1.64	2.55	2.08
Pt 3	97.1	92.1	1.81	3.78	2.61
Pt 4	96.4	97.9	1.66	2.9	4.02
Pt 5	54.3	77.1	3.55	6.99	3.85

Table 1. Comparison of MR-simulation motion emulation and average treatment delivery metrics, including duty cycle (%), tracking success (APM OK %), and 95th-percentile motion ranges (LR, SI, AP).

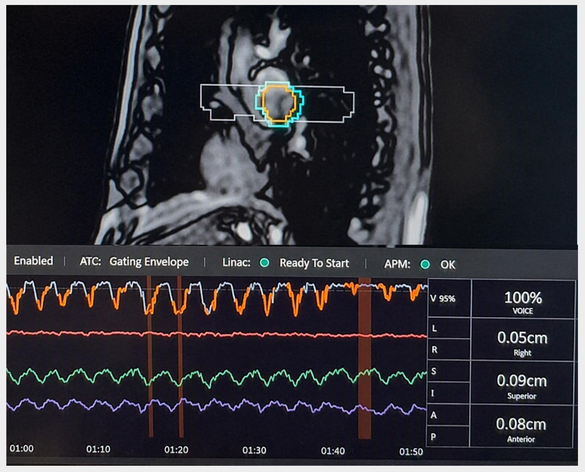

Figure 3. Example cine coronal view and corresponding motion trace of target(orange), envelope (cyan) and registration (gray). Note the periodic motion indication suitable tracking.

DISCUSSION

- Gating efficiency for ultra-central lung treatment is not driven primarily by motion magnitude; patients with larger SI/AP excursions did not necessarily show lower duty cycles.
- The tracking surrogate's ability to isolate respiratory motion from adjacent, independently-moving anatomy appears to be the dominant factor.
- Delivered duty cycle exceeding MR-simulation emulation suggests emulation captures initial breathing behavior but does not fully anticipate the improved respiratory regularity patients often develop during treatment.
- This supports a physics-driven framework pairing quantitative motion emulation with fixed, carefully selected tracking surrogates at MR-simulation, enabling direct comparison **without an additional simulation visit**.

CONCLUSIONS

- Gating efficiency instead depends on selecting a tracking surrogate that isolates respiratory motion and excludes nearby anatomy with independent motion.
- MR-simulation motion emulation reflects initial breathing behavior but does not capture subsequent improvements in respiratory regularity during treatment.
- With optimal surrogate selection, high gating efficiency can be achieved even for large-amplitude motion.

CONTACT

Justin Visak, PhD

justin.visak@utsouthwestern.edu