Implementing Visual Guidance in 0.35T MR-Guided Stereotactic Body Radiotherapy (SBRT): From Setup MRI to Radiotherapy

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

INTRODUCTION

- **Real-Time Motion Management**: Onboard real-time MRI imaging in MR-guided radiotherapy (MRgRT) provides excellent soft-tissue contrast and continuous target tracking for treating abdominothoracic cancers.
- **The Clinical Challenge**: Respiratory motion, such as irregular breathing patterns, introduces significant prolongment treatment, requiring respiratory gating for accurate tumor targeting and sparing of healthy organs from radiation. This leads to longer treatment times and greater patient discomfort.
- **Our Proposed Solution**: We implemented a comprehensive visual guidance system into a 0.35T MRgRT workflow, from the setup MRI to radiation delivery.
- **Improved Workflow**: This biofeedback mechanism spans from the setup MRI through radiotherapy delivery, helping patients regulate their own breathing to improve gating efficiency and shorten treatment times.

METHODS & MATERIALS-I

Visual Guidance Implementation

- Visual guidance was utilized as a patient biofeedback mechanism across two distinct phases of the MRgRT workflow.
- During setup MRI acquisition phase, the patient's respiratory waveforms were monitored and displayed in real time to establish a reproducible baseline breathing pattern.
- During treatment delivery phase, the real-time movement of the target, coupled with respiration, was shown to the patient to help them directly control their breathing motion.

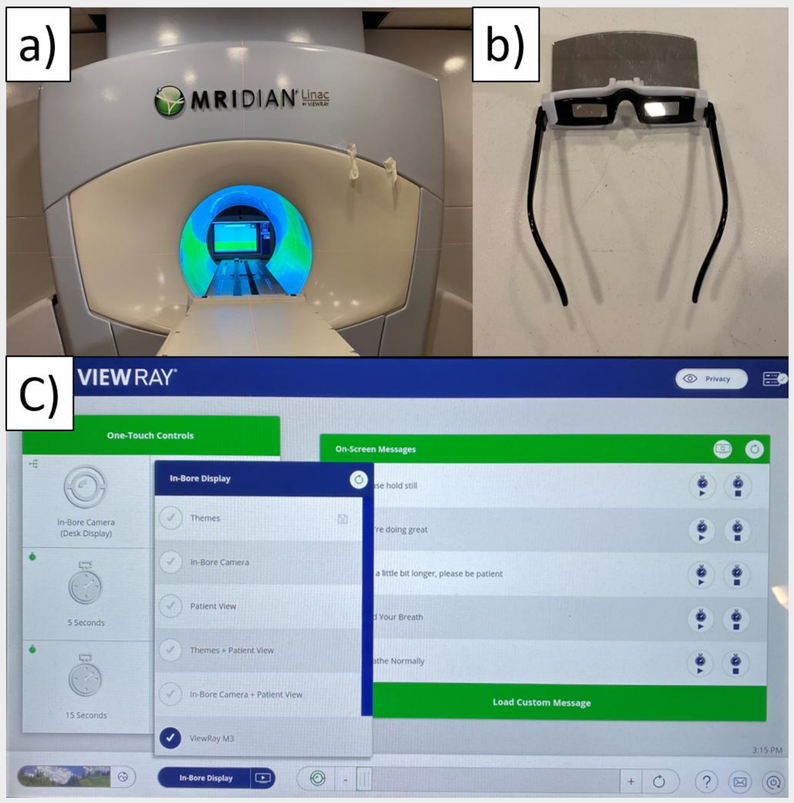

Figure 1. Commercial Visual Guidance. (a) MR-compatible LCD monitor outside of the end of the MRI bore, b) Mirrored horizontal prism glasses, c) display control interface on visual guidance controller.

METHODS & MATERIALS-II

- To provide continuous respiratory tracking, an MR-compatible monitor and mirrored glasses were installed so patients could view real-time feedback and self-regulate their breathing.
- Because the 0.35T MRgRT lacked a monitoring solution for the setup imaging phase, an in-house system was developed using an air pressure sensor to track breathing patterns.
- This setup enabled patients to maintain stable breathing within gating thresholds, directly improving treatment delivery efficiency.

RESULTS-I

Figure 2. In-House Monitoring Hardware. The custom in-house respiratory monitoring system utilizes an air pressure sensor to measure and display these breathing patterns to bridge the technical gap during the MRI acquisition phase.

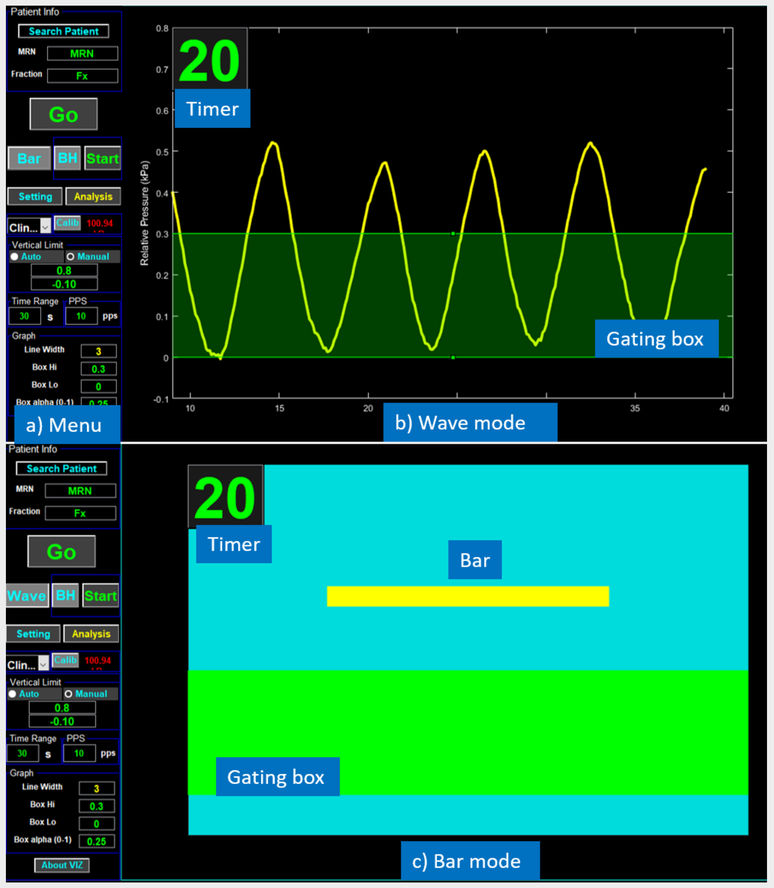

Figure 3. Examples of the developed visual guidance software. In-house visual guidance software with (a) wave mode and (b) bar mode; the components are: (1) respiratory motion trace of the wave mode, (2) gating window (upper and lower boundary), (3) patient information, (4) display setup menu, (5) display mode selection, (6) respiratory motion trace of the bar mode, and (7) breath-hold timer.

RESULTS-II

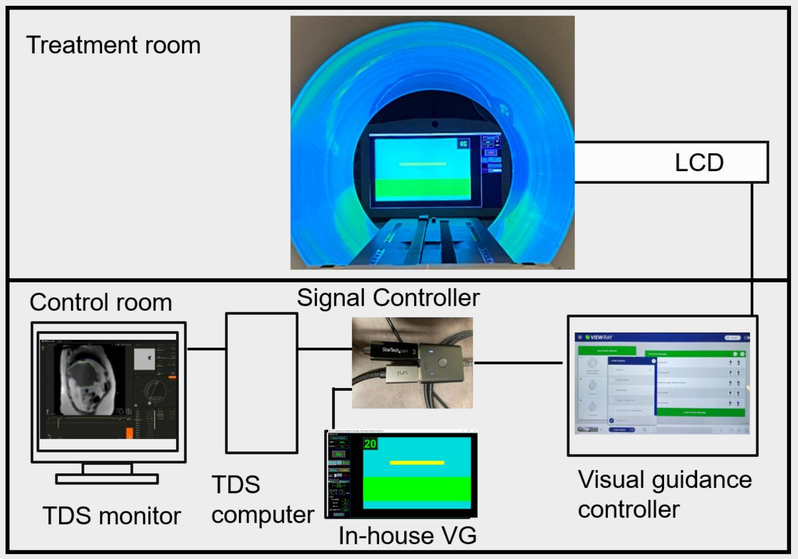

Figure 4. Components of respiratory motion trace management systems. The in-house solution uses a custom dual-source switching mechanism to transmit a direct video signal to an MR-compatible in-room LCD monitor, providing continuous feedback from setup through treatment. The example shows a bar mode with a gating window displayed on the LCD monitor via the visual guidance controller.

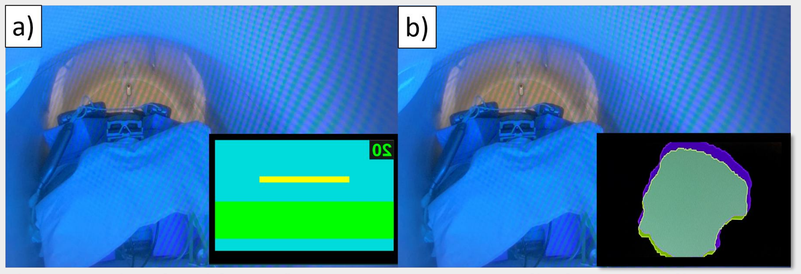

Figure 5. Visual Guidance from MRI: Setup to Radiotherapy Delivery.

1. Patient Preparation

The patient receives a brief orientation before entering the treatment room and continuous, real-time audio guidance throughout the procedure.

2. Setup MRI

Patient's respiratory motion is monitored via a pressure sensor during 3D MRI acquisition and activates an in-house visual guidance mode with a manually adjustable timer to assist the patient with a required 20-second breath-hold scan.

3. Radiation Delivery

During treatment, display switches to TDS screen mode, prompting the patient to align a green target contour within a purple gating boundary using either free breathing or voluntary breath-holding.

CONCLUSIONS

- We successfully established a comprehensive visual guidance workflow for 0.35T MRgRT by integrating a vendor-provided system with an in-house developed solution.
- This seamless, dual-source approach enables consistent respiratory control from imaging to treatment, enhancing the effectiveness of the MRgRT.

REFERENCES

1) Kim et al., "Direct tumor visual feedback during free breathing in 0.35 T MRgRT", JACMP (2020). 2) Kim et al., "Visually guided respiratory motion management for Ethos adaptive radiotherapy", JACMP (2021).