Optimized 0.35T Cine MRI with Implicit Neural Representation Reconstruction for Improved Real-Time Motion Monitoring in MR-Guided Radiotherapy

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INTRODUCTION

- MR-guided radiotherapy (MRgRT) enables real-time motion management using soft-tissue imaging.
- Clinical 2D cine MRI frequently trades spatial resolution for frame rate, which can limit soft-tissue contrast and visualization of small structures—particularly at 0.35T.
- **Purpose**: Optimize a 2D cine MRI protocol on a 0.35T MRgRT system and develop an AI-based reconstruction method to improve cine image quality and effective spatial resolution without sacrificing real-time imaging speed.
- Together, these advances can improve tumor/OAR visualization, enable more reliable motion assessment, and strengthen adaptive MR-guided radiotherapy workflows.

METHOD

Cine Protocol optimization

- Cine sequence optimization was performed on a **CIRS Triple Modality 3D Abdominal Phantom**, then validated in a **liver cancer** patient under an IRB-approved protocol.
- Key parameters were systematically adjusted to improve soft-tissue visualization while maintaining **~4 frames/s**.
- **Contrast-to-noise ratio (CNR)** between liver and surrounding tissue was measured to quantify contrast changes.

AI-Based enhancement

- An implicit neural representation framework (**NeRP**) with prior embedding-based reconstruction was designed.
- NeRP reconstruction was **compared with image-domain interpolation and k-space zero-padding**

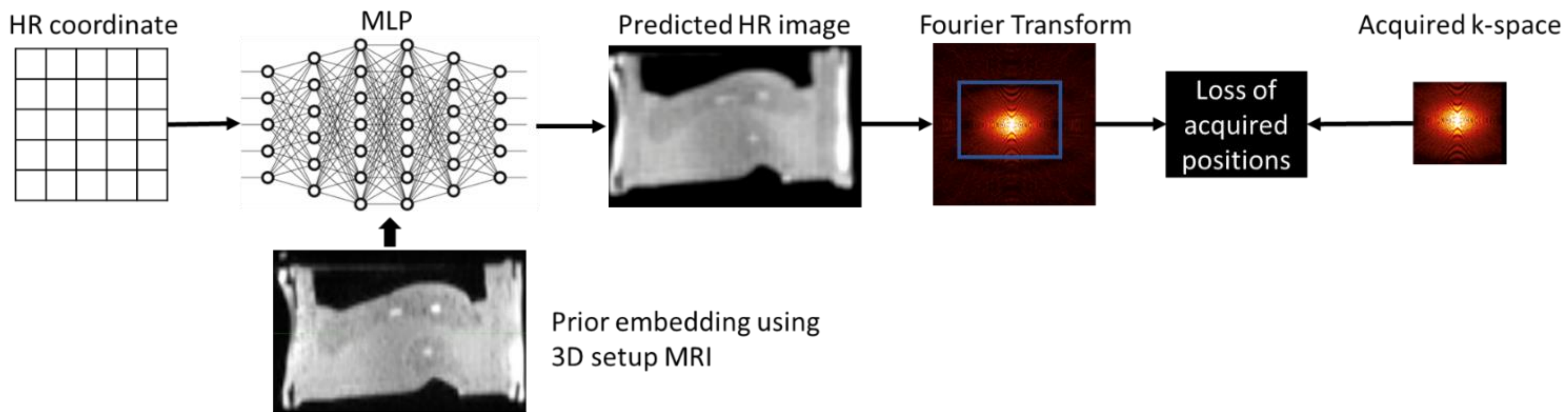

Figure 1. The proposed NeRP-based image reconstruction framework. A high-resolution 3D setup MRI was encoded as an anatomical prior using a coordinate-based multilayer perceptron. Cine images were reconstructed by constraining the network with acquired cine k-space data.

RESULTS

Cine Protocol optimization

- We observed a marked improvement in image quality as the flip angle increased to ~120°, which was then carried forward for patient validation.
- The optimized protocol improved liver contrast and enhanced visualization of small anatomical structures (Fig. 2).
- With the optimized protocol, **CNR** increased from **13.6 → 34.1** in the phantom and **48.5 → 69.0** for the patient.

AI-Based enhancement

- Figure 3 compares NeRP recon against conventional image-domain interpolation and k-space zero-padding.
- NeRP-SR produced sharper boundaries and soft-tissue definition than interpolation or zero-padding, more closely resembling high-resolution anatomy

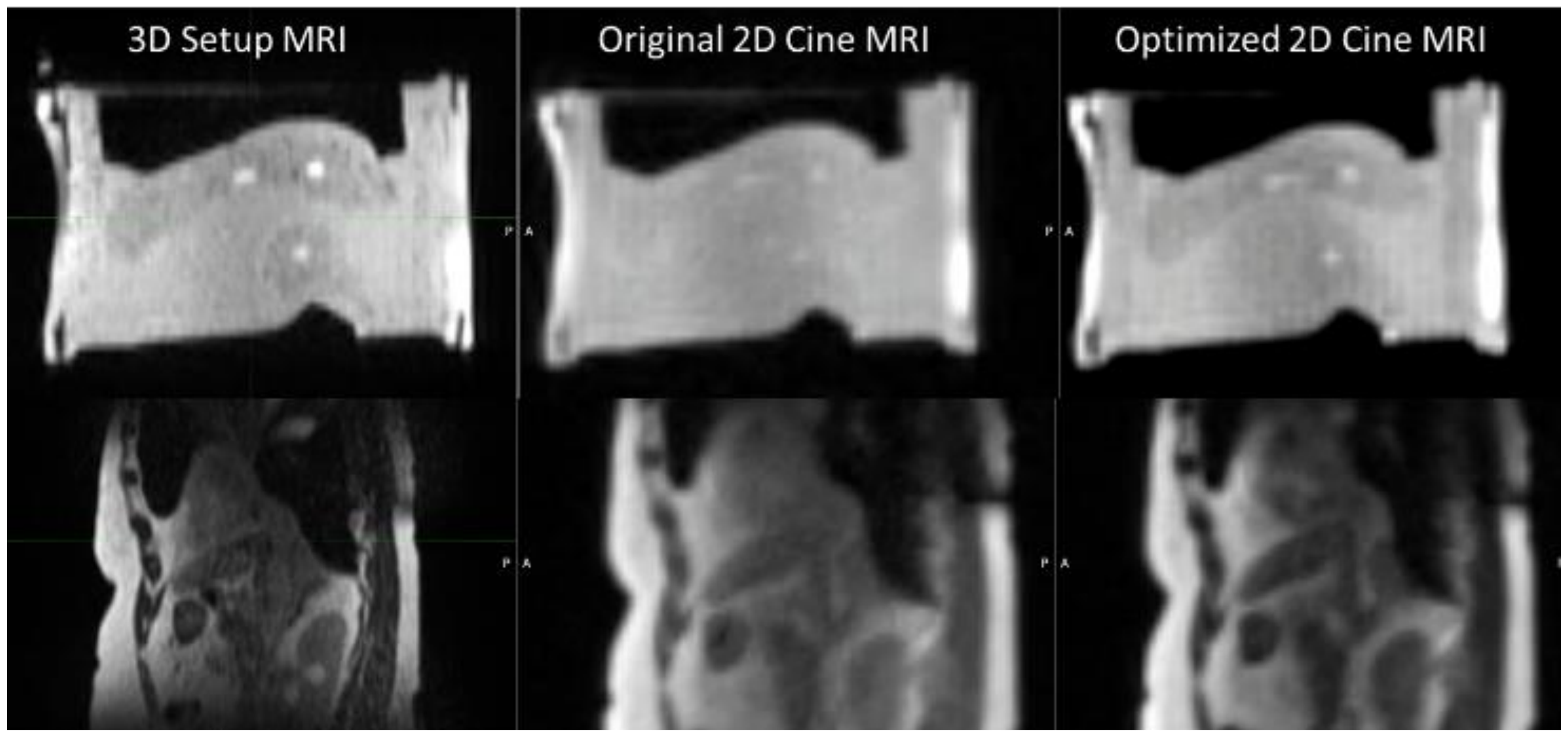

Figure 2. Representative sagittal images from the setup 3D MRI, the original 2D cine MRI, and the optimized 2D cine MRI. The top row shows the phantom study, and the bottom row shows the liver cancer patient acquisition.

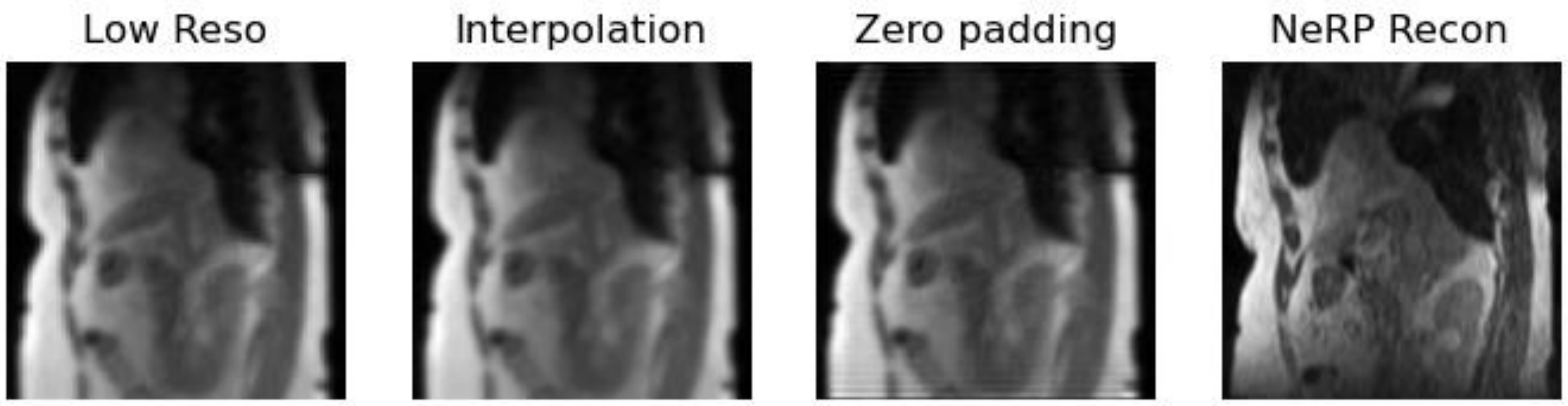

Figure 3. Comparison of different super-resolution approaches.

From left to right: original low-resolution cine image, conventional image space interpolation, k-space zero-padding reconstruction, and the proposed NeRP-SR reconstruction.

Simple interpolation or zero padding increases pixel density but remains blurred. In contrast, NeRP-based reconstruction produces sharper anatomical boundaries and improved soft-tissue definition, yielding image appearance and contrast more consistent with high-resolution reference anatomy.

CONCLUSIONS

- Systematic optimization of a 2D cine MRI protocol on a 0.35T MR-guided radiotherapy system significantly improved soft-tissue contrast and visualization for real-time imaging.
- NeRP-based reconstruction enhanced cine sharpness and effective spatial resolution, thus showing promise for improved target and organ visualization for motion monitoring and adaptive MR-guided radiotherapy.

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