Purpose: Due to its excellent soft tissue contrast, MRI is often integrated as an adjunct to computed tomography simulation (CT-SIM) for radiotherapy (RT) treatment planning to assist in tumor and organ at risk delineation. Recently, dedicated MR simulation (MR-SIM) platforms for radiation oncology have been introduced, although paucity in the literature exists on how to fully implement MR-SIM into the clinic. This work describes our initial experience with characterizing system performance, establishes quality assurance (QA) programs, and sets the context for dedicated MR-SIM for RT.

Methods: Characterization of a 1.0T Philips Panorama High Field Open (HFO) MRI (Philips Medical Systems) was conducted using integrated software (RT Oncology Configuration, v3.5.2). Patient workflow was optimized including immobilization devices, flat couch overlay devices, and use of an external laser positioning system (ELPS) with six Class II lasers for patient positioning and alignment to correlate external skin marks and MR images. Spatial and volumetric analyses were conducted between CT-SIM and MR-SIM using a phantom with known volumes. To evaluate system-level 3D distortion, a 40 cm × 40 cm × 40 cm phantom with known landmarks was scanned with MR-SIM (integrated coil, 3D T1 Fast-field echo (FFE), TE/TR= 3.83/9 msec, voxel size = 0.938 × 0.938 × 1 mm³) and CT-SIM (2 mm axial slice thickness, 120 kVp, voxel size = 0.68 × 0.68). To derive a 3D distortion map, B-spline deformable image registration was conducted between MR-SIM and CT-SIM using Velocity Advanced Imaging (VelocityAI, v2.6.2) that we previously benchmarked using CT-SIM as the distortion-free model. Displacement vector fields (DVFs) were exported and assessed in isocentric rings 5-20 cm from isocenter (Fig 1) with results summarized via displacement histograms.

Discussion: We have established clinical workflow and QA processes for MR-SIM. Image quality and mechanical tests were within accepted criteria. To guide our clinicians on expected geometrical accuracy due to image distortion, 3D distortion analysis was conducted and non-negligible displacements between MR-SIM and CT-SIM occurred >15 cm from isocenter, most notably in the anterior and posterior regions for the axial view. This suggests that distortion will impact regions near the patient periphery and would need to be accounted for in MR-SIM-only treatment planning. We expect the worst-case scenario results to occur for large phantoms without dedicated coils, but expect that lateral translation of the area requiring the highest geometric fidelity (i.e. tumor) toward isocenter will help mitigate this effect.

Conclusions: Through a series of mechanical and image quality characterization tests, we developed the routine QA procedures necessary to implement MR-SIM into RT planning. Future work will involve characterization of patient-specific susceptibility-related distortions, which will vary based on the type of anatomy being imaged. These artifacts are known to increase with B0 field strength, and at 1.0 T, are expected to be <1-2 mm for most sites not influenced by respiratory motion.