Purpose: To develop and implement a comprehensive framework for simulating MR-like images with associated distortions relevant to radiation therapy. The toolkit is designed to accurately determine image distortions and to be used to evaluate the performance of new MR-guided radiation therapy methods.

Methods: Techniques aimed to determine the 3D fields of both types of MR image distortions, i.e., system-related and patient-induced, were developed and extensively validated against experimental data (i.e., phantoms and patient data). MR-like images relevant to RT planning and verification were synthetically generated by applying the distortion field information to CT data (free of spatial artifacts). Specifically, partial (e.g., contours) or full (i.e., images) CT data was warped to embed and exhibit the local distribution of MR geometrical artifacts. Depending on the site of interest (e.g., brain, prostate, spine) one or both types of distortions were implied. Three types of MR-like image datasets were simulated: a) CT data warped to include the 3D system distortion field, b) CT data warped by applying the susceptibility distortion field, and c) CT data warped with both system and susceptibility distortion fields.

Results: The simulation platform for generating MR-like images was successfully implemented for a number of clinically relevant cases such as a) susceptibility-induced artifacts in hemorrhagic brain metastases treated with radiosurgery, b) evaluation of artifacts due to metal implants, c) evaluation of PTV margins for prostate MR-guided radiation therapy, and d) investigation of MR image susceptibility artifacts for patient verification. The metric of success of each project implementation was given by the clinical requirements.

Conclusions: The proposed simulation framework can be used to stress test ideas regarding the suitability of certain MR imaging techniques for newly emerging MRIgRT techniques (in particular applied to MR-linac systems).