Clinical assessment of spatial uncertainty for a combined 0.35T MR and EBRT treatment machine

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INTRODUCTION

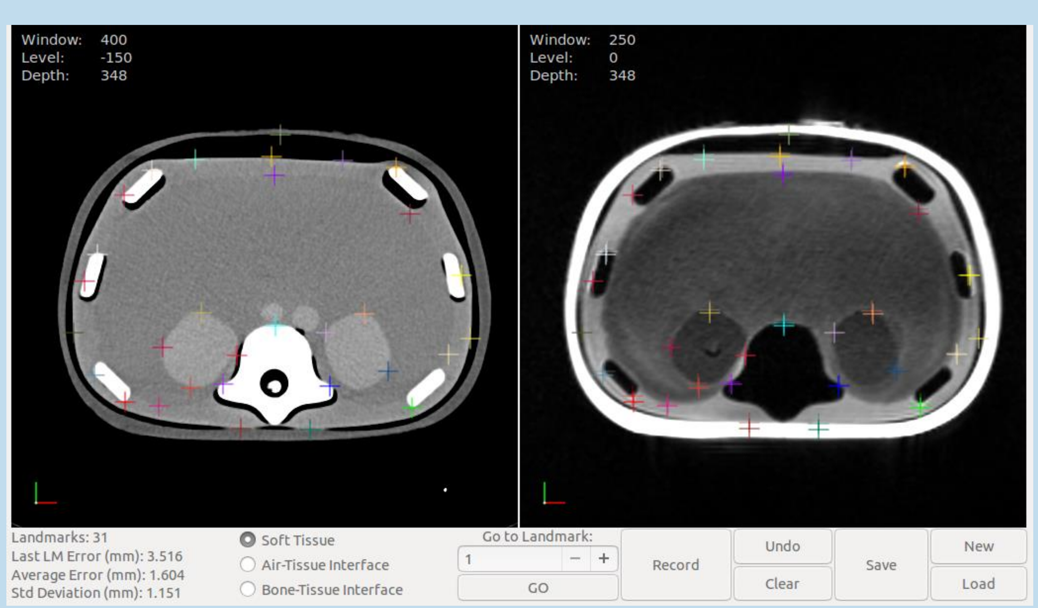
With the advent of magnetic resonance imaging guided external beam radiotherapy, there has been increasing interest in MR-only treatment planning. Spatial integrity in planning images is an important consideration for radiotherapy. Systematic distortion can be effectively minimized, however, patient-induced susceptibility and chemical shift distortions are difficult to address. This study attempts to estimate overall spatial uncertainty on clinical patient data for 0.35T MR images.

This work attempts to quantify total spatial distortion in clinical patient imaging for a 0.35T combined MRI-teletherapy machine, whereas previous work has focused on simulating or measuring magnetic field inhomogeneity for higher strength diagnostic level MRI machines.

METHOD

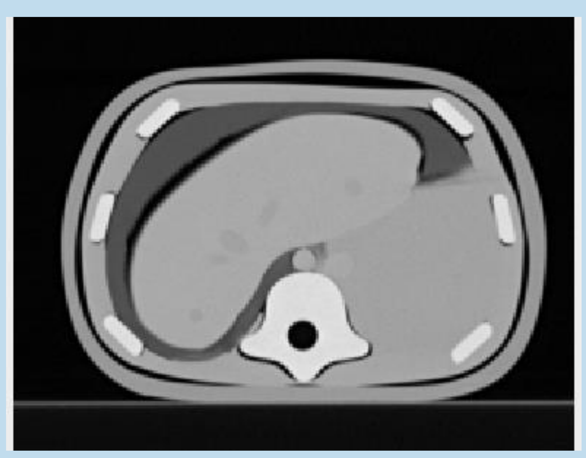
- Ten head-and-neck cancer patients with both CT and MR simulations were selected.
- Simulation images were rigidly registered, and aligned images were generated with matching size and resolution.
- Landmark-based analysis was performed with in-house software
- Spatial distortion was quantified as the Euclidean distance between landmarks.
- Landmarks were also tagged by tissue interface
- As baseline, a distortion phantom containing simulated bone and low density regions was also imaged and analyzed.

Figure 1. Landmark identification on distortion phantom using in-house software. CT shown on left, MR with corrected landmarks and error vectors on right.

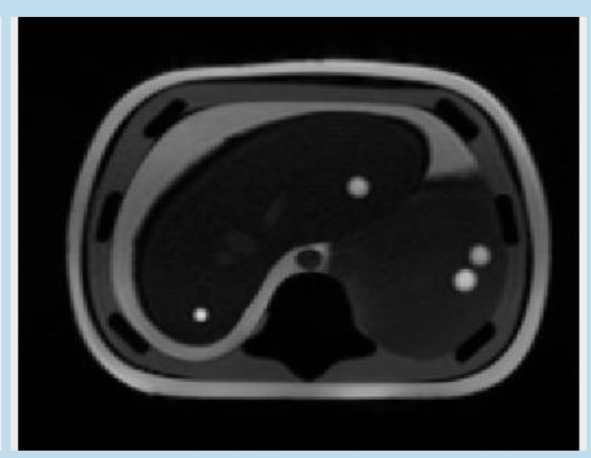


RESULTS

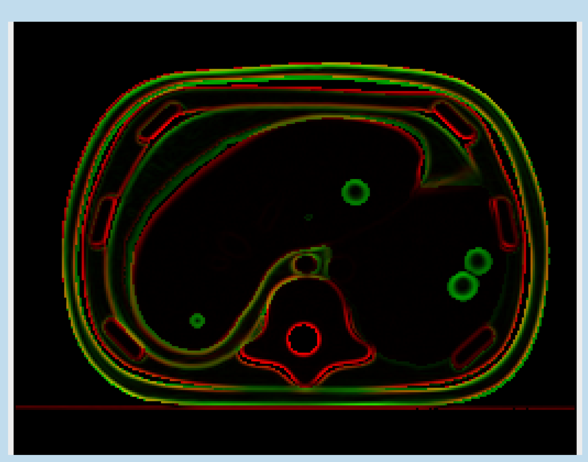
Average error was 1.15+/-1.14mm for the distortion phantom, and 1.46+/-1.78mm for the patient data. For landmarks with non-zero errors, the histogram peaked at 1.5-2mm error, which corresponded with the in-plane resolution of the CT image (1.2-1.5mm). Larger errors were observed at bone-tissue interfaces with an average of 2.01+/-2.20mm, compared to 1.41+/-1.56mm and 0.88+/-1.24mm for the soft tissue and air-tissue, respectively. Geometric error also generally correlated to the in-plane radial distance from the image center.



(a) CT Image of Distortion Phantom



(b) MR Image of Distortion Phantom



(c) Overlay of Edge Detection Images

Figure 2. Spatial comparison of CT (a) and MR (b) imaging of the distortion phantom after running an edge detection algorithm. The two edge detection images are overlaid in (c), with the CT in the red color channel, and MR in the green color channel.

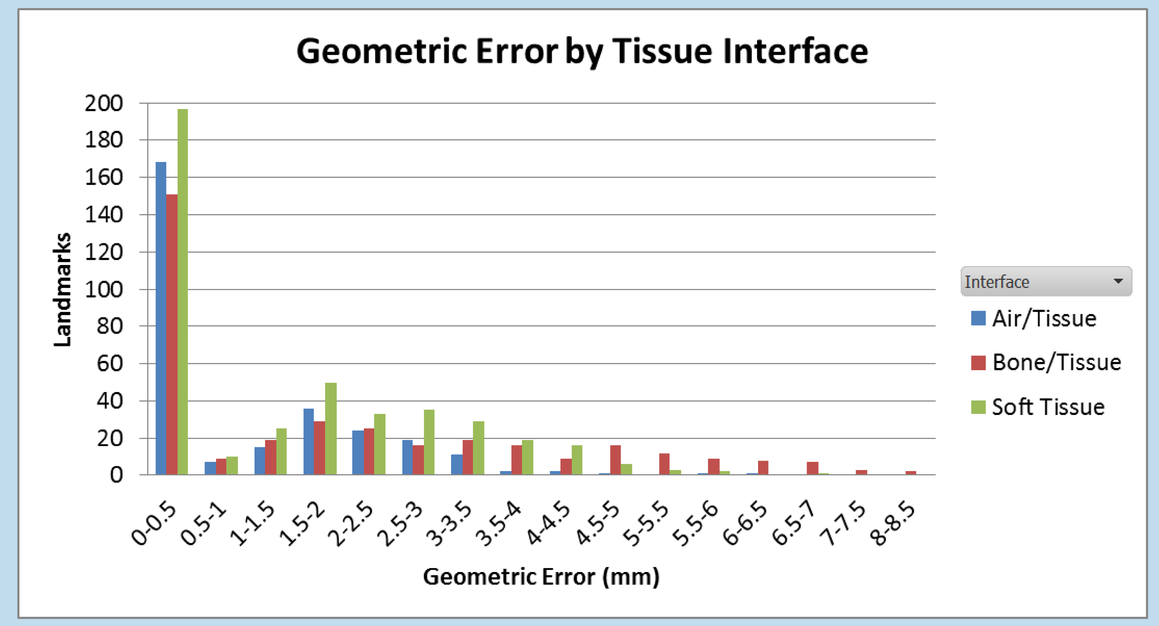
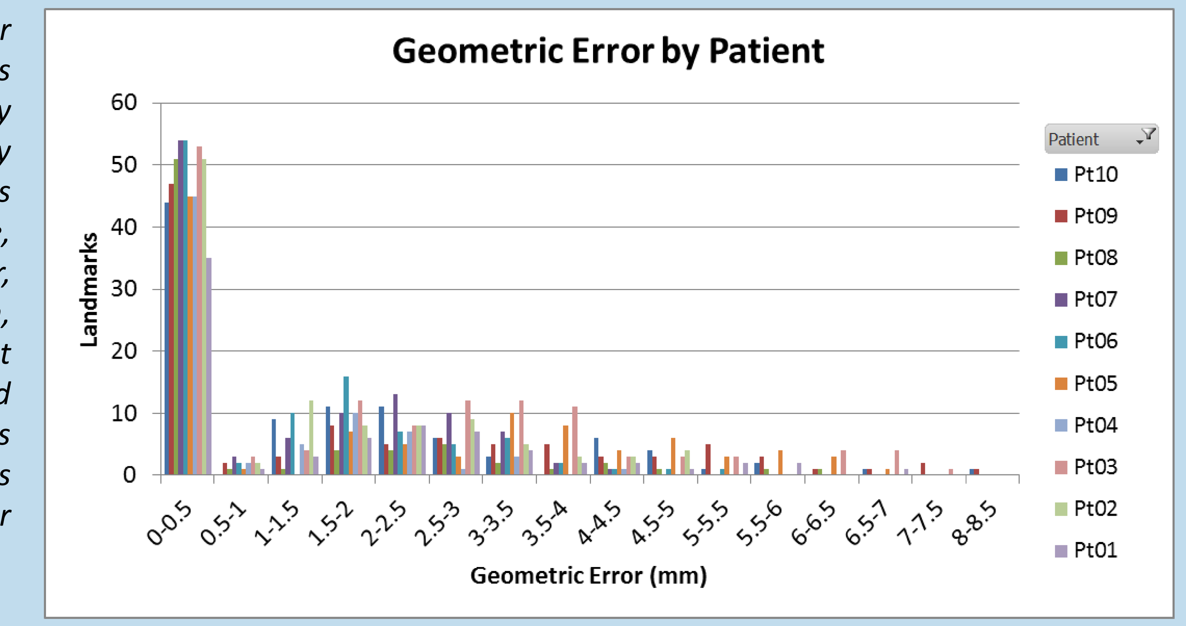


Figure 3. Geometric error histograms from all landmarks of all patients broken down by tissue interface type (a) and by patient (b). All distributions follow the same general shape, with a large peak at 0 error, then a second peak at 1.5-2mm, followed by a gradual fall off. It should be noted that the second peak at 1-2mm corresponds with 1-2 voxels, as the images had in-plane resolution of either 1.2 or 1.5mm.



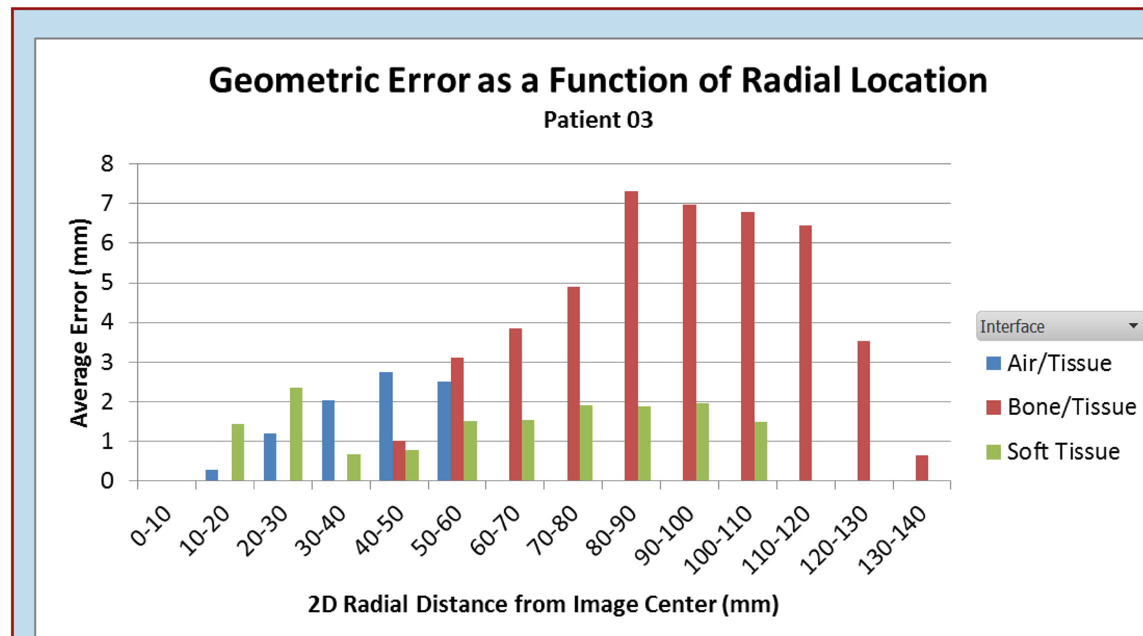
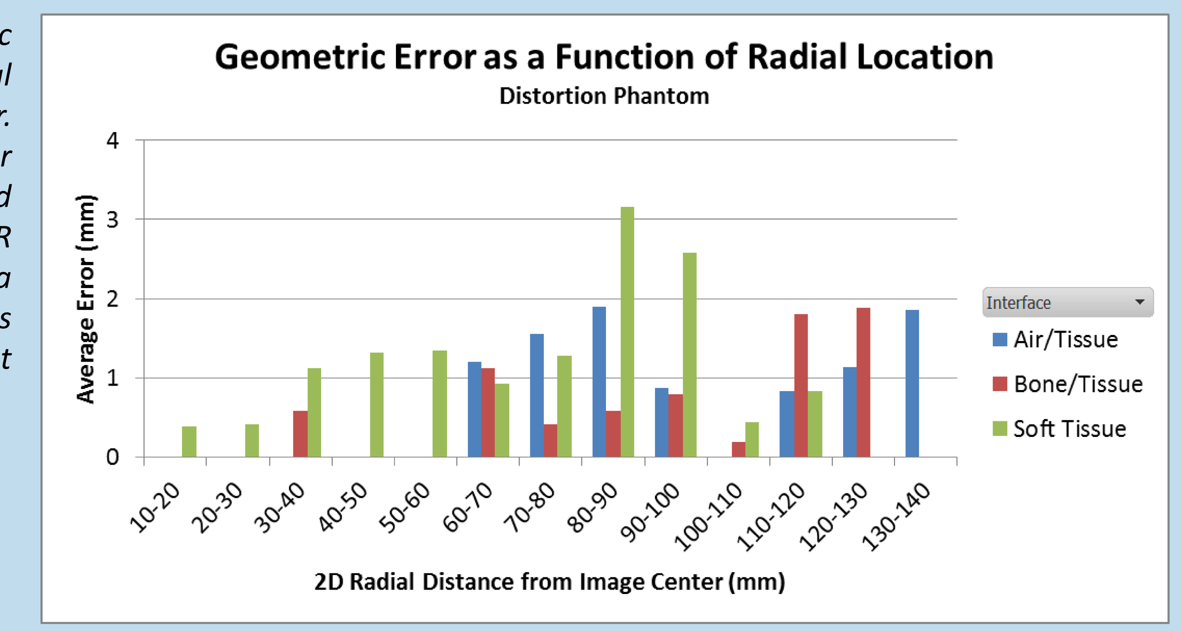


Figure 4. Average geometric error grouped by in-plane radial distance from the image center. Expectations are that larger distortion will be induced toward the periphery of the MR image. The observed data generally agreed with this hypothesis within the different tissue interfaces types.



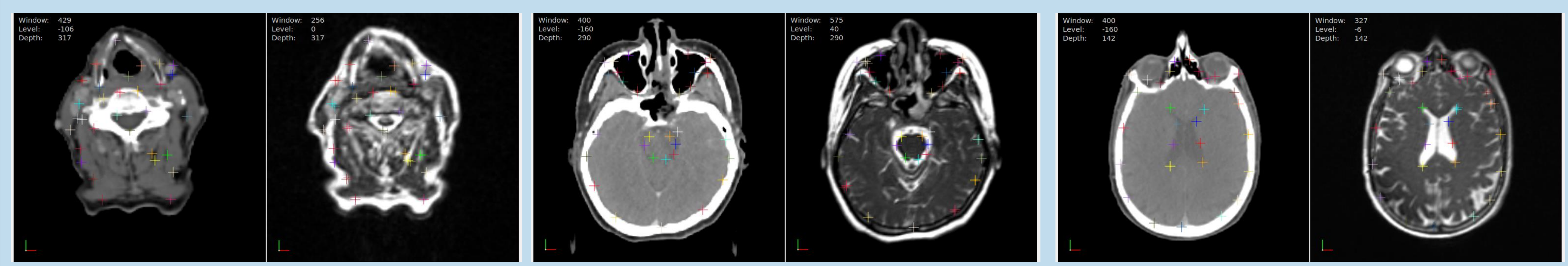


Figure 5. Captures from our in-house landmark-based target registration error assessment software for three axial planes of the head and neck. Each image displays a CT and MR pair, with the CT on the left where landmarks are initially identified. The MR is displayed on the right with corresponding DIR estimated landmarks connected by vectors to the user-corrected landmarks.

CONCLUSIONS

Results indicate that spatial uncertainty remains in the MR images after systematic distortion corrections are applied. Even though the observed errors were small and should have little to no clinical significance, the uncertainty emphasizes the need for continued development of quantitative methods for assessing patient-specific spatial distortions as an important consideration in moving towards MR-only treatment planning.

CONTACT INFORMATION

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