Factors Contributing to Geometrical Accuracy in Online MRI-Linac Guided Brain Radiotherapy

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INTRODUCTION

The MRI-linac (MRL) is novel technology that can monitor anatomical changes during radiotherapy not seen with cone-beam CT. Our institution has treated over 25 brain cancer patients on the MRL and monitor tumor and normal tissue changes. As MRL is new technology with new workflows, it is crucial to assess targeting accuracy and establish margins. This is the first study to assess a combination of patient setup and machine performance factors affecting targeting accuracy on the MRL.

AIM

To quantify the relative impact of patient setup, immobilization and machine performance on targeting accuracy of conventionally-fractionated (54Gy-60Gy in 30 fractions) brain patients treated on a 1.5-T MRI-Linac (MRL).

METHODS

Four factors contributing to geometrical accuracy were identified:

(1) Residual setup error;
(2) Patient immobilization;
(3) Machine MRI-to-MV alignment;
(4) Machine MLC positional accuracy.

For residual setup error, daily MR images of fifteen brain patients (269 fractions) clinically treated on MRL were retrospectively analyzed. The clinical workflow involved translation-only co-registration of daily MRI to the reference image. Anatomical landmarks were retrospectively identified by a radiologist and geometrically tracked on each co-registered MRI.

For immobilization, intra-fraction movement was determined as a surrogate by subtracting the position of the landmarks on a post-treatment MRI from the pre-treatment MRI in a subset of 7 patients (45 fractions).

Routine MRI-to-MV isocenter and MLC position tests were assessed for 5 consecutive months. The standard deviations in each factor were calculated for random and systematic components and presented in 3 directions: X(lateral), Y(superior-inferior), Z(anterior-posterior).

RESULTS

(1) and (2) Residual setup error and immobilization

Anatomical landmark tracking on MRI over the course of a patient's treatment is shown in **Fig 1.** It is important to note that positional variation is indicative of the actual patient treatment position, since each MRI is shown co-registered to the reference CT as per clinical setup. Reasons for variation in anatomical landmark position include: inter- and intra-observer variability in image registration and absence of rotational corrections. 3 or 4 landmark positions were averaged per scan to minimize sampling error/bias. The landmarks were often in the skull proximal to the target, and not necessarily reflective of the target position itself, which is a limitation of this approach, albeit a conservative one.

For immobilization, the same tracking approach was taken, a post-treatment MRI was compared with the pre-treatment verification MRI.

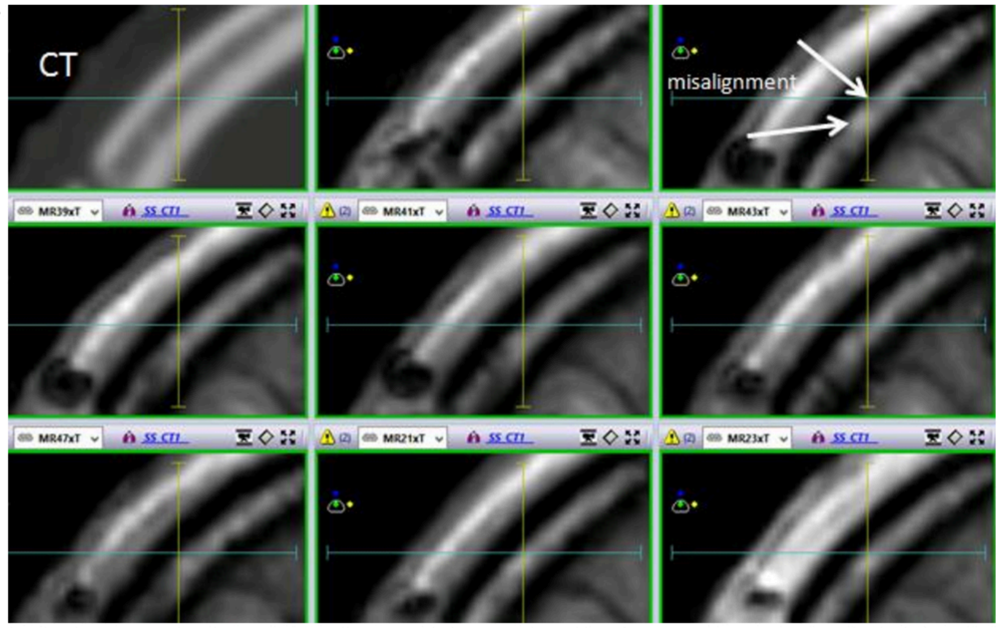


Fig 1: Illustration of landmark tracking. The location of a fat granule is identified with a cross-hair on the CT reference image (upper left). The landmark is shown to vary in location relative to the cross-hair on each daily MRI (each box is a slice from a different day). The cross-hair is positioned on each MRI and the coordinates and their variation are measured.

(3) **Machine MRI-to-MV alignment**

The daily machine MR-to-MV offset is plotted in **Fig 2** for x, y, and z. The MR-to-MV offset value ranged between -0.3mm and 0.3mm, with a standard deviation of 0.1mm.

(4) Machine MLC positional accuracy

For MLC position, we analyzed 5 months of picket fence tests. The standard deviation in mean position of each bank over the 5 months was taken as the systematic error, whereas the root-mean-square of standard deviation across the treatment field was the random error

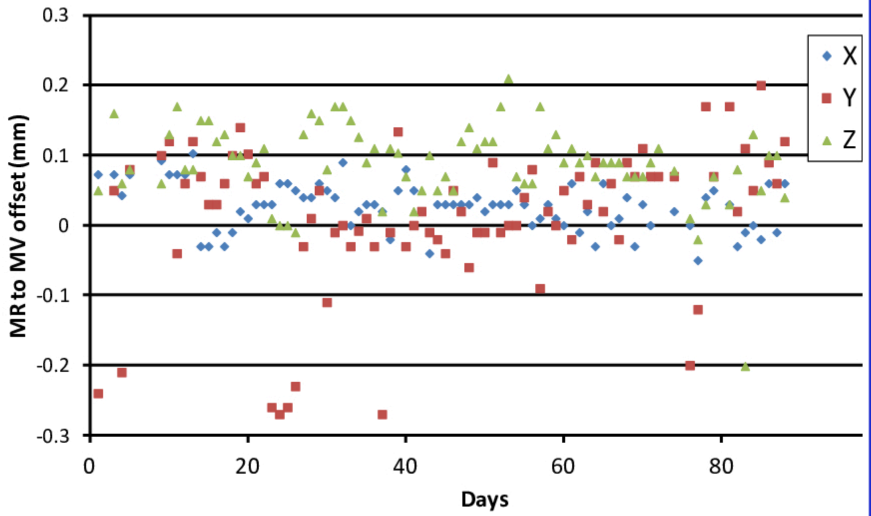
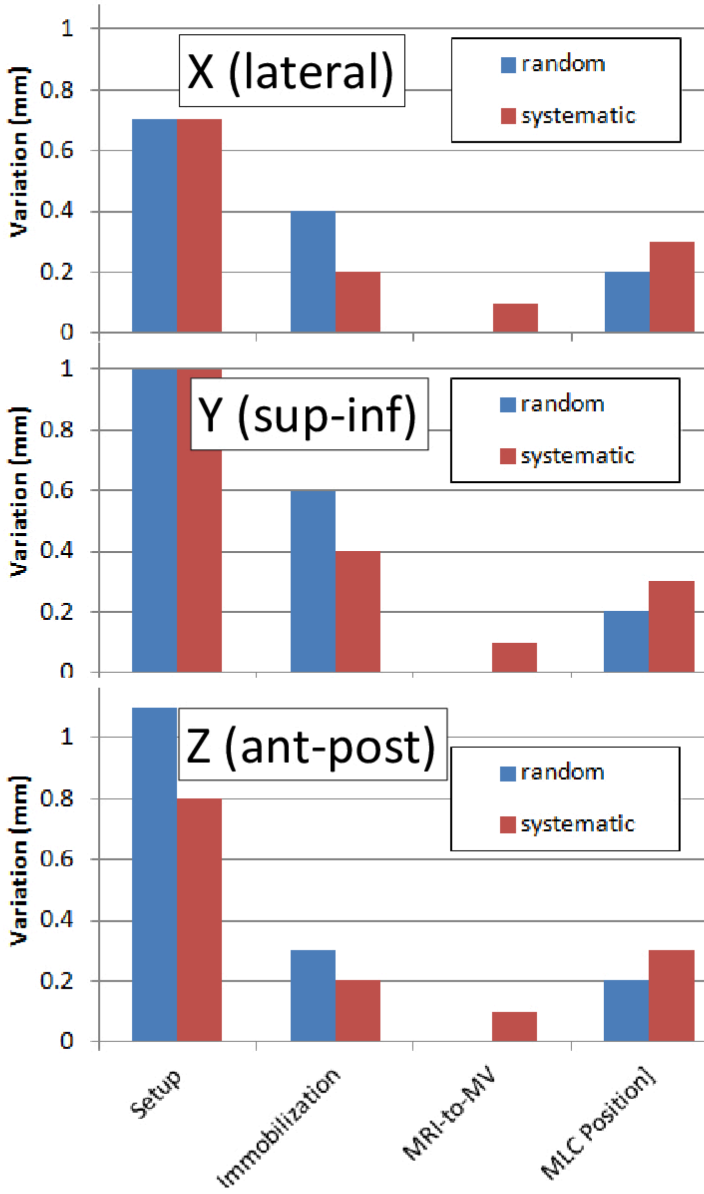


Fig 2: Daily MR-to-MV isocentre test results

RESULTS … CONTINUED



Residual error of daily plan adaptation using a translation-only correction was the largest source of uncertainty in targeting accuracy for brain MRL treatments. This is, in part, due to the inability to correct for rotational setup errors in the current workflow, which adapts the plan for translations only. The variation in sup-inf direction dominated, potentially due to pitch rotations and larger allowed movements in that direction, but this remains to be investigated.

Uncertainty mitigation methods are being investigated, including offline correction strategies and incorporating rotational corrections in order to reduce planning target volume margins.

Fig 3: Systematic and random components of all 4 factors investigated in each direction. Setup uncertainty was largest, followed by immobilization. Machine performance variation was minimal.

CONCLUSIONS

Patient setup factors (image fusion, uncorrected rotations) contribute the greatest uncertainty to geometric targeting and methods to account for these are currently being investigated. Machine performance variation contributes minimally to targeting accuracy, and having a robust QA program that monitors machine performance is essential.

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