

Evaluation of Real-Time Cine Imaging During MLC and Gantry Motion for MR-Guided Radiation Therapy

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INTRODUCTION

- The ViewRay MRIdian uses 2D cine imaging for real-time target tracking and gating during treatments
- Step-and-shoot delivery is used to avoid imaging artifacts caused by linac component motion
- Sliding window and VMAT delivery would result in faster treatments and higher quality plans¹
- Image uniformity (for target tracking and gating) and spatial integrity would need to be maintained during linac component motion for sliding window or VMAT delivery to be possible during MRgRT

AIM

To evaluate the percent image uniformity (PIU) and spatial integrity of cine images used for MRgRT target tracking during MLC and gantry motion.

MATERIALS AND METHODS

Phantoms

- PIU measurement: 24 cm spherical NEMA phantom (Fig. 1(a))
- Spatial integrity measurement: Uniform linearity phantom (Fig. 1(b))

Imaging conditions

- 2D cine mode (35 x 35 cm² FOV, 5 mm slice thickness)
- Phantoms positioned at isocenter
- Data collected under the following linac conditions:
 - Static MLC and static gantry (at 330°)
 - Moving MLC and static gantry (at 330°)
 - Static MLC and moving gantry (rotated from 360°-90°)

PIU calculation²

- $PIU = 100 \times \left(1 - \frac{MaxROI - MinROI}{MaxROI + MinROI}\right)$
- ROI area = 0.15% of FOV
- MaxROI = Mean signal of brightest pixels in phantom
- MinROI = Mean signal of darkest pixels in phantom
- Results are reported as percent variation from the static linac condition

Spatial integrity analysis

- Calculated the deviation of the measured marker position from its expected position
- Measurement points (Fig. 2):
 - 8 located 10 cm from isocenterS
 - 8 located 15.225 cm from isocenter
- Threshold for geometric distortion within 17.5 cm from isocenter is 1 mm

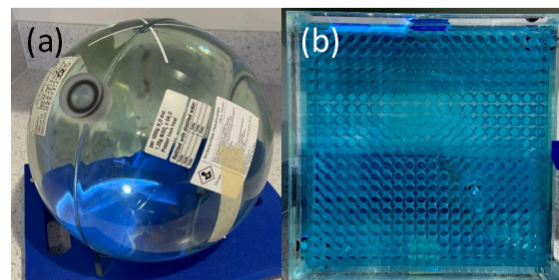


Fig. 1. Phantoms used to characterize cine images. (a) 24 cm NEMA phantom used for percent image uniformity measurements. (b) Linear uniformity phantom used for spatial integrity measurements.

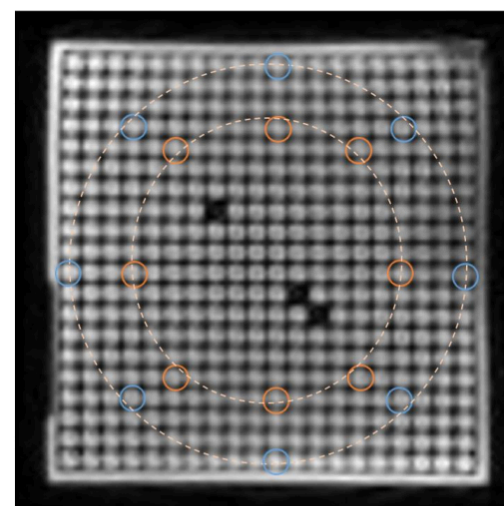


Fig. 2. MR image of the uniform linearity phantom. Measurement locations at 10 cm (orange circles on inner ring) and 15.225 cm (blue circles on outer ring)

RESULTS

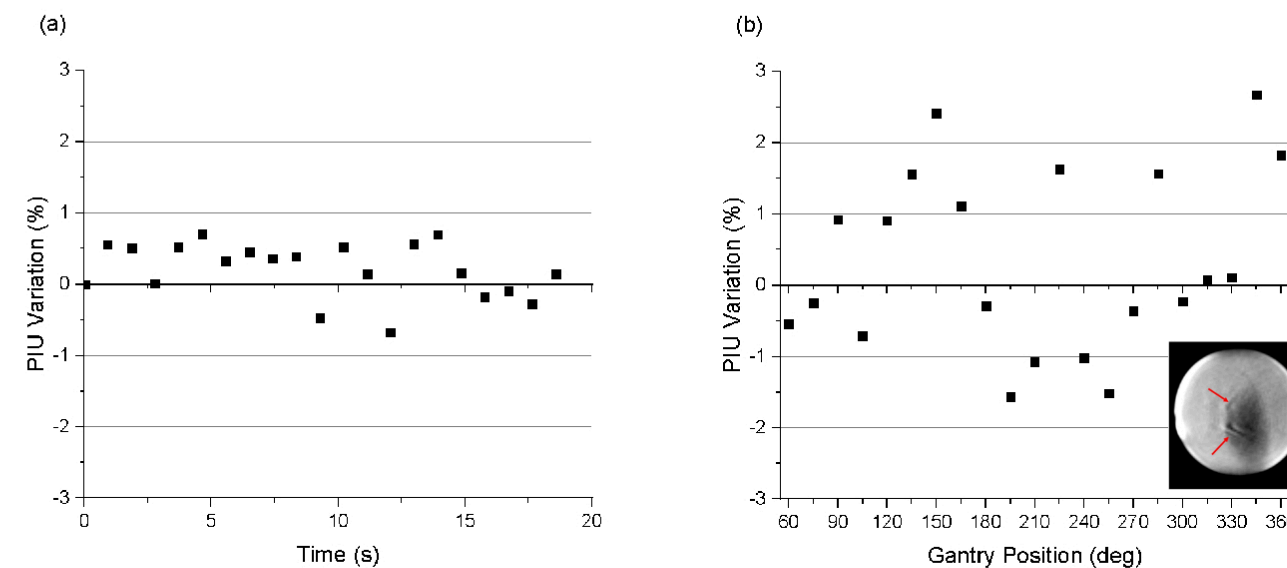


Fig. 3. Variation of the PIU from static linac component conditions as (a) the MLC is moved and (b) the gantry is rotated from 360° to 90°. Gantry rotation causes banding artifacts shown in the inset of (b) (red arrows)

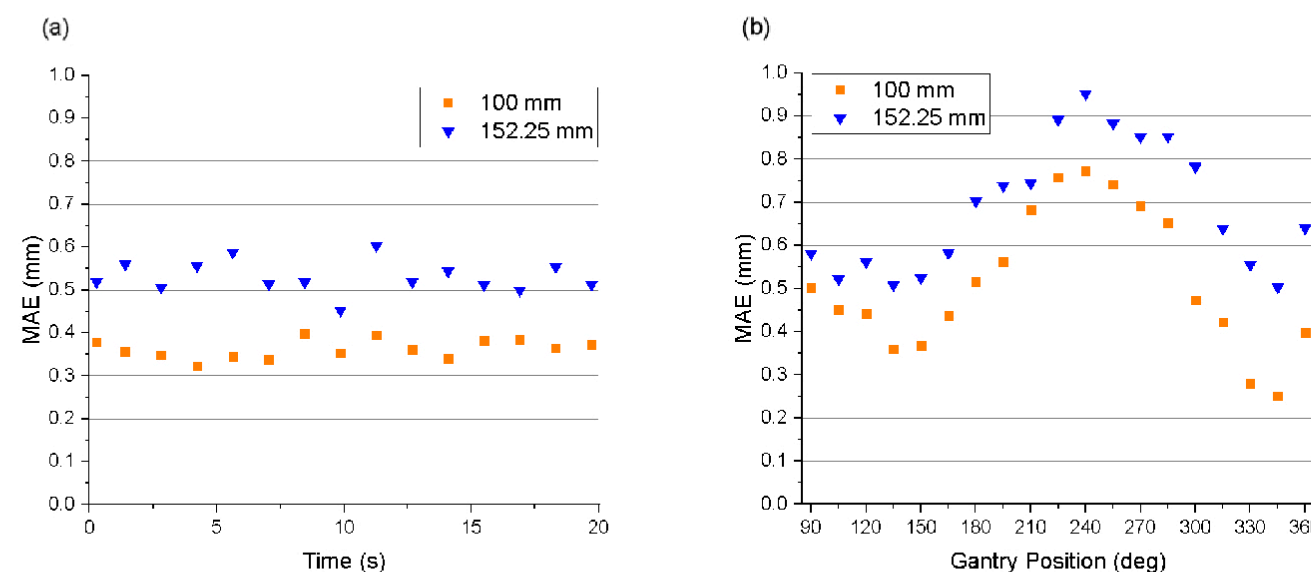


Fig. 4. Mean absolute error in the measured position of points lying 100 mm and 152.25 mm from isocenter (a) as the MLC is moved and (b) as the gantry is rotated from 360° to 90°.

CONCLUSIONS

Effect of MLC motion

- PIU did not vary from static linac conditions by more than $\pm 1\%$ (Fig. 3(a))
- Mean geometric distortion for points 10 cm from isocenter was less than 0.4 mm for all measurement points (max = 0.72 mm) (Fig. 4(a))
- Mean geometric distortion for points 15.225 cm from isocenter was less than 0.6 mm for all measurement points (max = 0.88 mm) (Fig. 4(b))

During MLC motion, PIU and spatial integrity (within 15.225 cm from isocenter) were adequate for cine target tracking and gating. This demonstrates the potential for sliding window delivery during MRgRT treatments

Effect of gantry motion

- PIU did not vary from static linac conditions by more than $\pm 3\%$ during MLC motion (Fig. 3(b))
- Mean geometric distortion for points 10 cm from isocenter was less than 0.8 mm for all measurement points (max = 0.92 mm) (Fig. 4(b))
- Mean geometric distortion for points 15.225 cm from isocenter was less than 0.95 mm for all measurement points (max = 0.1.6 mm) (Fig. 4(b))

During gantry motion, PIU was negatively affected by banding artifacts (Fig. 4(b) inset). Spatial integrity within 10 cm from isocenter was adequate for cine target tracking and gating. At 15.225 cm from isocenter, the geometric distortion exceeded the 1 mm threshold for several measurement points. VMAT delivery would require simultaneous MLC and gantry motion, which was not investigated in this work.

Future work should evaluate spatial integrity using more measurement locations, measure the effects of simultaneous MLC and gantry motion, and investigate the effect of banding artifacts on cine target tracking.

REFERENCES

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