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Validation of a New Tool for Testing Spatial Accuracy of Off-Axis Beam Apertures Used in Single-Isocenter Stereotactic Treatment of Multiple-Metastases of the Brain

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INTRODUCTION

- A prerequisite for simultaneous SRS treatment of multiple targets is validation of the spatial accuracy of off-axis beam apertures[1].
- Elekta machines currently lack a stereotactic end-to-end targeting validation tool for non-isocentric targets.
- Isocenter optimization with Winston-Lutz analysis is sufficient for single-target SRS, but is not sensitive to any angular inaccuracies. For multi-target SRS, a test is needed that is also sensitive to off-axis and angular offsets, including:
  - Angular misalignment of phantom
  - Angular misalignment of CBCT localization
  - MLC off-axis accuracy
  - Angular error in collimator rotation
  - Angular error in table rotation

AIMS

- To validate a method for testing the spatial accuracy of off-axis SRS beam apertures using a newly-developed phantom (Sun Nuclear MultiMet Winston-Lutz or MMWL) and software with Elekta LINACs.
- To illustrate how the tool might be used by a physicist for commissioning and QA of a stereotactic program on an Elekta LINAC.

MATERIALS & METHOD

- MMWL Phantom contains 6 tungsten ball bearings (BBs)
- BBs span 6 cm along X (IEC 61217) and 10 cm along y directions

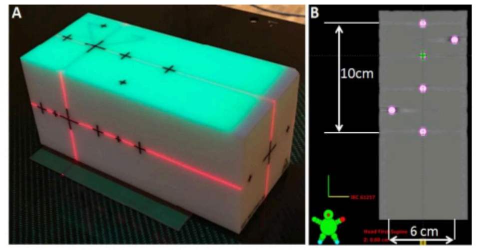


Figure 1: (A)MMWL phantom, (B) Layout of internal BBs

- Step-and-shoot fields for an Elekta LINAC with Agility MLC were designed to project six 2x2 cm^2 megavoltage apertures, centered on each of the phantom BBs.
- MMWL software currently supports two sets of projection angles:

Projection Set #1 (Basic)			
Proj. #	Gantry	Couch	Collimator
1	0	0	0
2	0	0	90
3	0	0	270
4	0	90	0
5	0	270	0
6	90	0	90
7	180	0	90
8	270	0	90

Projection Set #2 (Advanced)							
Proj. #	Gantry	Couch	Collimator	Proj. #	Gantry	Couch	Collimator
1	0	0	0	9	0	315	315
2	0	0	90	10	90	0	90
3	0	0	270	11	90	0	270
4	0	45	45	12	180	0	0
5	0	45	225	13	180	0	90
6	0	90	0	14	270	0	90
7	0	270	0	15	270	0	270
8	0	315	135				

- The MMWL phantom is set up at isocenter with the room lasers and digital level.

RESULTS

- Example images for two projection angles are shown in Figures 2 and 3.

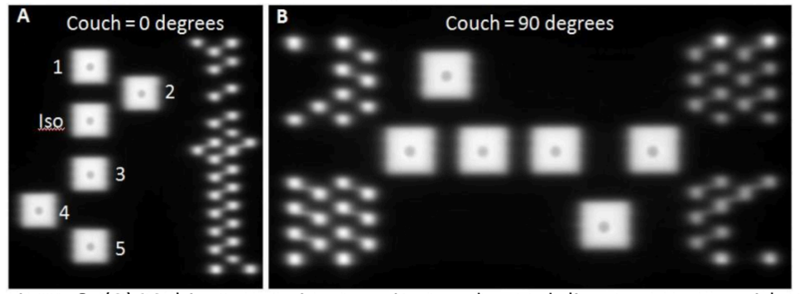


Figure 2: (A) Multi-aperture image using two beam delivery segments with gantry = 0, collimator = 0, couch = 0. (B) Multi-aperture image using four beam delivery segments with gantry=0, collimator=0, couch = 90 . Peripheral apertures appear in each image because of minimal leaf gap specifications and the absence of X jaws.

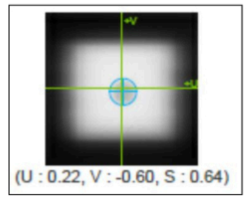


Figure 3: Projection offset data from the Sun Nuclear software provide information that can validate the combined effects, in six degrees of freedom, of mechanical calibration accuracy of the gantry, collimator, couch, and cube positioning offsets.

- All square apertures are formed by MLC leaf ends on two of the sides, and MLC leaf edges on the other two (see Figure 4).
- Fixing the couch position, and rotating the collimator 180º (or vice versa) reveals angular errors in either LINAC component
- For example, a 0.5º relative offset between MLC edge and phantom would manifest as a 0.9 mm relative lateral BB offset between farthest BBs.

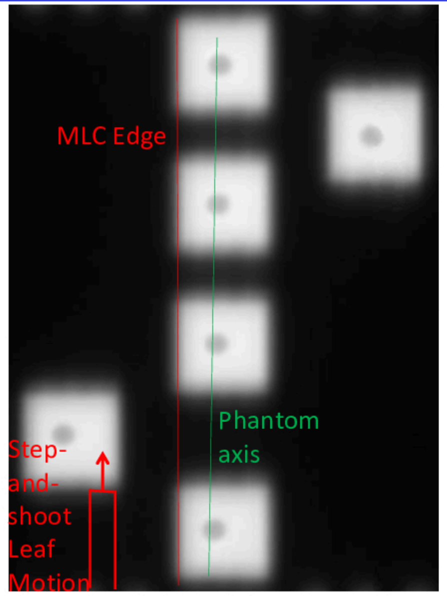
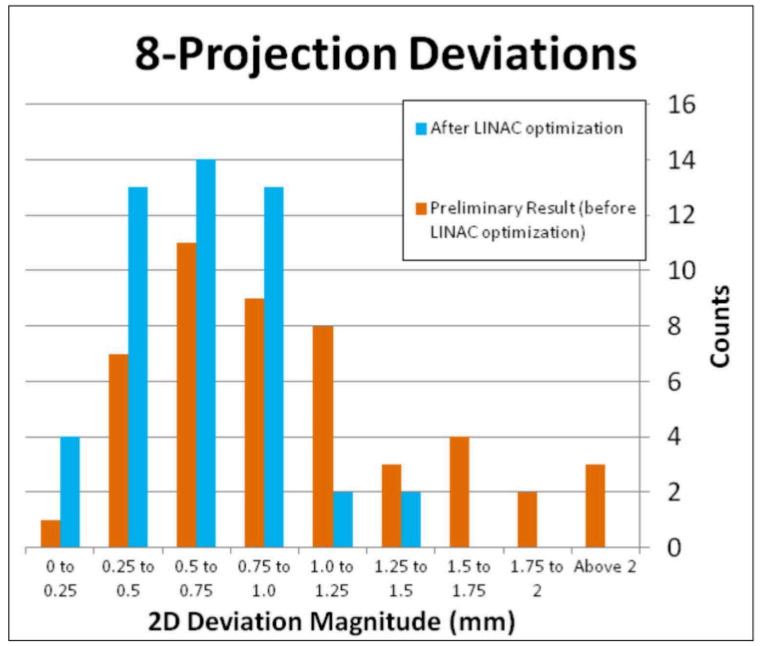
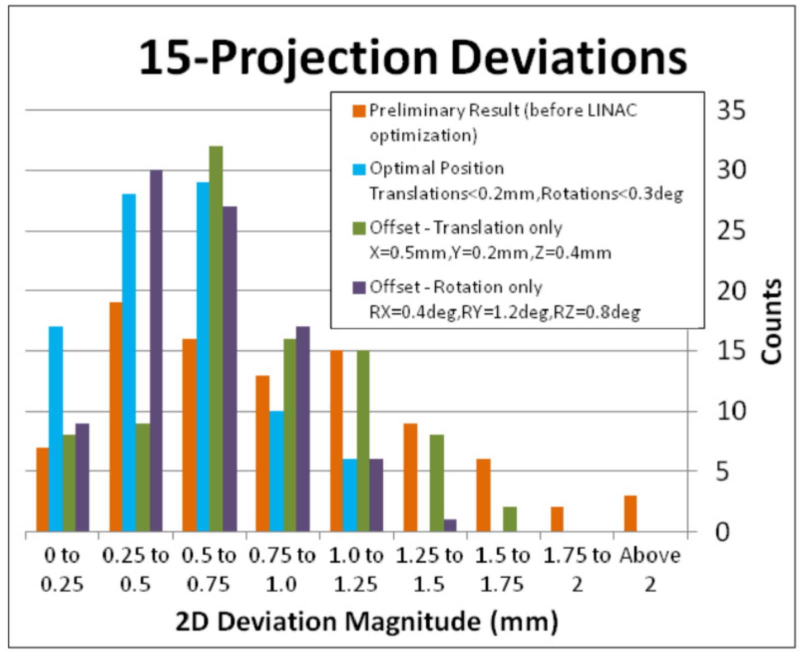


Figure 4: Relative misalignment of the phantom and field edges enables investigation of angular accuracy of the table and collimator. A small relative angle is shown here.

- The test analysis was found to be dependent upon accurate pixel density specifications on the iViewGT, which depends upon gantry angle due to gravitational effects on the EPID panel[2]. The pixel scaling can be determined from the known separation between BBs. A 1% scaling error in the (gantry = 0) EPID pixel density was discovered and corrected.
- Test analysis also revealed a lateral offset of the MLC leaf assembly in the direction perpendicular to the direction of leaf motion by ~ 0.5mm. Leafbank lateral adjustment was performed with LINAC field service engineers.
- A collimator angle calibration error of 0.2 to 0.3 degrees was detected and corrected after review of preliminary projection data.
- After the MMWL phantom was positioned in the optimal location (blue in the below histograms), it was offset by a set of small translations and rotations to illustrate how the overall projection deviations deteriorate.





CONCLUSIONS

- MMWL Phantom alignment can be achieved with clinically acceptable projection deviations, provided that adequate margins are applied to non-isocentric targets.
- The MMWL Phantom was used to optimize several LINAC parameters, demonstrating its value as a versatile tool for performing LINAC commissioning and QA.
- MMWL is an effective tool for evaluating the effects of angular inaccuracies on off-axis targets, in addition to that for translation offsets.

Future Work: Localization using CBCT to study the effects of possible angular offsets between CBCT and dose delivery.

REFERENCES

1. Halvorsen P-H et al. AAPM-RSS Medical Physics Practice Guideline 9.a. for SRS-SBRT *J Appl Clin Med Phy.*, ***18:5*** *; 10-21 (2017).*

2. Rowshanfarzad P et al. A comprehensive study of the mechanical performance of gantry, EPID and the MLC assembly in Elekta linacs during gantry rotation. *Br J Radiol*, **88**; 20140581 (2015).

CONTACT INFORMATION

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