

Validation of an optical surface monitoring system to detect submillimeter surface displacements at non-zero couch angles

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INTRODUCTION

- Surface-image guided radiation therapy (SIGRT) is being utilized clinically for various treatment sites, and has recently been applied to the tracking of intra-fractional patient motion during frameless stereotactic radiosurgery (SRS)¹.
- An SIGRT system may display non-zero real-time surface offsets at large angles of couch rotation even when motionless phantoms are observed.
- Such offsets may arise from:
 - Inherent couch walkout characteristics (real deviations from isocenter), or
 - Residual SIGRT calibration errors (virtual deviations² from isocenter)

AIM

- To validate the reported real-time stereotactic offsets detected by a commercial optical surface monitoring system against concurrent BB target localization with portal imaging at non-zero couch angles.

MATERIALS & METHOD

- Two phantoms were used:
 - (1) Head phantom with single BB and (2) Commercial Multi-target phantom with 6 BBs

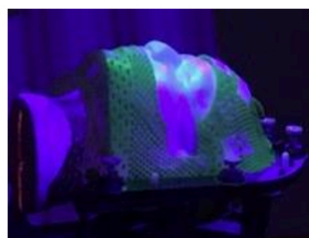


Figure 1: Styrofoam phantom in SRS mask

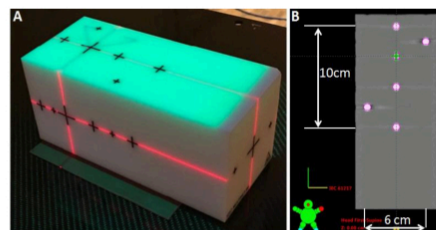
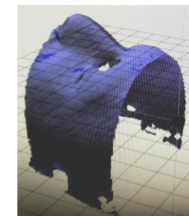


Figure 2: Sun Nuclear Multi-Met Winston Lutz Phantom³

- A set of clinical tools was used for submillimeter positioning/monitoring of both phantoms
 - Elekta HexaPOD couch: used to position phantoms with submillimeter accuracy
 - C-RAD Catalyst HD: to monitor the live positional offsets of both phantoms vs a reference surface position at multiple couch angles.
 - EPID imaging (Elekta iViewGT) with 2x2 cm² fields nominally centered on BBs. With a static gantry, the excursion of the BB is recorded at multiple couch angles.
 - Sun Nuclear MultiMet software: determines the 3D spatial orientation of the MMWL Phantom³ using a large set of step-and-shoot images.
- After aligning each phantom's central BB with imaging isocenter, translations were applied to each (to mimic patient displacement in the couch reference frame):
 - a translation (Y=-1.5 mm) was applied to Phantom 1 with the HexaPOD (IEC1217).
 - a 6D set of translations/rotations was applied to Phantom 2.
- EPID images are recorded simultaneously with C-RAD surface offsets
- Phantom 1 offsets were examined in the 2D (horizontal) plane.
- Phantom 2 (MMWL phantom) orientation is analyzed in 3D with vendor software.

RESULTS



- Real-time surface imaging offsets for Phantom 1 revealed features that coincide with known reproducible effects of rotational hysteresis with magnitudes as large as 0.5 mm, and couch axis wobble. (Fig 3).
- The longitudinal shift of 1.5 mm is seen to add constructively with these inherent offsets due to walkout or wobble.
- Results are plotted in the LINAC frame (IEC 1217) in Figure 3.

AP Winston Lutz BB tracking vs. C-RAD real-time offset

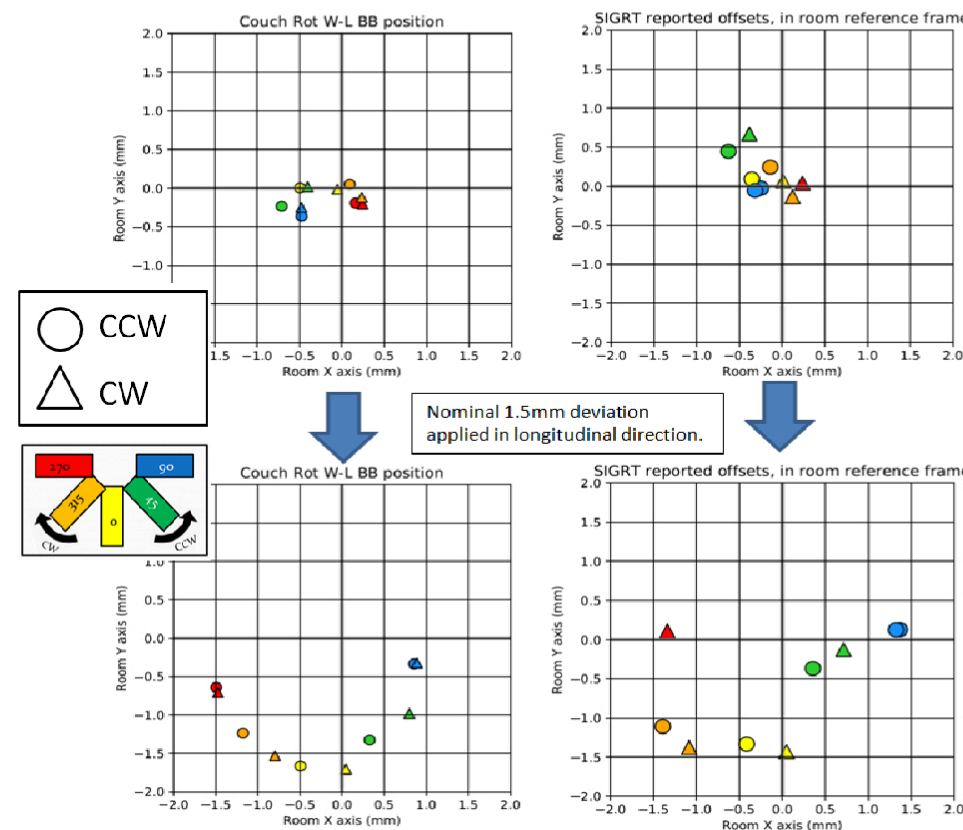
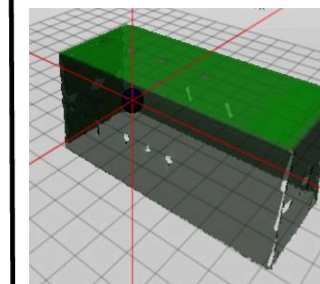


Figure 3: Path traveled by a BB (left) and surface contour (right). BB is initially aligned to imaging isocenter (top plots), then is displaced by 1.5mm inferiorly (bottom).

CONCLUSIONS

- Optical surface monitoring can detect deviations from couch axis wobble or rotational hysteresis with submillimeter accuracy at non-zero couch angles.
- Displayed real-time SIGRT offsets appear to consist of constructive contributions from known displacements and the underlying walkout characteristics of the couch.
- Real-time SIGRT offsets of a static phantom could potentially be subtracted from live patient monitoring data to provide a more accurate representation of patient motion relative to radiation isocenter at various couch angles.



- Phantom 2 was initially aligned to imaging isocenter, and real-time SIGRT offsets were collected over the full range of couch motion
- A 6D offset was applied with the HexaPOD (X/Y/Z/RX/RZ = 0.5mm/0.5mm/0.5mm/0.8°/2.4°/1.6°), and SIGRT offsets are collected again for the full couch range.
- The baseline C-RAD excursions (blue curves in Figure 4) appear to add constructively with the prescribed HexaPOD shift to arrive at the displayed C-RAD real-time offsets (red). This is most pronounced for the LAT and LONG directions (the plane of couch rotation), and also for ROLL offsets.
- The 3D orientation of Phantom 2 is also validated with the Sun Nuclear MMWL software³.

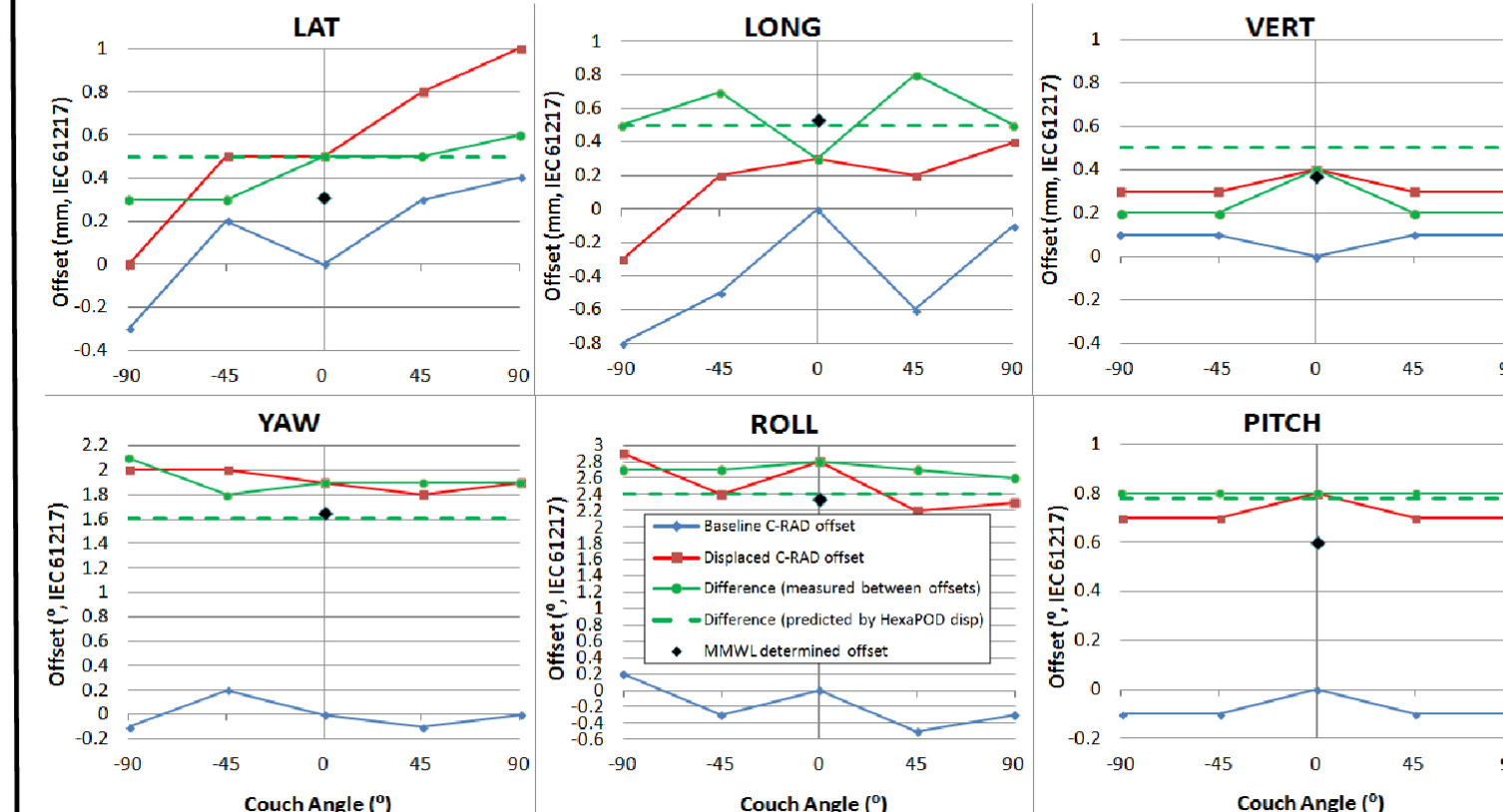


Figure 4: Translational and rotational offset plots for the MMWL phantom. Blue curves are the offsets displayed with the phantom initially aligned at isocenter. After displacement, offsets are shown in red. The difference is shown in green.

REFERENCES

1. J.D.P. Hoisak and T. Pawlicki, "The Role of Optical Surface Imaging Systems in Radiation Therapy," Semin Radiat Oncol **28**: 185-193 (2018).
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3. D. W. Pinkham et al. "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," AAPM-COMP General ePoster PO-GeP-T-838 (2020).

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