Concurrent 3D Isocentricity Analysis for Clinical LINACs

Christian Velten, Yi-Fang Wang, Paul J. Black, John Adamovics, Cheng-Shie Wuu
Department of Radiation Oncology, Columbia University, New York, NY, USA

Introduction

Gantry and couch isocenter sizes and locations relative to each other and to the laser cross-hairs are important factors in the accurate delivery of stereotactic and non-coplanar treatment plans. These quantities are usually assessed using 2D star shots on film or using on-board imaging technology, thus, being limited in dimension and relying on the hardware/software performance of the linear accelerator (LINAC).

The use of a 3D dosimeter allows for the concurrent measurement of couch and gantry rotation isocenter properties in 3D with one setup, providing valuable information conventional 2D films can not measure. The proposed method can thus, improve the isocentricity test currently used and, ultimately, the accuracy of non-coplanar treatment delivery.

Materials and Methods

In this study, comprehensive 3D information, including the size and location of gantry and couch rotation isocenters were measured using a 3D dosimeter. The results were compared with those from a stack of film to verify the accuracy of our measurements.

1. Irradiation

- Symmetric 1 cm^2 (at 100 cm SAD) square fields of 6 MV photon beams and 800 MU were delivered to a PRESAGE® (Heuris Ltd.) 3D dosimeter, which was set up with laser cross-hairs, on a Varian TrueBeam® LINAC (fig. 1).
- Irradiations were performed under gantry angles of 0°, 50°, 160°, and 270° with the couch fixed at 0° and subsequently, under couch angles of 10°, 330°, 300°, and 265° with the gantry fixed at 270°.

2. Readout and Analysis

- The dosimeter was scanned using a single-beam optical scanner and images were reconstructed with sub-millimeter resolution using filtered back-projection.
- The reconstructed images stack was resliced to extract stacks showing the gantry and couch star shots, and the view orthogonal to both.
- Beam trajectories and the smallest circle enclosing these were drawn and extracted from both star shots.
- Information from the third orthogonal view was used to analyze the longitudinal shift of gantry and couch sag during rotation.
- A stack of GafChromic® EBT3 (Ashland Inc.) was irradiated using the same protocol with 100 MU per field for verification.

Results and Discussion

1. Isocenter Diameters

In PRESAGE measurement, gantry and couch isocenter diameters (2D) were measured to be 0.08 mm and 0.23 mm (fig. 2), while film stack measurements yielded 2D isocenter sizes of 0.51 mm and 0.25 mm.

2. 3D Distance of Isocenters

With respect to laser cross-hairs: For PRESAGE, the distances are 0.71 mm and 0.62 mm for gantry and couch isocenters, respectively, while the distance between the two centers is smaller at 0.36 mm. Film stack measurements yielded 3D distances from the setup center of 0.99 mm and 0.80 mm for gantry and couch rotations, respectively, and 0.99 mm between both.

3. Plane of Rotation Size

The field sizes perpendicular to the respective star shots (fig. 3) are approximately 9.37 mm and 9.78 mm for gantry and couch rotations, which is slightly larger than the reference of 9.36 mm. This indicates that the couch rotation does not perfectly occur in one plane.

Conclusions

- 3D information about multiple rotational isocenters of a LINAC can be acquired using a single solid 3D dosimeter with increased accuracy over films.
- In film stack measurements, possible setup errors lead to larger measured isocenter sizes and positions compared to the use of a single 3D dosimeter.
- Future work will include higher resolution reconstruction and automated analysis similar to film star shots.

Fig. 1: PRESAGE® dosimeter before fixation after setup on the treatment couch.

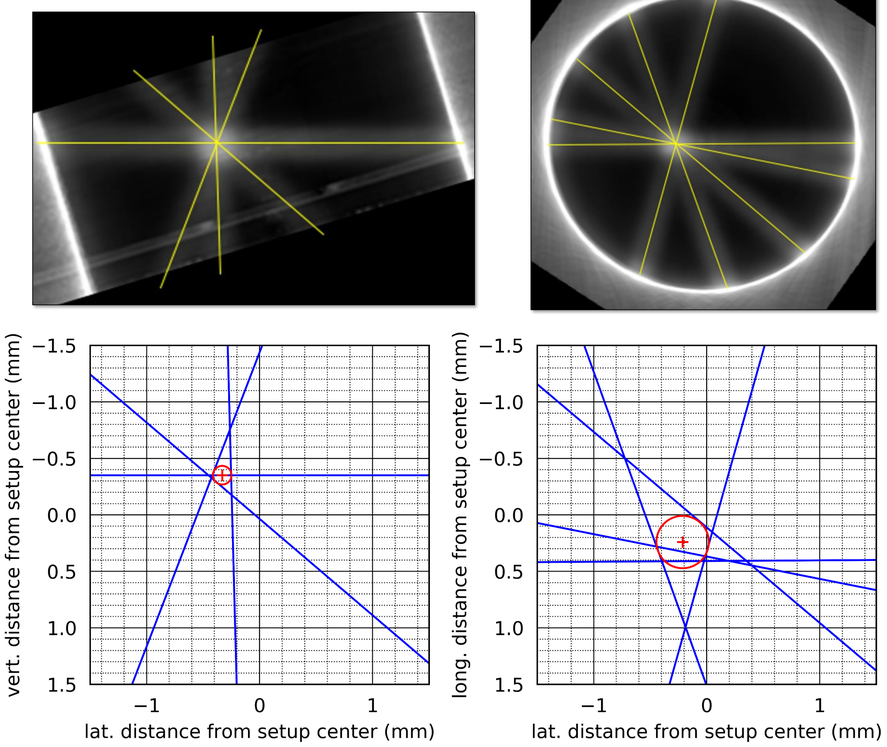

Fig. 2: Gantry (left) and couch (right) star shots in reconstructed images and the respective analyses in the top and bottom row, respectively. Isocenter diameters are 0.08 mm and 0.23 mm.

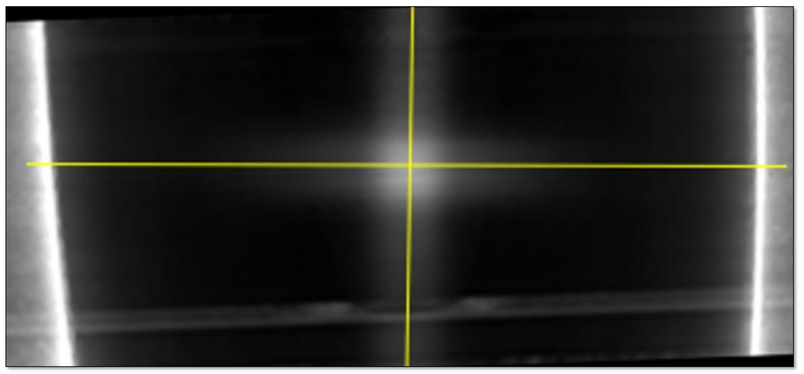

Fig. 3: View perpendicular to both star shots (gantry: couch: left-right) from which information about the third dimension of isocenter size and position is obtained.