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RESEARCH

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Assessing micro-irradiator accuracy

Precision delivery of small-volume radiation treatments in a pre-clinical setting can help researchers understand more about the effects of clinical radiotherapy. Such studies are performed using micro-irradiators that deliver radiation to volumes as small as 1 mm^3 in living animals. Determining the targeting accuracy of such small treatments, however, can be highly challenging.

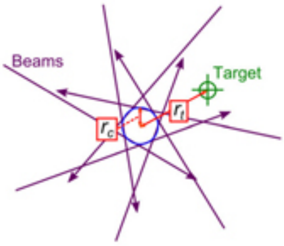
With this in mind, a research team from Duke University (http://radonc.duke.edu/research-education/research-labs/radiation-physics/oldham-lab) (Durham, NC) has investigated the use of PRESAGE dosimeters, read out by a DMOS optical-CT scanner, to characterize the targeting accuracy of a small-animal micro-irradiator. They examined the X-RAD 225Cx (http://www.pxinc.com/products/small-animal-igrt-platform/x-rad-225cx/), an image-guided radiotherapy (IGRT) system that produces photon beams as small as 1 mm (*Phys. Med. Biol.* **58** 7791 (http://iopscience.iop.org/0031-9155/58/21/7791/article)).

PRESAGE is a polyurethane plastic containing dyes that change colour upon exposure to ionizing radiation. To assess IGRT accuracy, the researchers used PRESAGE dosimeters containing thin channels of varying depth, with the tip of each channel corresponding to a target point. "The PRESAGE 3D dosimetry material has two main features that render it useful for this study," explained first author Leith Rankine. "First, it is flexible in the moulding process, making it easy to create multiple physical targeting channels in a single dosimeter. Second, PRESAGE is amenable to fast and very high-resolution 3D imaging by optical-CT. This paper is the first to show that 0.3 mm isotropic 3D dosimetry is feasible in dosimeters containing multiple channels."

Accuracy evaluation

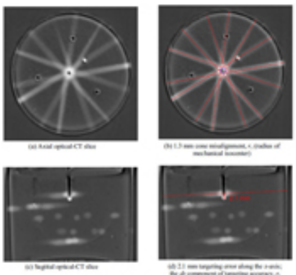
Rankine and colleagues irradiated the PRESAGE dosimeters to a dose of approximately 7 Gy, using a 7-field coplanar treatment. They positioned the targets using the on-board cone-beam CT (CBCT) of the X-RAD 225Cx, and examined the accuracy of three cones (tungsten collimators that define size of the radiation field) with sizes of 1.0, 2.5 and 5.0 mm, in the context of multiple-beam isocentric treatment.

Immediately after irradiation, the dosimeters were imaged in the DMOS scanner to acquire a high resolution 3D map of the changes in optical density, which are directly proportional to absorbed dose. The researchers then determined the accuracy of the treatments by studying positional discrepancies between the targets and the intersection point of the treatment beams.



(http://images.iop.org/objects/med/news/8/11/25/pic1.jpg)
Evaluating delivery accuracy (http://images.iop.org/objects/med/news/8/11/25/pic1.jpg)

The team used two criteria to evaluate delivery accuracy at each target point: isocentre precision – r_c – the radius of the smallest circle in the axial plane at the isocentre that intersects all beams; and the accuracy of coincidence – r_t – (or targeting accuracy) of the imaging and therapeutic systems – defined as the 3D distance between the radiation isocentre and the target.



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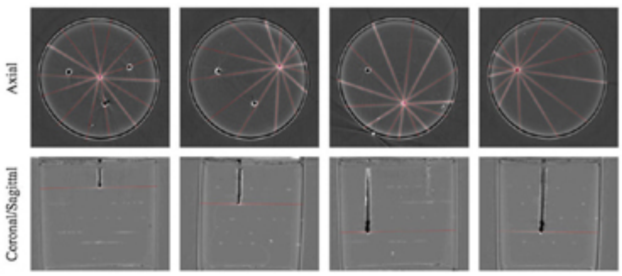
Example isocentre misalignment (http://images.iop.org/objects/med/news/8/11/25/pic2.jpg)

Initial evaluation of the X-RAD 225Cx with the 2.5 mm cone identified an isocentre misalignment of 1.3±0.1–mm. This error was revealed in optical-CT images of the dosimeter, where the beam line trajectories did not intersect exactly at the mechanical isocentre. The overall targeting accuracy was 2.1±0.6–mm (mainly due to a large targeting error in the superior-inferior direction), larger than the manufacturer's specification of 0.5–mm.

The X-RAD engineers corrected this targeting error by mechanical realignment and recalibration of the micro-irradiator, and then repeated the measurements using a new dosimeter. After recalibration, the isocentre precision for the 2.5 mm cone was 0.18±0.04 mm and the targeting accuracy was 0.5±0.1 mm.

They then repeated the experiment using the 1.0 and 5.0 mm cones (after the IGRT re-calibration). The isocentre precision and targeting accuracy were 0.4±0.1 mm and 0.5±0.3, respectively, for the 1.0 mm cone, and 0.18±0.06 and 1.0±0.2 mm for the 5.0 mm cone



(http://images.iop.org/objects/med/news/8/11/25/pic3.jpg)
Optical-CT analysis to verify IGRT accuracy (http://images.iop.org/objects/med/news/8/11/25/pic3.jpg)

Precision X-ray, the manufacturer of the X-RAD 225Cx irradiator, states that its IGRT targeting is accurate to 0.5 mm. Using the PRESAGE dosimetry tool, the researchers verified that the isocentre precision was within this specification for all cones. The accuracy of coincidence was also met for the 1.0 and 2.5 mm cones, but was slightly worse for the 5.0 mm cone, which was within about 1 mm. Further work is currently being performed to determine whether the cause is due to the machining of this cone.

The authors note that there are small uncertainties (about 0.3 mm) in defining the target tip location of the drilled channels, and estimating the *z* location of the channel tip. The team now plans to develop targets with sharper tips to reduce random error and increase sensitivity to targeting errors.

"This paper shows that we can accurately target small lesions to within 0.5 mm in three dimensions, but we still need to verify the various therapeutic dose distributions and treatment plans in realistic geometries," senior author Mark Oldham told *medicalphysicsweb*. "In future work, we are moving towards verifying small-animal treatment plans in anatomically realistic 3D rodent dosimeters."

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About the author

Tami Freeman is editor of *medicalphysicsweb*.