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Validating Delivered Dose In a 3D Printed Phantom Using Surface Guided Gating

Rishab Singh[1]; Tatsiana Rreynolds, PhD[1]; Mustafa Ozer, MS[1]; John Miller, MS[1]; Richard Meyer, MS[2] ;Daniel Craft, PhD[1]
[1]Minnesota Oncology, [2]Radiotherapy Clinics of Kentuckiana

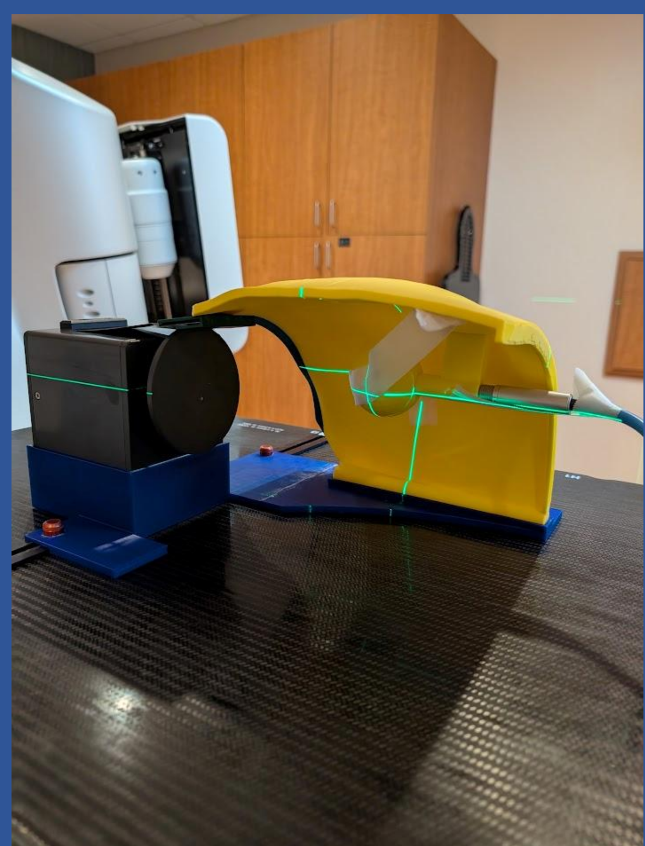

Figure 1. A picture of the 3D printed phantom with the larger target and ion chamber in place.

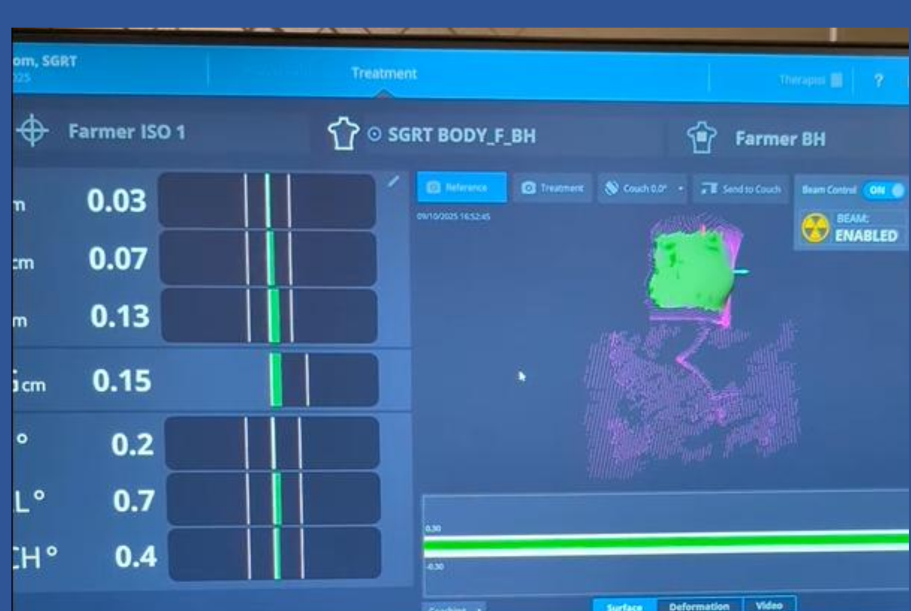

Figure 2. Vision RT tracking of the phantom in the breath hold position.

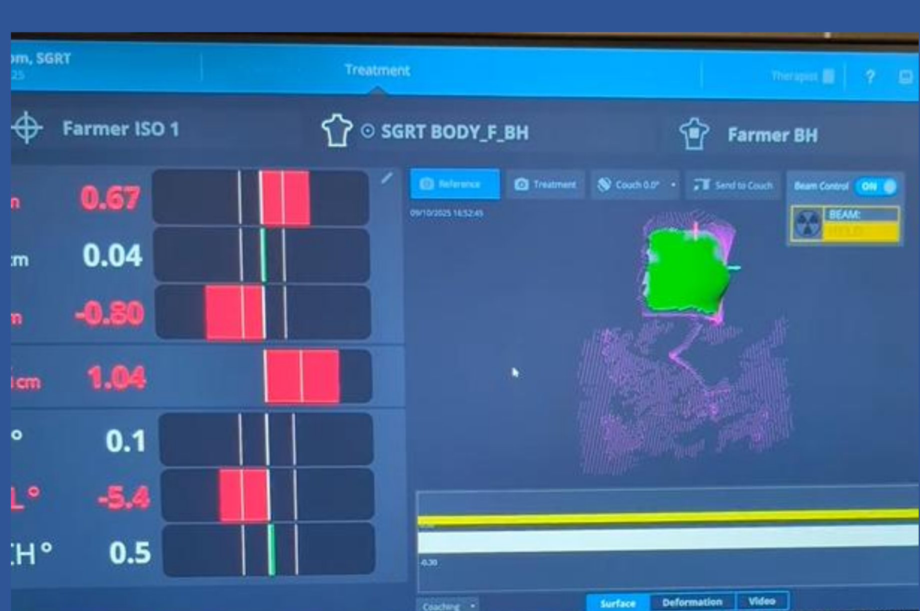

Figure 3. Vision RT tracking of the phantom in the free breathing position.

CONTACT

John Miller
Minnesota Oncology
John.miller@usoncology.com

INTRODUCTION

The purpose of this project was to create and use a moving 3D printed phantom to validate delivered dose to a moving target when using surface guidance based beam gating.

Surface guidance systems are widely used to automatically do beam hold gating, and this phantom allows direct measurement of treatment planning system calculated doses.

The advantage of this system is to use a phantom with realistic anatomy, realistic breathing motion, and a moving target.

The long-term objective is to use this phantom for end-to-end testing of SGRT workflows as well as SGRT annual QA.

METHODS AND MATERIALS

The phantom was designed to mimic a patient chest surface, with hidden lung lesions. Two different lung lesions were designed, one with a 3 cm diameter to mimic an SBRT size lesion and the other with a 5 cm diameter to mimic a more standard fractionation size lesion. The smaller lesion insert was designed to fit a diamond detector, and the larger lesion was designed to fit a standard Farmer type ionization chamber.

The entire assembly fits over a standard Varian RPM motor, allowing the chest and target lesion to move up and down. The phantom was 3D printed in PLA plastic with 3D printed tabs connecting the different sections where needed.

The phantom was simulated without motion to imitate the breath hold state, and treatment plans were created for both target sizes. Using surface guidance to gate the beam, each plan was then delivered to the moving phantom, and delivered doses were compared with TPS planned doses.

Another physicist then repeated the planning and dose delivery for a second set of plans to test for additional set up and measurement robustness. This second plan was delivered using VisionRT gating and RPM gating.

Finally, the phantom was tested for use in SGRT annual tests including drift/reproducibility and static localization. For drift testing the phantom was set up, baselined, and left in the room under continuous monitoring for 1.5 hours to determine long term drift. For static localization a set of specific translations and rotations were applied to the phantom, then compared with VisionRT readings of offset.

RESULTS

The phantom motion and tracking with surface guidance worked as intended.

The delivered dose to the larger chamber planned with standard fractionation measured 202.8 cGy compared to the TPS calculated dose of 199.4 cGy, a 1.7% error. The smaller SBRT style target and plan with a diamond detector measured a delivered dose of 1012.9 cGy vs a TPS calculated dose of 1005.1 cGy, a 0.77% error.

The second set of plans delivered using both VisionRT and RPM agreed with calculated TPS doses within 2% and 0.7%, respectively. All these dosimetric results are shown in Table 1.

The drift testing was successful, showing a total drift in magnitude over the 1.5 hours of only 0.01 cm.

Table 2 shows the results for the static localization testing. Again, the phantom was accurately tracked through all shifts and rotations.

Table 1. Measured Vs. Calculated Errors in Phantom Doses.

	Large Lesion	Small Lesion
Plan 1	1.7%	0.77%
Plan 2	-2.0%	-1.3%
RPM	-0.7%	-1.1%

Table 2. Static localization test results.

	Applied Shift	Vision+ Reading	Vision- Reading
Vert (cm)	3.00	3.00	-3.00
Long (cm)	3.00	3.00	-3.00
Lat (cm)	3.00	3.01	-2.98
Rot (deg)	3.00	3.00	-3.00

DISCUSSION

The results of this study show that the moving phantom successfully met its goal of testing surface guidance-based beam gating by directly measuring the delivered radiation dose. Additionally, the phantom has been shown to be an excellent option for annual and end-to-end testing of SGRT systems.

For all treatment plans, the measured doses were very close to the doses calculated by the treatment planning system (TPS). The larger target had a dose difference of 1.7%, while the smaller SBRT target had a difference of only 0.77%. Both values are within a very close range of their predicted values, showing that the phantom can accurately test gated radiation treatments. Additionally, the doses were very similar to those measured when using RPM gating, which has long been the standard.

One of the biggest strengths of this phantom is that it combines realistic breathing motion with dose measurements. The phantom was designed so that the outside surface, which is tracked by the surface guidance system, moves together with the hidden target inside. This allows it to more accurately represent what happens during patient treatments than a more traditional phantom.

Although the phantom worked well, there are some limitations. The breathing motion followed a smooth, regular pattern, which is much more consistent than the breathing of patients. Real patients will often breathe at different speeds and with inconsistent patterns. In the future, the breathing motion could be programmed to follow more irregular breathing.

One additional future application could be to use this phantom to determine the appropriate size of gating windows to achieve acceptable dosimetric results for certain breathing patterns and lesions sizes.

Overall, this phantom provides a simple and effective way to check that surface guidance beam gating is delivering the correct dose to a moving target. It provides a more realistic setup for annual end to end quality assurance along with a way to test the accuracy of varying gating windows.

CONCLUSIONS

The phantom was successful and proved to be a useful device for validating surface guidance based beam control gating. Future work could include using this phantom to more accurately determine proper gating windows or including more erratic breathing rhythms.