AAPM SPRING CLINICAL MEETING 2022

Best Poster Competition

Utility of 3D Printer In Brachytherapy to Fabricate End-To-End Testing Phantoms For Multiple Purposes

A. Gomez, L. Rodriguez, W. Romaguera, T Phoozhikala, T. Romaguera, A. Gutierrez, J. Contreras, R. Tolakanahalli, V. Chaswal

Department of Radiation Oncology, Miami Cancer Institute, Baptist Health South Florida, Miami, FL

Miami Cancer Institute
BAPTIST HEALTH SOUTH FLORIDA

INTRODUCTION

We commissioned a brand new HDR afterloader and associated applicators: Elekta Flexitron afterloader, Oncentra TPS and advanced hybrid CT/MRI compatible applicators. End-to-end testing goals were expanded to include imaging and therapist workflow optimization and training, in-media dose verification as well as primary goal of DICOM-data transfer streamlining.

To this end, CT/MRI compatible phantoms were fabricated for end-to-end testing for three different HDR gynecological applicators.

AIM

To demonstrate the utility of in-house 3D-printing to produce brachytherapy phantoms for multiple purposes in HDR gynecological brachytherapy applicators.

METHOD

- Three CT/MRI compatible phantoms were designed using AutoCAD Fusion 360 & printed with Airwolf AXIOM 20 Large Format 3D-Printer.
- Single Channel Vaginal Cylinder (SCVC) phantom contained 5 optically stimulated luminescence dosimeters (OSLD) 0.5-2.0 cm from the cylinder surface.
- Geneva applicator phantom, engineered as a clinically relevant sized indexed frame (12 cm x 10 cm x 5 cm) contained 7 OSLD positions & an optional Gafchromic film holder, to support an assembled Geneva applicator with needles in a water-bath.
- Venezia applicator Phantom, fabricated as an insertion phantom contained 8 OSLDs embedded in gel at 1–2 cm parallel to the tandem plane of an assembled Venezia applicator with vaginal caps.
- All phantoms functioned ensured stable reproducible positions od OSLDs & applicator.
- Table 1 shows attributes of the 3 phantoms.

Table 1:

Applicator	Single channel Vaginal Cylinder	Geneva Universal Gyn applicator	Venezia advanced Gyn applicator
Phantom material	Near tissue equivalent silicone rubber	Polylactic Acid (PLA) and Water	Near tissue equivalent silicone rubber
Phantom type	Cylindrical holder for multiple cylinders	Frame to connect applicator in water bath	Insertion phantom for single applicator
Imaging compatibility	CT/MRI	CT/MRI	CT/MRI
Dose verification points	5	11	7
Used for	DICOM workflow, Process workflow, Personnel training, Dose verification	DICOM workflow, Process workflow, Personnel training, Dose verification	DICOM workflow, Process workflow, Personnel training,

RESULTS

- **3 end-to-end testing phantoms were successfully fabricated using an in-house 3D-Printer.**
- Fabrication of phantoms did not add extra time for commissioning.
- Phantoms aided in testing and hands-on training on new equipment.

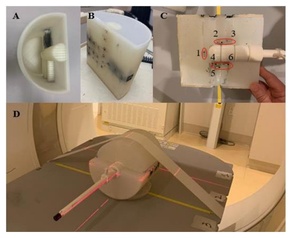

Figure 1: (A-D) Silicone-gel phantom for single channel vaginal cylinder with OSLDs for dose verification

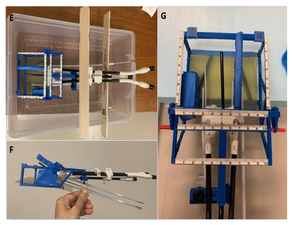

Figure 2: (E-G) Indexed frame phantom for in-water testing of the Geneva applicator

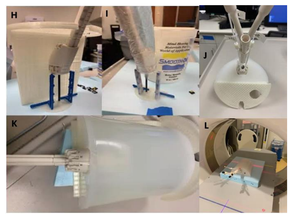

Figure 3: (H-L) Silicone-gel insertion phantom for the Venezia applicator.

- **All phantoms were used for Imaging workflow testing & optimization.**
- In-media CT/MRI imaging of applicators new to us aided in valuable workflow decisions to make our process optimal towards use of these applicators.

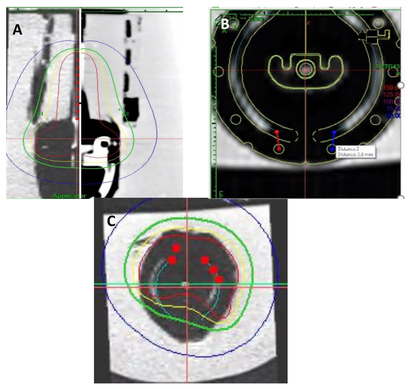

Figure 4: (A-C) Venezia phantom in-gel images used for multiple purposes

- Venezia phantom images in an in-gel phantom demonstrated the importance of CT to MRI image fusion to the process, and MRI-lumen markers for model commissioning and applicator model fitting.

- **All phantoms were used for personnel & process workflow testing, development & training.**
- Multiple RTTs practiced patient treatment workflow using phantoms repeatedly. This assisted in familiarity towards handling of new equipment while mimicking a patient treatment setting.
- SCVC and Venezia Phantoms were easiest to use for this purpose.

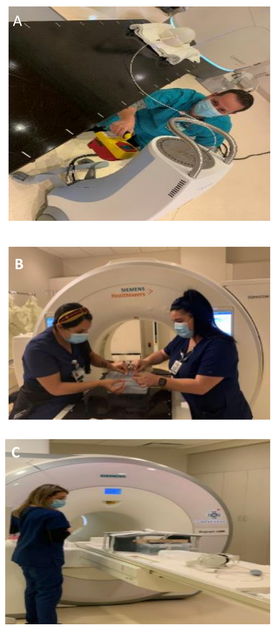

Figure 5: (A-C) RTTs practicing workflow steps. Insertion phantom was valuable to practice and appreciate force used to insert and retract markers in patient.

- **HDR Dose Delivery verification workflow during end-to-end testing:**

Phantoms scanned in CT & MRI scanners with OSLDs in place.
↓
CT & MRI images with markers fused in RayStation
↓
Treatment planning on fused images in Oncentra TPS
↓
Treatment delivered to phantoms on Felxitron afterloader with OSLDs in place

- Standard prescription and loading for HDR Vaginal Cylinder and Geneva applicator were used for planning. Treatment plans were optimized and normalized to a point of clinical significance.
- Extra control OSLDs placed during scanning were removed before HDR plan delivery.

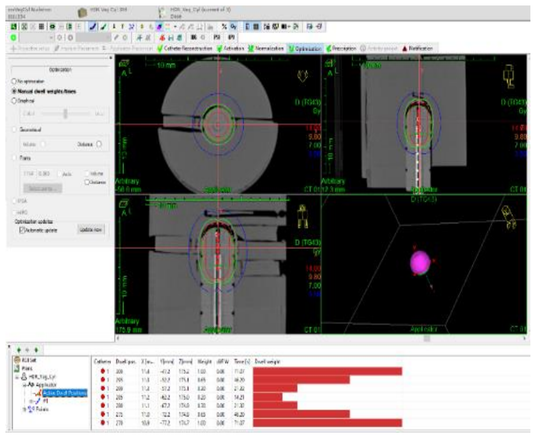

Figure 6: Single channel vaginal cylinder standard plan to deliver 7 Gy to 0.5 mm from cylinder surface. Table 2 shows the OSLD dose verification at different OSLD points.

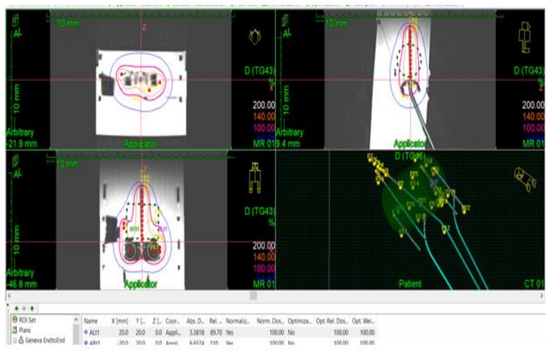

Figure 7: Geneva applicator standard T&O plan to deliver 6 Gy normalized to point A's (L and R). Table 3 shows the dose verification results on OSLDs placed near the ovoids and in the needle planes.

- Observed dose deviation tested on multiple brachytherapy applicators ranged between 2.6% - 10.2%, for all points measured using SCVC and Geneva Phantoms.

Table 2: Single Channel Vaginal Cylinder plan dose verification results

SCVC OSLDs	TPS Dose (Gy)	Measured Dose (Gy)	9 MV corrected (Gy)	% Difference
1 (8 mm L)	4.06	3.87	3.86	-5.2
2 (5 mm R)	5.63	5.44	5.43	-3.7
3 (11 mm R, control)	*	0.01	0	*
4 (4.3 mm, L)	5.35	4.9	4.89	-9.5
6 (4 mm, L)	7.1	6.93	6.92	-2.6

Table 3: Geneva Phantom based HDR plan Dose verification results

Geneva OSLD positions (planar)	TPS Dose (Gy)	Measured Dose (Gy)	6 MV corrected (Gy)	% Difference
O2	12.1	13.5	13.5	10.2
O2	7.06	6.74	6.74	-4.73
O1	9.54	10.2	10.2	6.38
O1	5.75	5.48	5.48	-4.85
Needles	5.13	5.37	5.37	4.47
Needles	3.79	3.94	3.94	3.76
Needles	2.72	2.6	2.6	-4.62

Additionally, Radcalc planned dose verification was performed and resulted within 0.5% for all points. We consider our HDR dose delivery verification reasonable within 10% due to the uncertainties involved – primarily, finite size of OSLD, OSLD sweet-spot determination (central 1mmx1mm region used) & calibration.

Institutions do not employ dose delivery verification during commissioning due to complexity involved. **Here, we demonstrate that simple, reusable, dose verification phantoms fabricated on a 3D printer can be used for multiple purposes during end-to-end testing.**

Note: Venezia insertion phantom was not broken to get the embedded OSLDs out due to its value in process-practice and RTT training.

CONCLUSIONS

We demonstrated from our commissioning experience that a 3D-printer is valuable tool that can be used to create simple reusable phantoms for brachytherapy dose delivery verification in tissue-equivalent media with reasonable accuracy. Additionally, these phantoms can play an important role in repeated imaging workflow development, personnel training and practice and workflow optimization during end-to-end process testing and commissioning.

REFERENCES

S. Gohlami et al, A novel phantom design for brachytherapy quality assurance, International Journal of radiation research, Vol 14, No.1 Jan 2016

S. Bassi et al, End-to-end dosimetric audit: A novel procedure developed for irish HDR brachytherapy centers, Australas Phys. Engg. Sci. Med, 35, 335-339, 2012

A. Palmer et al, A multicentre 'end to end' dosimetry audit for cervix HDR brachytherapy treatment, Cervical Cancer Brachytherapy, 2010

CONTACT INFORMATION: vibhac@baptisthealth.net