Pre-clinical and Clinical Evaluation of the HYPERSCINT Scintillation Dosimetry Research Platform

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INTRODUCTION

Advanced radiation techniques like IMRT, VMAT and SRT make quality assurance more and more complex. Previous radiation accidents have shown the increased need for in-vivo dosimetry to ensure patient safety. [1,2]

Plastic scintillators offer several advantages compared to existing systems: They are water-equivalent, have a long lifespan, are capable of real-time dosimetry, and they are suitable for internal use. [3,4]

A concern for the use of plastic scintillators is the temperature dependency which has been addressed in a previous publication. [5]

AIM

To evaluate the HYPERSCINT scintillation dosimetry research platform (Medscint Inc., Quebec City, Canada) designed for clinical QA for use in in-vivo dosimetry measurements.

METHOD

Pre-clinical evaluation:

- Irradiation of the scintillator with a Varian TrueBeam.
- Comparison of measurements to calibration data from commissioning and annual QA.
- Dependency on energy, field size, dose rate, temperature, depth, and radiation type were measured in a water tank.
- For angle dependency, a 3D printed phantom was used.

Clinical evaluation:

- Two cadaver dogs and three companion animal dogs with nasal tumors were irradiated with VMAT plans.
- A treatment planning CT scan was performed for cadavers and clinical patients.
- Prior to treatment, the probe was inserted into the radiation field.
- Radiation was then delivered and measured with the scintillator.
- Cadavers were first irradiated in the correct position. Then an intentional shift in patient position was made before another treatment to simulate an error in dose delivery.
- CBCTs showing the exact position of the scintillator were matched with the treatment planning CT in order to contour the scintillator on the planning CT in Eclipse. Mean dose delivered to the scintillator structure was calculated.

RESULTS

Preclinical evaluation.:

- Measured dose differed as follows: photon energies 0.09 – 3.03%, field size -0.8 – 0.43%, dose rate 0.3 – 3.6%, angular dependency -0.01 – 1.18%, depth dose measurement -1.14 – 0.36%.
- A linear temperature dependency was detected and required a correction factor of 0.11/°C.
- Electron data showed the largest dose difference with values ranging from 0.1 – 5.8%.

Clinical evaluation:

- In two cadaver heads, the dose difference was between -0.24 and 1.34%.
- When intentionally treated in the wrong position with a significantly lower expected dose, the scintillator detected this new dose within -0.7 and +1.4%.
- The visibility of the scintillator was inadequate in patients with larger amounts of mucous within the nasal cavity. A fiducial was attached to the tip of the scintillator. Subsequent measurements in the water tank confirmed that the fiducial did not impact the dose measurements.
- Three clinical patients were treated with 3 fractions of VMAT SRT. The detected dose ranged from 98.33 – 103.15% of the expected dose.
- The effective dose rates of the VMAT plans with 2 to 6 arcs were within a range where the detector is largely dose rate-independent.

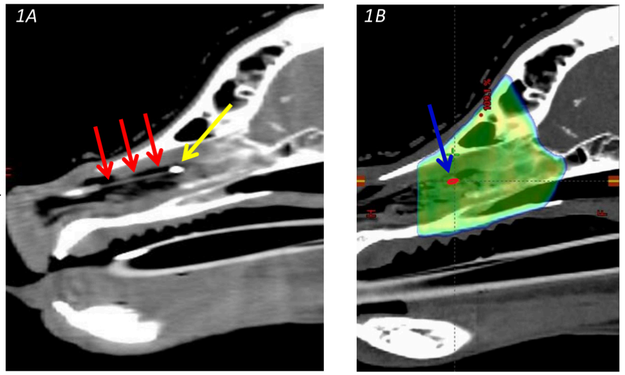

Figure 1.
A: CBCT with the scintillator (red arrows) positioned within the nasal cavity. Fiducial (yellow arrow) placed at end of scintillator.
B: Treatment planning CT with the dose color wash of the treatment plan. The blue arrow indicates the position of the 3mm long scintillator structure (red) that was contoured off the CBCT after matching the latter with the treatment planning CT. The mean dose delivered to the scintillator was then calculated by Eclipse.

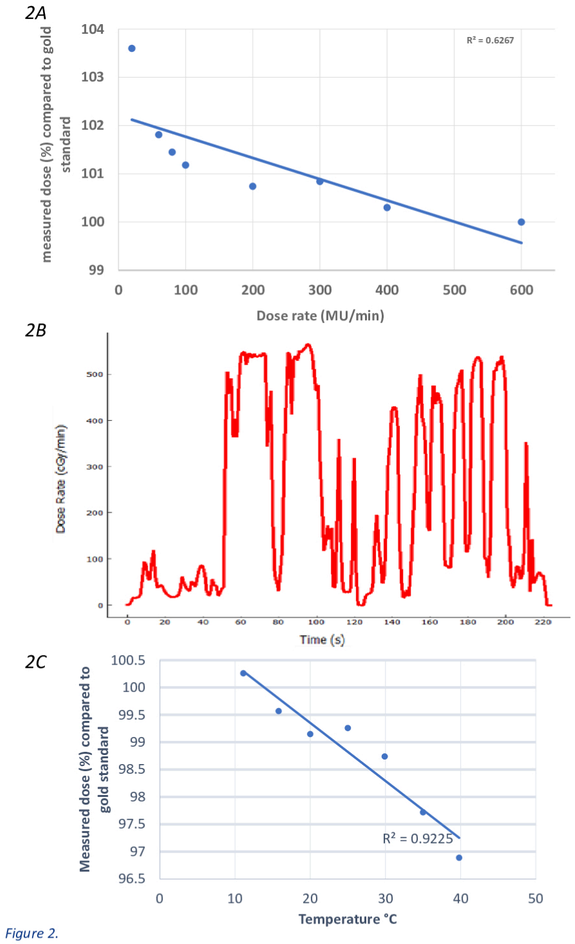

Figure 2.
***A:** Dose dependency on dose rate. X axis: Dose rate (MU/min), y axis: Measured dose in percent of the expected dose.*
***B:** Dose rate spectrum of a VMAT plan in a clinical patient. The dose rate (y axis) is measured in real time over the course of the treatment (x axis). The summed dose at the scintillator position was 843.32 cGy.*
The effective dose rates are within a range where the detector is largely dose rate-independent.
***C:** Dose dependency on temperature. X axis: Measured dose in percent of the expected dose, y axis: water temperature (°C). An inverse linear relationship was detected and a correction factor of 0.11%/°C was calculated.*

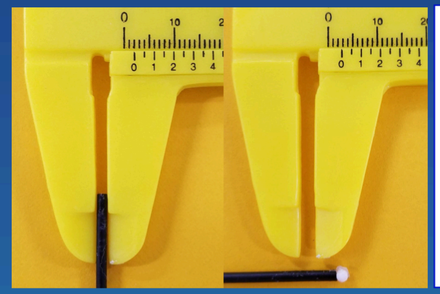

Figure 3.
HYPERSCINT scintillation dosimetry platform.

On the left: Scintillator without fiducial. Total probe diameter = 2mm. On the right: Scintillator with fiducial. The detector with a length of 3 mm is located 3mm upstream of the tip of the probe as indicated by the opened calipers.

CONCLUSIONS

- The scintillator was easy to use, it was suitable for internal use.
- Initial results indicate that the HYPERSCINT is performing with similar accuracy and reproducibility compared to other established devices for in-vivo dosimetry.
- Additional work needs to be done to evaluate temperature and dose rate dependency under clinical conditions. Dose rate appears to work well within clinically used ranges.
- A separate calibration step is likely needed for electron energies.

ACKNOWLEDGEMENTS

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