Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 23-24, 2019

Development of a 3-D Printed Tumor-Shaped Scintillator Measurement System

Tae Hoon Kim[a], Sangmin Lee[a], Dong Geon Kim[a], Hye Jeong Yang[b],
Yong Kyun Kim[a, *], Hyun-Tai Chung[c, *]
[a]*Department of Nuclear Engineering, Hanyang University, Seoul, Republic of Korea*
[c]*Department of Biomedicine & Health Sciences and Biomedical Engineering, Catholic University College of Medicine, Seoul, Republic of Korea*
[b]*Department of Neurosurgery, Seoul National University College of Medicine, Seoul, Republic of Korea*
[a, *]*ykkim4@hanyang.ac.kr*, [c, *]*htchung@snu.ac.kr*

1. Introduction

Recently, treatment plans for radiation therapy are getting more complex because multiple beams with various modulation technique have been included in irradiation procedure. In addition, the amount of dose to treat the tumor varies from patient to patient. In order to assure the safety of advanced radiation therapy, it is essential and important to verify the treatment plan as accurate as possible. In this study, using the 3-D printable scintillating plastic resin developed in the previous study [1], we developed tumor-shaped scintillator measurements system. The response to radiation was measured using ^{60}Co-based Leksell Gamma Knife™ Perfexion® (PFX, ELEKTA Instruments AB, Sweden) which treats with complex treatment plan beams, and scintillator light to dose conversion factors were obtained by using Monte Carlo simulation. Finally, the 3-D printed tumor-shaped plastic scintillator was irradiated as the treatment plan and dose conversion was performed to determine the total dose rate of each plan beams and the total dose absorbed in the tumor.

2. Methods

A scintillating plastic material was developed to be used in a commercial 3-D printer (Pico2 HD, ASIGA, Australia). The patient specific scintillator was printed along the shape of the tumor which was extracted from patient DICOM images. The three same models of tumor-shaped scintillators were printed (Fig. 1). The

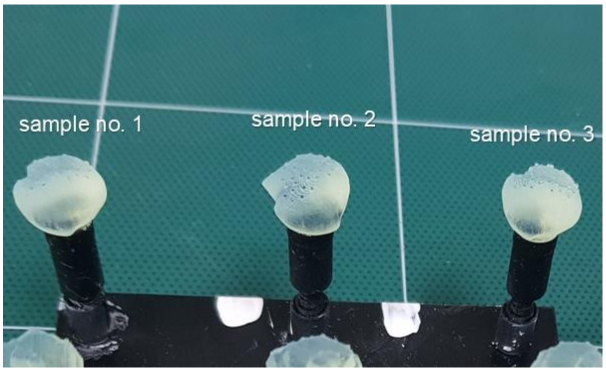

Figure 1. The 3-D printed tumor-shaped scintillator for three same models

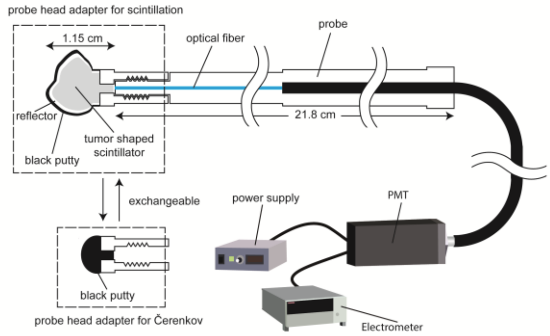

Figure 2. Diagram of the 3-D printed tumor-shaped scintillator measurement system.

tumor-shaped scintillator was fixed by probe head adapter which connectable to optical fiber probe, and they inserted into the isocenter in the dosimetry phantom. Each tumor-shaped scintillator model was coated with plastic scintillator reflector (EJ510, Eljen Technology, USA) in a thickness of about 0.3 - 0.5 mm and then also was coated a black putty in a thickness of about 1 mm to block external light. To measure scintillation light emitted by the radiation, photomultiplier (PMT, H10721-20, Hamamatsu Photonics, Japan) was used. The light generated from the scintillator was transported to the PMT by optical fiber. The light detected at the PMT window was converted to current and we measured current using the electrometer (6517B, Keithley, Ohio, USA).

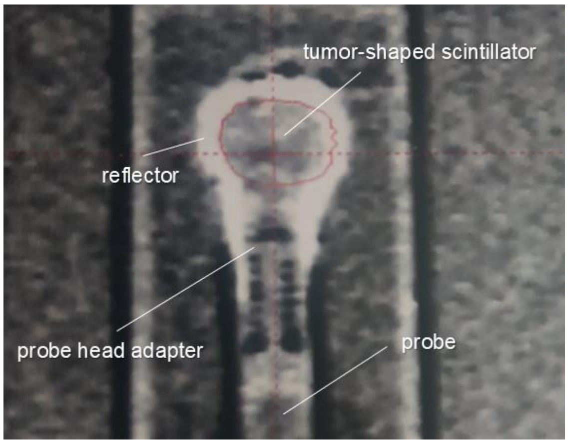

Figure 3. Computed tomography (CT) images of tumor-shaped scintillator and probe holding optical fiber at isocenter of the dosimetry phantom.

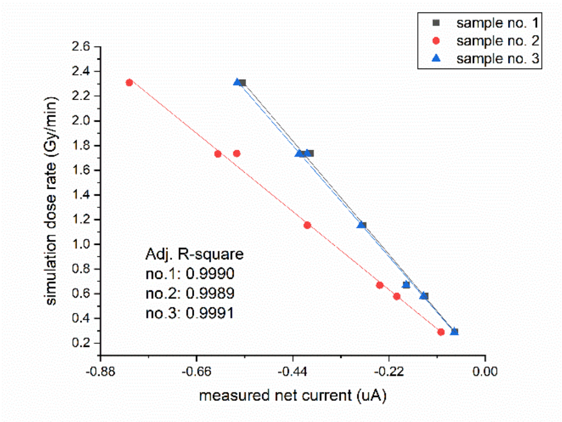

Figure 4. Linear fitting of measured current to simulation dose rate for each model sample for conversion factor calculation.

To remove the Čerenkov light generated the optical fiber, the probe head was designed exchangeable with that covered with black putty (Fig 2). The Čerenkov subtraction was performed by subtracting the measured current of the total light using the scintillator adapter from the current measured by the Čerenkov adapter without any scintillator in the same environment.

The conversion factors from net current subtracted Čerenkov to absorbed dose rates were obtained using Monte Carlo simulations with Geant4 10.03 and measurement with the PFX. The PFX beams used for calibration were several 16mm beams with different dose rates and 16mm, 8mm and 4mm single-shot beams at the isocenter which is the center of the dosimetry phantom. The conversion factor was calculated by linear fitting of the measured scintillator current output and the absorbed dose rate in the simulated tumor shape. The computed tomography (CT) of the measurement system inserted in the dosimetry phantom was obtained (Fig. 3). Using the CT image, a treatment plan was carried out for the tumor shaped scintillator. The treatment plan is consisted of five independent shots to compose the uniform dose to the tumor. The current measured by the treatment plan shots were converted to the dose rate and compared with the treatment plan dose rate. The total absorbed dose to the tumor-shaped scintillator by all shots was obtained by integration over the time and also compared treatment plan dose.

3. Results

The conversion factor from the linear fitting using the measured scintillator current output and the simulated dose rate was -4.18 ± 0.05 (Gy/min·uA), -2.88 ± 0.04 (Gy/min·uA) and -4.09 ± 0.05 (Gy/min·uA) for each of the three models, and the adjusted R-square was 0.9990, 0.9989 and 0.9991 (Fig. 4).

For the measurement with plan shots in a tumor-shaped scintillator, the dose rates converted using the conversion factor were 0.285 ± 0.004 Gy, 0.090 ± 0.004 Gy, 1.023 ± 0.002 Gy, 0.953 ± 0.005 Gy, 1.049 ± 0.021 Gy for each plan shots, respectively. For three models, the average values and standard deviations was calculated. When compared the treatment plan dose rate with calculated values for each plan shots, difference were -9.2%, -1.9%, 2.9%, 1.8%, and 0.2%, respectively. The total dose measured on the tumor-shaped scintillator according to the treatment plan was 7.493 ± 0.034 Gy, which is 1.3% different from treatment planning system.

4. Conclusion

This study showed that the developed scintillation material and the patient specific detectors system made of it can be used to assess the accuracy of the total energy absorbed to the tumor of radiation treatment plans. The accuracy of the factor to convert light output to absorbed dose rate showed good linearity. Feasibility of the system was proved in this study, but more sophisticated manufacturing and verification are necessary to be used in actual patient specific quality assurance (QA).

REFERENCES

[1] Son, J., Kim, D. G., Lee, S., Park, J., Kim, Y., Schaarschmidt, T., & Kim, Y. K., Improved 3D Printing Plastic Scintillator Fabrication, Journal of the Korean Physical Society, 73(7), 887-892, 2018.

.