Preliminary dosimetry investigation of Tc-99m diagnostic radionuclide by NIPAM gel dosimeter

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Abstract. The N-isopropylacrylamide (NIPAM) gel dosimeter was investigated as a suitable material for measuring absorbed doses from radionuclide sources. In this study, NIPAM gel dosimeter was used to evaluate the dose distributions of the Tc-99m radionuclide in NIPAM gel. The accumulated radioactivity range of the Tc-99m NIPAM gel is from approximately 0 MBq to 13.6 MBq (about 0.37 mCi). The NIPAM gel dosimeter with high stability and high-dose linear and non-energy dependent properties can provide various radiopharmaceutical activity intensities in the conduct of dose assessment in nuclear medicine, thereby producing the most promising dose verification tools.

1. Introduction

Treatments involving the use of ionizing radiation, such as radiotherapy and targeted radionuclide therapy (TRT), play an essential role in medicine and are fast becoming common with the development of new therapies and technologies [1]. TRT involves the intravenous or oral administration of a radionuclide-labeled pharmaceutical that is appropriate for a type of cancer. Along with these treatments is the need for dosimeter materials that can absorb radiation doses to ensure the health and safety of the patient [2]. Such common dosimeters as ionization chamber, thermoluminescent diodes, and radiographic film do not allow the measurement of three-dimensional (3D) dose distribution due to several spatial laminations [3]. Polymer gel dosimeter provides true 3D absorbed dose information and is very suitable as a dose distribution tool for radionuclide dosimeters [4].

In recent years, polymer gel dosimeter is used for radionuclides in brachytherapy and TRT for the purpose of obtaining dose distribution. Dosimetry for radionuclide therapy and diagnostic studies currently relies on imaging to map the distribution of the radiopharmaceutical in the body. Absorbed radiation dose from radionuclide is more difficult to measure than that from an external beam. Wuu et al., for example, used Re-188 source inserted into BANG gel to measure dose distribution [5], while Kelly et al. used MRI to evaluate dose uniformity with Tc-99m source in PAG gel dosimeter [6].
The current study investigates the polymer gel dosimeters of the Tc-99m radionuclide in conjunction with the N-isopropylacrylamide (NIPAM) gel for the production of nuclear medicine. The radiation doses from different activities of the radionuclide are measured by analyzing the radiation-induced change in the gels with optical computed tomography (OCT).

2. Materials and Methods

2.1. NIPAM gel preparation and Optical Computed Tomography measurement

The NIPAM gels were manufactured following the method described by Hsieh et al. [7]. A 4 wt% gelatin (300 Bloom Tape A. Sigma-Aldrich) was added to 88 wt% deionized water and stirred for 10 min at room temperature of 22 ℃. The gelatin solution was heated to 45 ℃ with a hot plate until it became clear and transparent. With continuous stirring, 4 wt% NIPAM (97%, Sigma-Aldrich) and 4 wt% BIS (Merck) were poured into the gelatin solution and dissolved for 20 min. The solution was left to stir for 5 min, after which 3320 MBq of the Tc-99m, was added to the Pyrex test tube via a syringe. Next, 10 mM THPC (80%, Sigma-Aldrich) was added to the solution, which was continuously stirred for 2 min before the NIPAM gel was added to the Tc-ppm in the Pyrex test tube via a syringe. After removing the empty syringes, the tubes were shaken and stored behind a lead shield.

After 12 T1/2 to 15 T1/2 decay time, the irradiated tubes were analyzed via an OCT using Chang et al.’s protocol [8]; Afterwards, an NRC Model 127 He-Ne laser with 20 mW power and 632.8 nm wavelength was used in CT-s1. After a 140 min laser warm up, the laser power deviation was less than 1%. Room temperature was maintained at 22±1 ºC, and a photodetector was used to scan the gel dosimeter as depicted in a previous research.

2.2. External beam irradiation

In the present study, a Varian 21EX Clinic linear accelerator was used as a high energy irradiated apparatus. The setup condition of linear accelerator included gantry at 0°, energy of 6 MV, dose rate of 400 MU/min, and field size of 20 cm x 20 cm. Another medium energy X-ray apparatus used was the Pantak HF 420C. The condition of Pantak HF 420C included an energy range of 80 kVP to 250 kVP, and source-axis distance (SAD) of 150 cm. Furthermore, the absorbed dose calibrations were performed using Kodak X-O mat V film.

3. Results and Discussion

3.1. Dose response of the NIPAM gel

Fig. 1(a) shows the dose response of the NIPAM gel presented in this study. The dose response is linear from 0 Gy to 3 Gy, with linearity of 0.999 and sensitivity of 0.009 Gy-1. Fig. 1(b) shows the dose response curve for different beam energies of 100, 150, and 250kV. No significant changes in the dose responses at 0.1 and 0.5 Gy appear in the NIPAM gel.

3.2. Dose verification of the radiochromic film

Fig. 2(a) shows the energy dependence of the V film. When its irradiated dose is above 2.25 Gy, energy dependence is significant. Hence, the radioactivity of Tc-99m is approximately 1600 MBq (about 2.2 Gy). The result avoids the energy dependence that influences the accuracy of the measurement dose.

3.3. Dose verification of Tc-99m NIPAM gel dosimeter

Based on the results, the NIPAM gel dosimeter has the potential to measure absorbed dose from the Tc-99m radionuclide. When using the V film as a dose verification dosimetry, the corresponding dose of the Tc-99m ranges up to 2.2 Gy. The V film is the most commonly used radiochromic film in clinical practice. Its energy range is from 8 MV to 18 MV. The V film dose verification range is 2.25 Gy, and the accumulated radioactivity range of the Tc-99m NIPAM gel is approximately 0 MBq to 13.6 MBq (about 0.37 mCi) (Fig. 2(b)).
Figure 1: (a) Dose response and (b) Energy dependence of the NIPAM gel

4. Conclusion
This study suggests that the radiolabeled NIPAM gels are suitable as dosimeters in radionuclide studies. The NIPAM gel dosimeter provides a variety of radiopharmaceutical activities of dose assessments in nuclear medicine that, in turn, lead to the development of the most promising dose verification tools.

References
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