Absorbed Dose from Large Balloon Filled with Liquid Ho-166

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ABSTRACT

Large balloon angio catheter is used for Percutaneous Transluminal Angioplsty(TPA) of the iliac, femoral and renal arteries as well as after Transjugular Intrahepatic portosystemic shunt(TIPS). The use of angioplasty balloon filled with liquid form of radioisotope reduces the rate of restenosis after PTA. The purpose of this study was to evaluate the absorbed dose to the target vessels from various sized large balloon filled with liquid form of Ho-166-DTPA. Four balloons of balloon dilatation catheters evaluated were 5, 6, 8 and 10 mm in diameter. GafChromic film was used for the estimation of the absorbed dose near the surface of the balloon catheters. Absorbed dose rates are plotted in units of Gy/min/GBq/ml as a function of radial distance in mm from the surface of balloon. The absorbed dose rate was 1.1, 1.6, 2.2 and 2.3 Gy/min/GBq/ml at a balloon surface, 0.3, 0.4, 0.5 and 0.6 Gy/min/GBq/ml at 1 mm depth for various balloon diameter 5, 6, 8 and 10 mm in diameter respectively. The study was conducted to estimate the absorbed doses to the vessels from various sized large balloons filled with liquid form of Ho-166-DTPA for clinical trial of radiation therapy after the PTA. The absorbed dose distribution of Ho-166 appeared to be nearly ideal for vascular irradiation since beta range is very short avoiding unnecessary radiation to surrounding normal tissues.

Keywords: Absorbed Dose, Ho-166, GafChromic Film, Large Balloon

1. INTRODUCTION

Large balloon angio catheter is used for Percutaneous Transluminal Angioplsty(TPA) of the iliac, femoral and renal arteries as well as after Transjugular Intrahepatic portosystemic shunt(TIPS). The use of angioplasty balloon filled with liquid form of radioisotope reduces the rate of restenosis after PTA. In radiation dosimetry there are numerous problems associated with the measurement of isodose curves and depth dose distributions in high gradient regions of beams using conventional measuring systems such as ionization chambers, semiconductors, thermoluminescent detectors(TLDs), and radiographic films. GafChromic film has become a standard medium for dosimetric measurements because it is nearly tissue equivalent, has a linear response to optical density in proportion to dose, and requires no postirradiation processing[1,2]. In recent years various radiochromic dosimeters have also been used for nonclincal applications[3]. The purpose of this study was to evaluate the absorbed dose to the target vessels from various sized large balloon filled with liquid form of Ho-166-DTPA.

2. MATERIALS AND METHODS

Ho-166-$(NO_3)_3 \cdot 5H_2O$ was produced at the Korea Atomic Energy Research Institute(KAERI, Taejon, Korea) by neutron reaction [^{165}Ho (n,γ) ^{166}Ho] of naturally abundant non-radioactive Ho-165. Ho-166 has 26.8 hours physical half-life and emits high-energy beta particles with maximum energies of 1.85 MeV(51%) and 1.77 MeV(48%) with average energies of 0.69 and 0.65 MeV respectively, and a small portion of gamma rays (80.6 keV at 6.6% and 1.38 MeV at 0.9%). K-shell x-rays of 48.2 keV at 2.8% and 49.1 keV at 5.0% are also emitted. Maximum and average range of beta particles are about 8.6 and 1.2 mm in tissue respectively [4-7]. We used GafChromic film(MD-55, ISP Technologies Inc., Wayne, NJ, USA) for the estimation of beta dose from Ho-166. Co-60 teletherapy beam and 6 MV photon beam were used to generate dose vs. optical density calibration curve for the GafChromic film. A series of calibration films from the same batch were prepared and irradiated. The dose outputs were verified by ion chamber measurements. The exposed GafChromic film was read using a videodenstometer(Model # WP700, Wellhöfer Co., Schwarzenbruck, Germany). The lower portion of micrometer(Mitutoyo Co., Kanagawa, Japan) was removed by cutting off, and the solid water phantom was attached to the end in order to avoid back scattering effect from the carbide tip. The GafChromic film was divided into 5 x 5 cm square pieces and was positioned under the upper solid water phantom paralleled to the long axis of the balloon on the lower phantom. Four balloons of balloon dilatation catheters(Ultra-thin™ Diamond™, Boston Scientific MEDI-TECH, Watertown, MA) evaluated were 5, 6, 8 and 10 mm in diameter. The balloons were filled with concentration activities of 1.6, 2.4 and 3.8 MBq/ml Ho-166 solution for various balloon diameter of 5, 6, 8, 10 mm. Each film was exposed for the different radial distances from balloon surface up to 10 mm away. Several film exposures were made for 5, 10, 15 and 20 min in order to verify the linearity of exposure time. The exposed films were read using the videodensitometer. Optical density was converted into radiation absorbed dose utilizing the measured absorbed dose vs. optical density calibration curves.

3. RESULTS

Graphs in Figure 1 illustrate the absorbed dose rate(Gy/min) at balloon surface versus balloon diameter for Ho-166-DTPA activity concentrations of 1.6, 2.4 and 3.8 MBq/ml. Figure 2 depicts absorbed dose rate at balloon surface versus activity concentration for various balloon diameter of 5, 6, 8, 10 mm. Figure 3 depicts absorbed dose at balloon surface versus balloon diameter for various exposure durations of 5, 10, 15 and 20 min. Figure 4 depicts absorbed dose at balloon surface versus exposure duration for various balloon diameter. All absorbed dose rates are plotted in units of Gy/min/GBq/ml as a function of radial distance in mm from the surface of balloon. The absorbed dose rate was 1.1, 1.6, 2.2 and 2.3 Gy/min/GBq/ml at a balloon surface, 0.3, 0.4, 0.5 and 0.6 Gy/min/GBq/ml at 1 mm depth for various balloon diameter 5, 6, 8 and 10 mm in diameter respectively. Figure 5 depicts absorbed dose rate versus balloon diameter at balloon surface and 1 mm distance respectively. With these results one can easily calculate dwell time to deliver a desired radiation absorbed dose to any point with a known concentration of Ho-166-DTPA solution.

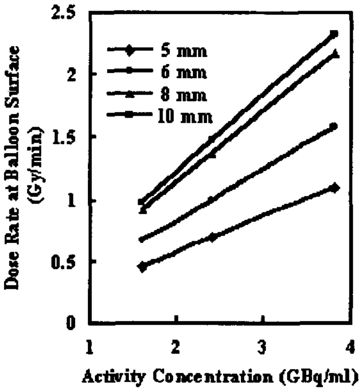

Fig. 1. Absorbed dose rate at balloon surface versus activity concentration for various balloon diameter.

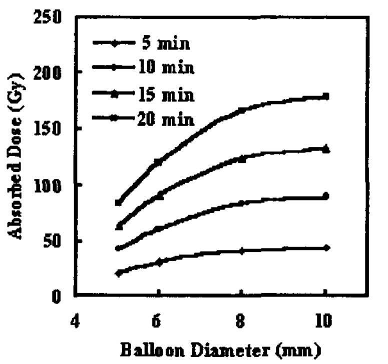

Fig. 2. Absorbed dose at balloon surface versus balloon diameter for various

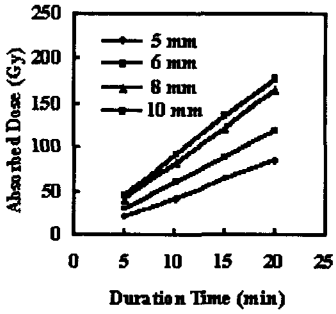

Fig. 3. Absorbed dose at balloon surface versus exposure duration for various

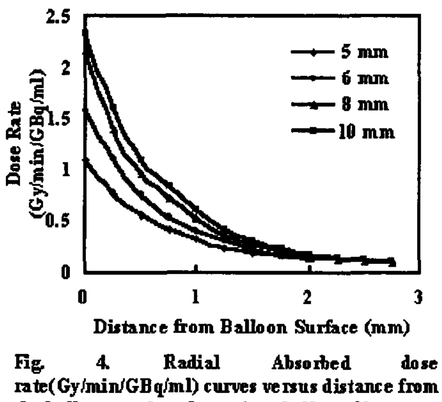

Fig. 4. Radial Absorbed dose rate(Gy/min/GBq/ml) curves versus distance from the balloon surface for various balloon diameter.

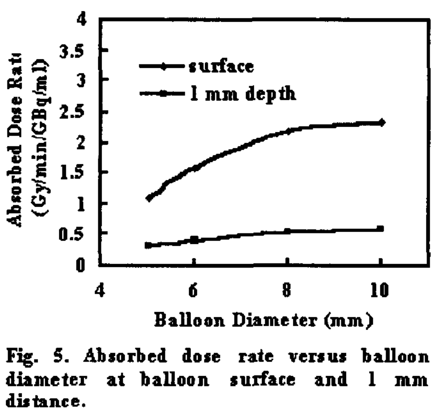

Fig. 5. Absorbed dose rate versus balloon diameter at balloon surface and 1 mm distance.

4. DISSCUSION AND CONCLUSION

For the absorbed dose measurement in the endovascular brachytherapy using a balloon catheter TLD or GafChromic film have been used. Recently GafChromic film is widely used because it can provide continuous radial direction dose and it is very convenient to handle. In this study a technique was used to estimate more accurate radiation absorbed dose distribution of Ho-166 vascular irradiation using a balloon catheter. The measurement was done using GafChromic films and a modified micrometer. The exposed films were read by a videodensitometer. With this method the dose distributions near the balloon surface were measured more precisely. In order to use this technique in vascular brachytherapy characteristics of balloon such as size, model and type should be known. The absorbed doses for different source concentration activities revealed a linear relation. Theoretically the absorbed dose should not be linear to the duration of irradiation because of activity decay. In clinical situation of vascular brachytherapy the dwell time should be less than several minutes. Therefore, with this relatively short range of exposure time the absorbed doses appear to be linear. While this irradiation technique using a balloon catheter clearly yields desirable dose distributions, the chemical and radiation toxicity of the radioactive liquid must be considered as there is always a remote risk of balloon rupture with approximately 0.1% reported incidence[8]. In order to lessen these effects, Ho-166-$(NO_3)_3 \cdot 5H_2O$ was chelated to DTPA (diethylenetriaminepentaacetic acid) for rapid excretion through the kidney from the blood in the case of balloon rupture. The vascular brachytherapy following PTA or stenting is currently being performed using high energy gamma or beta emitters. An ideal isotope would have a high specific activity, uniform dose over the treated area and a penetration depth of at least 2 to 3 mm. Beta emitters have advantages in terms of high specific activity and dose rate. The radiation absorbed dose distribution of Ho-166 appeared to be nearly ideal for vascular irradiation since beta range is very short avoiding unnecessary radiation to surrounding normal tissues

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