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Dosimetry of Ho-166 Balloon Catheter Using GafChromic Film

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INTRODUCTION

Percutaneous transluminal coronary angioplasty (PTCA) is an established therapeutic modality for occlusive coronary artery disease. However restenosis after balloon angioplasty occurs in thirty-five to forty percent of patients undergoing PTCA. Endovascular irradiation of various forms have been used in an attempt to prevent restenosis by neointimal hyperplasia. Most commonly the radiation is administered immediately after angioplasty by insertion of high activity radioactive seed or wire sources via conventional catheters, after which the sources and catheters are removed. Other techniques, such as inflation of the angiographic balloon with radioactive liquid or gas, infusion of radioactive liquid into the vessel wall via infusion catheters, and the use of balloons with radioactive walls, have also been suggested[1]. The purpose of our study was to estimate absorbed dose distribution of Ho-166 endovascular beta irradiation using angio catheter. The measured data were obtained using GafChromic films. GafChromic film has become a standard medium for dosimetric measurements because it is nearly tissue equivalent, has a linear response of optical density in proportion to dose, and requires no postirradiation processing[2,3].

METHOD

Ho-166-$(NO_3)_3{\cdot}5H_2O$ was produced at the Korea Atomic Energy Research Institute(KAERI) by neutron reaction [^{165}Ho (n,γ) ^{166}Ho] of naturally abundant non-radioactive Ho-165 at a thermal flux of 4.2 x 10^{13} n/cm$^2{\cdot}$sec for 60 hours. A specific activity of Ho-166[$^{166}Ho(NO_3)_3{\cdot}5H2O$] is 200 mCi/mg. Ho-166 has 26.8 hours physical half-life and emits high-energy beta particle with maximum energy of 1.85 MeV(51%) and 1.77 MeV(48%), average energy of 0.67 MeV, 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 48.3 keV at 2.8% and 49.1 keV at 5.0% are also emitted. Maximum range of beta particle is about 8.6mm in tissue.

We used GafChromic film(MD-55, model No. 37-041, Lot #941206) for the estimation of beta dose from Ho-166 obtain from International Specialty Products(Wayne, NJ, USA). Co-60 teletherapy beam and 6 MV photon beam were used for making dose vs density curve for GafChromic film. The exposed GafChromic film was red using Wellhöfer videodenstometer.

The balloon angio catheter was 2 cm long and 3 mm in diameter(total volume = 0.14 ml) and inflated with a 4 atm nominal inflation pressure. Tissue equivalent solid water phantom was constructed in the form of 5x5 cm rectangular solid cylinder and cut in half radially to permit insertion of a slice of GafChromic film. Both the phantom and the film had central holes 3 mm in diameter drilled axially to permit insertion and inflation of the balloon catheter. Because of possible local damage to the film from the punching the hole, radial dose distributions around the hole(0-0.5mm from the cut edges) were uncertain. Therefore, using a modified micrometer, film was approached to the surface of balloon in water. The balloon was filled with 105, 131 and 240 mCi/ml Ho-166 solution to a pressure of 4 atm. Several film exposures were made for 5-20 min.

RESULTS

Calibration curve i.e. radiation absorbed dose versus optical density for the film was obtained by exposing film to doses of 100-5000 cGy with a calibrated Co-60 teletherapy source and 6 MV radiation therapy photon beam. The difference of curve for Co-60 and 6 MV photon were less than 5% at the 5000 cGy or lower dose.

Each film was exposed for 5, 10, 15 and 20 min at distance ranging from the balloon surface to 10 mm. All doses are plotted in units of cGy/min/mCi/ml as a function of radial distance in mm from the surface of balloon. The radiation absorbed dose rate was 3.71, 1.90 and 1.28 cGy/min/mCi/ml at balloon surface, 0.5 and 1 mm from the balloon surface respectively. From this result, irradiation durations are 2.63 and 3.90 min at 0.5 and 1 mm from the balloon surface with a specific concentration of 300 mCi/ml for a dose 1500 cGy.

DISCUSSION

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. In recent years, various radiochromic dosimeters have also been used for nonclincal applications[4]. Our study was to estimate absorbed dose distribution of Ho-166 endovascular beta irradiation using angio catheter. The measured data were obtained using GafChromic films.

Calibration curve revealed a non linear response, because our videodensitometer is an imaging systems with charge-coupled device (CCD) detector instead of He-Ne laser light source.

In punching hole method, because of local damage to the film from the punching the hole, radial dose distributions around the hole were uncertain. Using a modified micrometer, dose distributions of near the balloon surface were obtained more precisely.

Irradiation times can be calculated from the results of this study. However one must still assess the radiation toxicity of the injected dose in the case of balloon rupture.

CONCLUSION

Endovascular brachytherapy is currently being performed with high energy gamma or beta emitters. The ideal source would have a high specific activity, long half-life, uniform dose over treatment distances of at least 2 to 3 mm, and low cost. 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 endovascular irradiation since beta radiation range is short avoiding unnecessary radiation to normal tissue. It was feasible to deliver intravascular irradiation to prevent restenosis after PTCA using Ho-166 solution in animal model as well as human subjects.

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