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Investigation of Medical Neutron Radiation Doses Using Two types of bubble Detectors

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Abstract—This study measured the amount of pollution of fast and slow neutrons generated from a Elekta Synergy linear accelerator, using various photons and electrons and two bubble detectors, BDT and BD-PND. The BDT bubble detector is preferentially sensitive to thermal neutrons. The BD-PND is the recommended detector for personal neutron dosimetry.First, 10-MV photon radiation fields of 40×40 cm^2, 30×30 cm^2, 20×20 cm^2, 10×10 cm^2, 5×5 cm^2, and 0.4×0.4 cm^2 were measured electron energies of 6, 9, 12, 15, and 18 MeV, irradiated by 10 cm^2 electronic-cone, to probe for the equivalent dose of fast neutrons and thermal neutrons in the center during quality examination. After measuring the equivalent dose of fast and slow neutrons, the equivalent dose of neutrons changed depending on the irradiated field and energy in 10-MV photon. The equivalent doses at 40×40 cm^2 and 0.4×0.4 cm^2 were 1125 ± 34 and 390 ± 20 μSv per Gy X-ray, respectively. Using 12, 15, and 18 MeV electrons, the equivalent doses were 2.2 ± 1.5, 9.9 ± 3.2 and 19.8 ± 4.5 μSv per Gy-electron, respectively. When electron energy was below 9 MeV, the amount of neutron pollution was lower than its detection limit.Neutron equivalent doses decreased as the irradiated field became smaller, and increased as the electron energy increased. The result of this study can be regarded as a reference for estimating neutron pollution for dose quality assurance.

Index Terms—**neutron equivalent dose, bubble detectors, quality assurance**

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1 INTRODUCTION

In the process of producing high-energy X-radiation and electron radiation, medical linear accelerators (Medical LINACs) produce neutrons because of the interactions of (γ,n), (γ,pn), (γ,xn), and (e,n) with target and beam conditioners, such as collimators.Focusing on the crucial organs near the treatment sites, such as the eyeballs and crystalline lenses during nasopharyngeal cancer treatment and the gonads during prostate cancer treatment, the neutron dosage caused could have considerable ramifications in health physics[1].

Excessive amounts of photons are the major cause of difficulty in measuring the secondary neutrons using medical LINAC. The presence of a neutron is typically accompanied by

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thousands of photons. Removing the interference caused by photons is difficult [2].

Passive approaches have been used for measuring secondary neutrons. Several measurement methods, such as thermoluminescence dosimeters (TLD) [3], activation analysis, and particle size track etching, have been frequently used [4].

Bubble detectors can directly obtain neutron equivalent dose. They are suitable for measuring contamination of neutrons in medical hospital l[5][6].

In this study, BD-PND and BDT bubble detectors were used to measure the neutron equivalent dose as function of beam size of photons and electron energy at Elekta Medical LINACs (Synergy). This paper will present the results of measurements.

2. Materials and methods

The neutron equivalent doses of fast and slow neutrons were measured using BD-PND and BDT bubble detectors (Bubble Technology Industries, Chalk River, ON, Canada) (see Figure 1). The bubble detector comprises 10^4–10^5 superheated droplets distributed evenly within 8-cm^3 elastic solid polymer. The average diameter of the superheated droplets is about 20μm.[7] When a neutron hits on a superheated droplet, the recoil nucleus or charged reaction product produced by neutrons may cause evaporation of the droplet, forming a bubble at the site of the droplet. The number of bubbles is proportional to the number of neutrons and is related to the energy of neutrons [8].

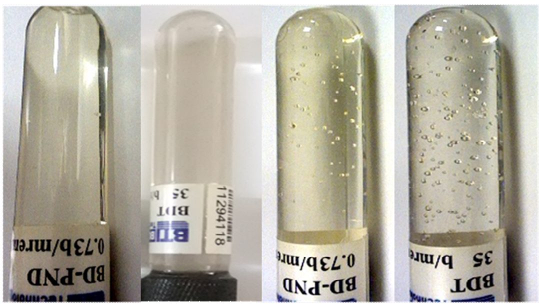
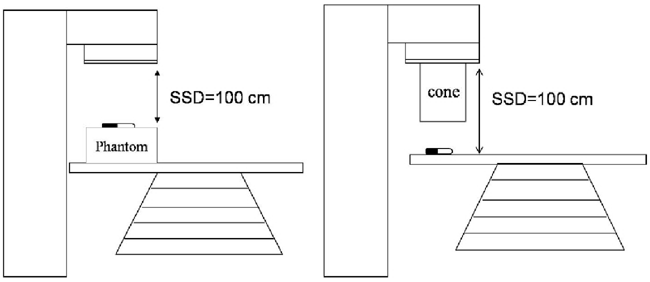

(a) (b)

Figure1. Photographs of BD-PND and BDT bubble detector used in our study before (a) and after (b) exposure to the LINAC.

The same types of bubble detector as used in this measurement had been calibrated by using standard ^{252}Cf neutron sources, which had a neutron energy spectrum similar to that at the medical accelerator [9].

The sensitivity of the BD-PND bubble detector which we used is 0.073b/μSv and that of the BDT bubble detector is 3.5b/μSv. The BDT and BD-PND bubble detectors were deployed at the position where the dose was rectified. The measurements were performed with 6-MV and 10-MV photons distributed in radiation fields of 40×40 cm^2, 30×30 cm^2, 20×20 cm^2, 10×10 cm^2, 5×5 cm^2, and 0.4×0.4 cm^2, and electron energies of 6, 9, 12, 15, and 18 MeV, and 10-cm^2 electronic-cone illumination. Three times of measurements were carried out in the study.



(a) (b)

Figure 2. Layout of bubble detector to measure neutron equivalent dose of photon beam (a) and electron beam (b).

To maintain consistency in the bubble detectors, more than 20 bubbles were used in each illuminating dose and more than 1 h was used as an interval for each measurement. After being illuminated, the bubble detectors were set aside for approximately 10 min until the bubbles appeared on them. Two observers counted the bubbles using white slide viewers.

Both bubble detectors were deployed in the center under various energy and radiation field conditions. The distribution of the neutron equivalent dose in the radiation fields were measured under the conditions in which the distance between the beam and bubble detectors was 100 cm and the dose rate was 400 MU/min. Figure 2 shows the setup of the bubble detectors and the photon and electron beams. Three observers counted the bubbles as mentioned above to avoid errors.

3. Results and discussion

Figures 3 and 4 show the results for the measurements of a 10-MV photon radiation fields of 40×40 cm^2, 30×30 cm^2, 20×20 cm^2, 10×10 cm^2, 5×5 cm^2, and 0.4×0.4 cm^2, by using the BDT and BD-PND bubble detectors. The equivalent doses of fast neutrons became lower as the radiation fields became smaller. This decrease was much more drastic in the equivalent dose of a 0.4×0.4-cm^2 fast neutron. The neutron's direction was determined by bubble detectors. It showed that the neutrons were generated from the accelerator and the control apparatus. Scattering neutrons from the treatment tables just take a few percent of neutron dose.

No dosage of fast neutrons was detected using the 6-MV photon beams. Using 10-MV irradiation, the equivalent dose of fast neutrons in the center of the 40×40-cm^2 radiation field was about three times higher than that of the 0.4×0.4-cm^2 radiation field (see Figure 3). The equivalent doses were respectively 1125 ± 34 and 390 ± 20 μSv per Gy X-ray. The equivalent doses of thermal neutrons in the center of 40×40 cm^2 and 0.4×0.4-cm^2 radiation fields were 54.9 ± 7.4 and 31 ± 5.6 μSv per Gy X-ray, respectively (see Figure 4) . The latter was about two times lower than that of the former.

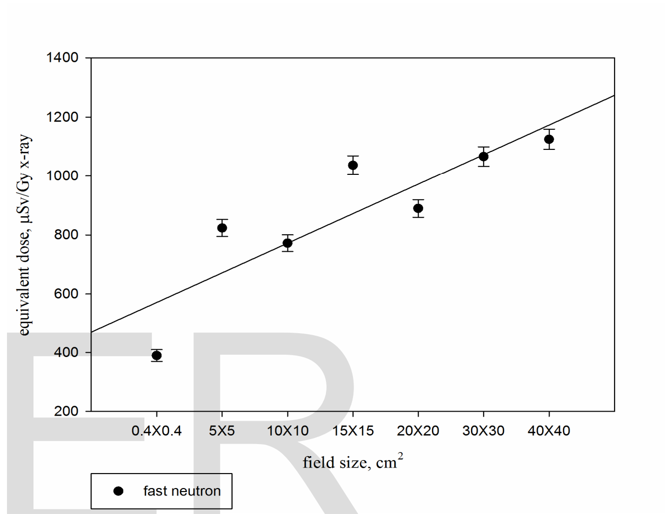


Figure3. Fast neutron equivalent dose of different radiation field size at 10MV photon beams and the distance from source to surface (SSD) 100cm.

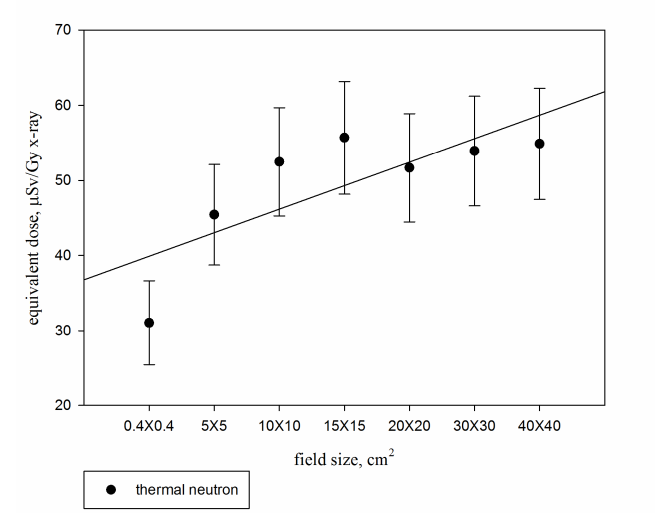


Figure 4.Thermal neutron equivalent dose of different radiation field size at 10MV photon beams and source to surface (SSD) 100cm.

Figures 5 and 6 show the equivalent dose of the fast and thermal neutrons respectively generated by 6-, 9-, 12-, 15-, and 18-MeV electrons. The electron beam produces neutrons primarily from the high bremsstrahlung (γ,xn) reaction that is generated from electrons as well as the beam conditioner and collimators, and partially results from the (e,xn) reaction.

Generally, higher electron energy causes substantial secondary neutrons. In 6-MeV and 9-MeV electrons, no fast neutrons were detected (see Figure 5). In 12-, 15-, and 18-MeV electrons, the equivalent dose of fast neutrons in the center were 2.2 ± 1.5, 9.9 ± 3.2, and 19.8 ± 4.5 μSv per Gy-electron.

Comparably, low thermal neutrons were detected in the 6-MV electrons. The equivalent dose of thermal neutrons in the center generated from 9-, 12-, 15-, and 18-MeV electrons were 1133 ± 34, 2265 ± 48, 2560 ± 51, and 2677 ± 52 μSv per Gy-electron, respectively.

When electron energy was below 9 MeV, the bubble detectors could not detect any fast neutron pollution. Even when the irradiated electron dose was larger than 1Gy, no bubbles were observed. The secondary neutrons were lower than its detection limit.

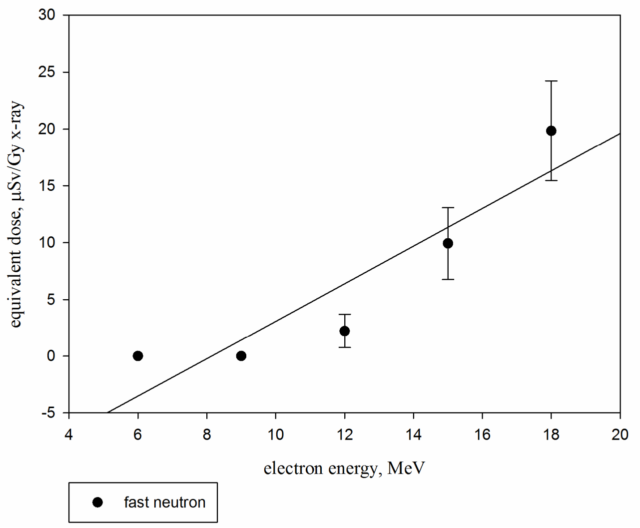


Figure5. Fast neutron equivalent dose of different electron energy at 10x10 radiation field and source to surface (SSD) 100cm.

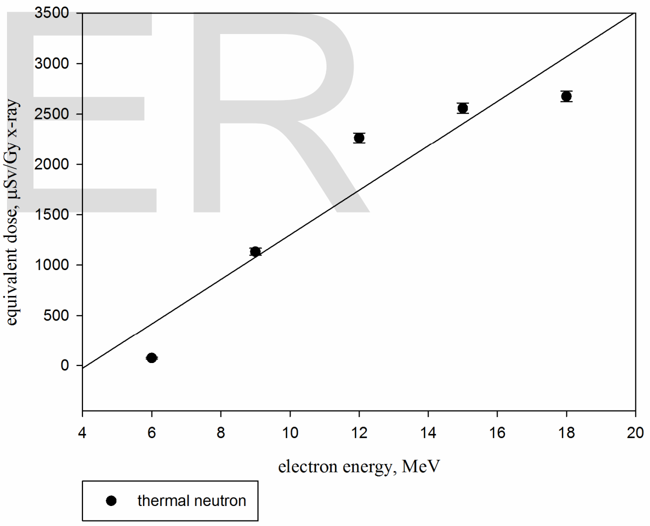


Figure 6.Thermal neutron equivalent dose of different electron energy at 10x10 radiation field and source to surface (SSD) 100cm.

4. Conclusion

The convenience, accuracy, and stability of bubble detectors enable appropriate measurement of the secondary neutrons by using a Medical LINAC. Bubble detectors rarely responded to high-energy photons, which prevented neutron dose disturbance during measurement.

This study used several conditions: Measuring 10-MV photons by using BD-PND and BDT bubble detectors (Bubble Technology Industries, Chalk River, ON, Canada), radiation fields ranging from 40×40 to 0.4×0.4 cm^2, and 9-, 12-, 15-, and 18-MeV electrons for which the electronic-cone was 10 cm^2. The results indicated that the equivalent dose of fast neutrons located in the center decreased as the radiation field decreased in size. The equivalent doses of thermal neutrons changed to a small degree depending on the radiation field size.

Regarding the 10-MV photon, the energy of fast neutrons in the center of the 0.4×0.4 cm^2 radiation field was reduced by the collimator shield. Its equivalent dose reduced to one-third of the neutron equivalent dose in the center of the 40×40 cm^2 radiation field. The results of this study are useful as reference data in the future for contrasting the pollution of neutrons in the process of assuring the quality of doses.

References

[1] River, J.C., Falca, R.C., de Almeida, C.E., 2008. The measurement of photoneutron dose in the vicinity of clinical linear accelerators..Radiat. Prot Dosim. 130(4), 403-409.

[2] Awotwi-Pratt, J.B., Spyrou, N.M., 2007. Measurement of photoneutrons in the output of 15 MV Varian Clinac 2100C LINAC using bubble detectors. Journal of Radioanalytical and Nuclear Chemistry 271, 679-684.

[3] Hsu, F.Y., Chang, Y.L., Liu., M.T., Huang, S.S., Yu, C.C., 2010. Dose estimation of the photoneutrons induced by the high energy medical linear accelerator using dual-TLD chips. Radiat. Meas. 45, 739-741.

[4]Attix, F.H., 1986. Introduction to radiological physics and radiation dosimetry. Wiley, New York, pp. 415-416.

[5] Vanhavere, F., Huyskens, D., Struelens, L., 2004. Peripheral neutron and gamma doses in radiotherapy with an 18 MV linear accelerator. Radiat Prot Dosim 110, 607-612.

[6]Ing, H., Noulty, R.A., Mclean, T.D., 1997. Bubble detectors - a maturing technology..Radiat. Meas. 27, 1-11.

[7]Lin, J.P., Liu, W.C., Lin, C.C., 2007. Investigation of photoneutron dose equivalent from high-energy photons in radiotherapy. Appl. Radiat. Isotopes 65, 599-604.

[8] Vanhavere, F., Loos, M., Plompen, A.J.M., Wattecamps, E., Thierens, H., 1998. A combined use of the BD-PND and BDT bubble detectors in neutron dosimetry. Radiat Meas 29, 573-577.

[9]NCRP, 1984. Neutron contamination from medical accelerators. Publication 79.