

The effect of external wedge on the photoneutron dose equivalent at a high energy medical linac

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Abstract. Medical linacs used in radiotherapy produce bremsstrahlung spectra. In the energy range from 8 to 25 MV medical linacs produce, besides the clinically useful electron and photon beams, secondary neutrons. The aim of this study was to investigate the effect of an external wedge filter on the photoneutron dose equivalent produced by a medical linac at patient plane. Polycarbonate (PC) films were used for the determination of photoneutron dose equivalent produced by a Varian 2100 C/D linac working at 18 MV photon mode. Neutron dose equivalent was measured at distances 0, 10, 20 and 50 cm from the center of the X-ray beam for open field and after inserting a wedge filter. It was noted that by inserting the external wedge in the path of the X-ray beam, the photoneutron dose equivalent was increased compared to open field. It can be concluded that an external wedge, made from heavy materials may act like the other components of linac head, producing undesired photoneutrons and thus increasing patient dose.

Key words: photoneutron • linac • polycarbonate (PC) • external wedge • radiotherapy

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Introduction

Neutron production in radiotherapy facilities has been studied from the early days of linacs. High energy linacs have several advantages including lower skin dose and higher dose rate at deep sighted tumors. Photons with the energies higher than 8–10 MV can produce neutrons through photonuclear giant dipole resonance reactions [9]. After the collision of high energy photons with the main components of linac's head including the primary collimator, flattening filter and secondary collimators, they act as the sources of photoneutrons [9]. The average energies of neutrons produced in the X-ray target and the beam flattening filter are close to those of fission neutrons [9]. In addition, the shielding around the accelerator head cannot reduce photoneutrons [9]. According to ICRP Report no. 60, the radiation weighting factor (W_R) for neutron are quite large [8] and would expect a quite significant dose equivalent in patients. Therefore, to optimize the treatment conditions, it is important to take into account the photoneutron contamination [10].

PC films have been used frequently to determine neutron contamination in treatment rooms of high energy linacs. They are not sensitive to photons, but they are sensitive to neutrons of 500 keV energy and higher [4]. So, they are appropriate to be used as neutron detectors in the presence of high intensity photon fields.

An investigation on a Saturne 20 linac, using PC sheets through electrochemical etching (ECE), has reported a value about 3.3 mSv/Gy as the dose equivalent in the center of the 40 × 40 cm^2 field size of that linac [11]. In an other study, the effect of automatic internal wedge filter on the photoneutron dose equivalent has been carefully investigated using ECE, the results indicate a significant increase in photoneutron dose equivalent due to using wedge filter [5]. Some measurements with bubble detectors using high energy linear accelerators have shown about 4.5 mSv/Gy photoneutron dose equivalent in the water phantom. In these measurements the detectors are chosen in such a way that the photoneutron spectrum is covered completely [1]. In a work the neutron source strength was investigated around the Elekta, Varian and General Electric linacs [2]. It should be expected that patients treated with high energy linacs might show a higher incidence of second malignancies [3]. In a number of treatment protocols at radiotherapy the use of wedge filters is essential, but there seems to be a lack of studies about the effect of external wedge on photoneutrons. In this work, using PC films, we study the effect of external wedge on the dose equivalent of fast photoneutrons produced by a high energy medical linac at patient plane.

Methods and materials

In this investigation a Varian 2100 C/D linear accelerator working at high energy (18 MV) was studied. SSD was set to 100 cm and the open field size of 20 × 20 cm^2 was applied. The measurement of fast photoneutrons were performed with PC films of 0.25 mm thickness. Detectors placed at distances of 0, 10, 20 and 50 cm from the central axis of X-ray field on the couch (Fig. 1). The amount of radiation was set to be 300 MU, equal to X-ray dose of 3 Gy in standard conditions [6]. Then, external wedge, 45° and 20 × 40 cm^2 (W_R = 0.53) was inserted in the X-ray field and irradiation repeated. ECE of the PC films was conducted in the Ionizing Radiation Dosimetry Department of the Iranian Organization of Atomic Energy, using a routine standard protocol developed and used there [12]. The PC film dosimeters were calibrated to fission neutrons from a ^{252}Cf neutron source. To convert neutron fluence to dose equivalent, H_P (10) factor [7] was used. Accounting S_{cp} of 20 × 20 cm^2 field size, which was equal to 1.0765, in calculating dose equivalent the results should be divided by S_{cp}. Finally, after inserting wedge filter in X-ray beam, in order to obtain dose equivalent of neutrons at patient plane, it is required to divide this parameter by a wedge factor, 0.53. So, photoneutron dose equivalents were normalized to 1 Gy X-ray. The results were analyzed using the Mann-Whitney statistical test.

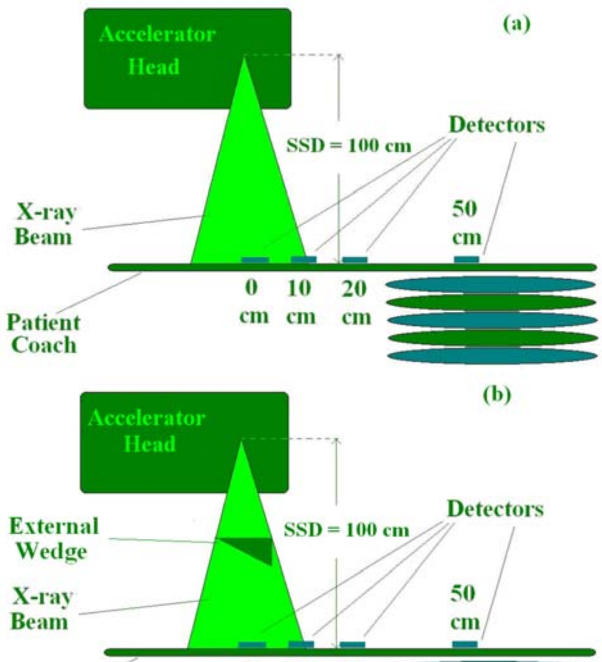

Fig. 1. Schematic view of irradiating polycarbonate films. a – open field; b – wedge field.

Results

Results of measurement have been shown in Figs. 2 and 3 and Tables 1 and 2. In general, this study shows that in the open field, the dose equivalent of photoneutrons at the center of the open X-ray field is about 3.3 mSv/Gy X-ray and decrease to 1.9 mSv/Gy X-ray at the distance of 50 cm. The results also show that in the presence of the external wedge, the dose equivalent to photoneutrons at the center of the X-ray field is about 3.8 mSv/100 MU X-rays, but decreases with distance and gradually reaches 3.2 mSv/100 MU X-ray at the distance of 50 cm from the center of X-ray field. After dividing dose equivalent by wedge factor, results show that in the presence of the

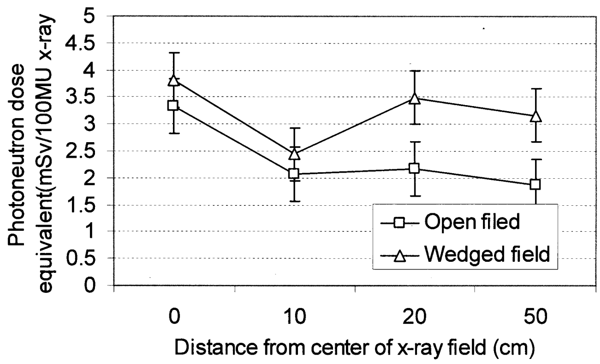

Fig. 2. Photoneutron dose equivalent at the patient plane for the Varian 2100 C/D (18 MV) for the open and wedged X-ray fields.

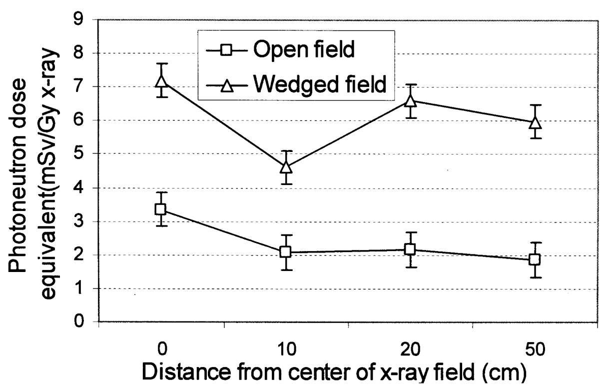

Fig. 3. Photoneutron dose equivalent at the patient plane for the Varian 2100 C/D (18 MV) at the open and wedged X-ray fields. (To obtain photoneutron dose at wedged field, it is divided by the W_R, 0.53).

Table 1. Photoneutron dose equivalent (mSv/100 MU X-ray) ± uncertainty, at four points on the patient couch for 18 MV photon beam (SSD = 100 cm) of the Varian 2100 C/D linac

Distance (cm)	Field	
	Open	Wedged
0	3.3 ± 0.5	3.8 ± 0.5
10	2.1 ± 0.5	2.4 ± 0.5
20	2.2 ± 0.5	3.5 ± 0.5
50	1.9 ± 0.5	3.2 ± 0.5

Table 2. Photoneutron dose equivalent (mSv/Gy X-ray) ± uncertainty, at four points on the patient couch for 18 MV photon beam (SSD = 100 cm) of the Varian 2100 C/D linac. (To obtain photoneutron dose at wedged field, it is divided by the W_R, 0.53)

Distance (cm)	Field	
	Open	Wedged
0	3.3 ± 0.5	7.2 ± 0.5
10	2.1 ± 0.5	4.6 ± 0.5
20	2.2 ± 0.5	6.6 ± 0.5
50	1.9 ± 0.5	6.0 ± 0.5

external wedge, the dose equivalent of photoneutrons at the center of the X-ray field is about 7.2 mSv/Gy X-ray, but decreases with distance and gradually reaches 6.0 mSv/Gy X-ray at a distance of 50 cm from the center of X-ray field. The uncertainty of the reported measurement values for each single point is 0.5 mSv as shown in Tables 1 and 2.

Conclusion

Undesired neutrons produced by the components of a medical linac head may induce secondary malignancies [3]. Using a wedge in most of treatment protocols is convenient. In this study the effect of an external wedge on photoneutron dose equivalent produced by a Varian 2100 C/D linac was investigated. Although, some amount of X-ray (300 MU) is produced by the linac in both wedged and open fields, it can be seen that using the wedge filter causes a considerable increase in photoneutron dose equivalent specially at points far from the center of X-ray field (Table 1 and Fig. 2). Using the Mann-Whitney statistical test, it was shown that the difference of the dose equivalent due to the photoneutrons, for the open and wedged fields, is statistically meaningful ($p < 0.05$). This means that an external wedge, which is made from heavy elements, when inserted in X-ray beam, like other heavy structures of linac head, acts as a photoneutron source. Additionally, using the wedge filter reduces the X-ray dose prescribed by physician. So, it is convenient to divide the X-ray dose by the "wedge factor" to compensate absorbing effect of the wedge filter and restore the prescribed dose. So, due to the increase of X-ray monitor units, the dose equivalent of photoneutrons increases compared with that of the open field (Table 2 and Fig. 3). Since the W_R, of fast neutrons is high, so it is predictable that the absorbed dose by a patient can be increased when using wedge filters. In developing countries in which a number of patients are under treatment by high energy linacs, it seems important to consider photoneutron dose received by patients.

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