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Determination of room entry times for radiation therapists after routine 15 MV photon treatments

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► ***Short report***

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ABSTRACT

Background: Radiation therapy uses high-energy radiation to kill cancer cells. Photoneutron contamination and induced radioactivity of high energy therapeutic photon beams are considered as the main source of occupational exposure to radiation therapists who works with linear accelerators operating above 10 MV. ***Materials and Methods:*** The gamma dose rates were measured after termination of different treatment approaches using 15 MV photons and room entry times for each approach was determined. Based on the results of this study, the annual dose of radiation therapists was estimated. ***Results:*** The highest dose rate that measured in the treatment room was belonged to 3-field pelvic approach which was equal to 5 ± 1.1 μSv/h. The radiation therapist's room entry times were determined between 3 to 10 minutes and the annual dose was estimated up to 5.9 mSv/y. ***Conclusion:*** Although the estimated annual dose is less than the internationally permitted value, the undesirable dose to radiation workers could be reduced through considering recommended room entry times.

Keywords: *Linear accelerator, high energy photons, radiation therapists, room entry times.*

INTRODUCTION

High energy photons from medical linear accelerators (LINACs) have several advantages comparing to low energy photons and they are routinely used for treatment of deep-seated tumors (1). Medical accelerators generate photon beams in the energy range of 4 to 25 MV. Neutrons production occurs using photons at energies over than 10 MV (2). The interaction of photons with accelerator head components (target, collimation system and other high atomic number elements which used in accelerator head), treatment room, and patient can produce neutrons and cause photoneutron contamination of the treatment room and the maze (3-5). Despite all high energy photon treatment advantages, the photoneutron production increases the undesired dose to patients as well as radiation therapists.

About 54% of the annual effective dose to personnel is due to the radioactivity induced by neutron interaction which remained and accumulated in the treatment room, and can be detected several days after the last exposures (2, 3, 5). Therefore, it can be considered as the main cause of occupational exposure to radiation workers who are involved with high-energy LINACs.

The aims of the present study were:

1) Dose rate evaluation in the treatment room, maze and operating console after termination of the 15 MV exposures for different techniques that are used in trunk and pelvic treatments.
2) Estimation of radiation therapist's annual dose due to the induced radioactivity, and
3) Determination of room entry times for radiation therapists after each treatment approach.

MATERIALS AND METHODS

The study was carried out in a governmental oncology department in Tehran. The Siemens Primus LINAC which has been used in this study can provide 6 and 15 MV photon energies and six electron energies in the range of 5 to 14 MeV.

Seven treatment approaches which are often used in pelvic and trunk tumors were examined (table 1). A trunk tissue-equivalent phantom with a separation of 25 cm was used for measurements of the stomach, esophagus, and vertebra fields and a pelvic tissue-equivalent phantom with a separation of 24 cm was used for measurements of pelvic approaches. ISO gray (version 4.1) treatment planning system was used for simulating treatment conditions and total monitor ranging from 184 to 337 were calculated in these treatment techniques. Also, there was a 30 degree external wedge in three-field pelvic approach.

A GRAETZ X5C plus dose-rate meter was used for measurement of dose rates that were produced by gamma and X-rays after termination of 15 MV exposures. It is suitable for photon energies in the range of 40 KeV to 1.3 MeV and dose rates in the range of 0 nSv/h to 20 μSv/h. Measurements were performed at three locations: Location A: inside the treatment room close to the accelerator, 70 cm right lateral and 100 cm posterior to isocenter in a height of 100 cm from the floor, Location B: in the center of the maze and 100 cm above the floor, and Location C: in the operating console. It should be noted that radiation therapists are usually in location A for patient set up and in location C during beam-on times [3, 6].

Table 1. The average maximum and minimum dose rates ± standard deviation of treatment room and room entry times for different approaches.

Treatment Approach	Dose-Rates at Location A (μSv/h)		Room Entry Time (min)
	Max	Min	
PA of Vertebra	4.1 ± 0.7	0.5 ± 0.1	**10**
3-field of Pelvic	5 ± 1.1	0.5 ± 0.1	**6**
AP-PA of Stomach	2.3 ± 0.3	0.5 ± 0.05	**3**
AP-PA of Esophagus	2.4 ± 0.4	0.5 ± 0.1	**4**
4-field of Pelvic	2.1 ± 0.4	0.4 ± 0.1	**3**
AP-PA of Pelvic	2.2 ± 0.6	0.5 ± 0.1	**3**
5-field of Pelvic	1.9 ± 0.3	0.4 ± 0.1	**3**

The dose rates in locations A and B were measured at intervals of 10 seconds in the first 15 minutes after termination of the exposures, but all measurements for location C were performed during the exposure. Measurements were repeated five times for each approach with considering 10 minutes delay time between the measurements. The delay time allows the long-lived radioisotopes to decay and reduces the influence of previous exposures [2, 3].

In this study, the following model is used for estimation of radiation therapist's annual dose due to each approach:

$$\mathbf{D = a \times b}$$

It is considered that the radiation therapist spends 5 minutes for patient set up. The "D" is radiation therapist's annual dose due to each approach, "a" represents how many times each approach was used during one year, and "b" is the sum of the all equivalent doses that have been received by a radiation therapist in 5 min during the patient set up. With this model the total annual dose to a radiation therapist will be integrated doses due to all treatment approaches.

RESULTS AND DISCUSSION

The average background dose rate was 150 nSv/h. The relationship between dose rate and time after the beam-off was evaluated for all treatment approaches, and the results are shown in figures 1 and 2. After termination of exposures, the dose rate in location A decreased as time passed, but radioactivity remained measurable even 15 minutes after the beam-off and it was about 0.5 μSv/h. The maximum and minimum dose rates for each approach at the location A, and recommended room entry times are shown in table 1. According to table 1, the highest dose rate is recorded for 3-field Pelvic approach at location A and it was equal to 5 ± 1.1 μSv/h. For the PA- vertebra approach maximum dose rate was 4.1 ± 0.7 μSv/h and in other approaches it was about 2 μSv/h after finishing the exposure.

The maximum dose rate at the maze (location

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B) was recorded for 3-field Pelvic approach which was equal to 1 ± 0.2 μSv/h. For other approaches the maze radiation level was not significant. The radiation level at the operating console (location C) didn't change during the exposures and it was near to the background level for all treatment techniques.

In this study, the moment that the dose rate reduced less than 1 μSv/h is considered as the recommended room entry time for all approaches (table 1). The maximum and minimum room entry times were obtained 10 and 3 minutes, respectively. The maximum is related to PA-Vertebra approach. With this entry times the maximum patient treatment time would be 17 min for 3-field pelvic approach.

Table 2 shows the relation between radiation therapist's annual doses with different delay entry times. According to our results, the highest annual dose was equal to 5.9 mSv which was obtained in a position when radiotherapist immediately entered the room after high energy treatments. As can be seen, the annual doses decreased with increasing delay times.

In a similar study, Lavine Ho *et al.* [3], showed that optimum entry times ranged from 7 to 11 minutes in three pelvic approaches. In their study, AP-PA opposing and 3-field techniques were studied by an Elekta Precise accelerator that was operating up to 18 MV, and the highest dose rate inside the treatment room was reported for 3-field technique (about 7 μSv/h) and the highest annual dose of radiation therapist was obtained in immediately entering the room after 18 MV opposed technique which was equal to 4.9 mSv. Both studies indicated the highest dose rate after the beam-off is belonged to 3-field pelvic approach.

The estimation of radiation therapist's annual dose was based on the number of patients who were treated during one year. The radioactivity of maze and operating console were considered zero. Under those assumptions, the maximum annual dose was calculated equal to 5.9 mSv.

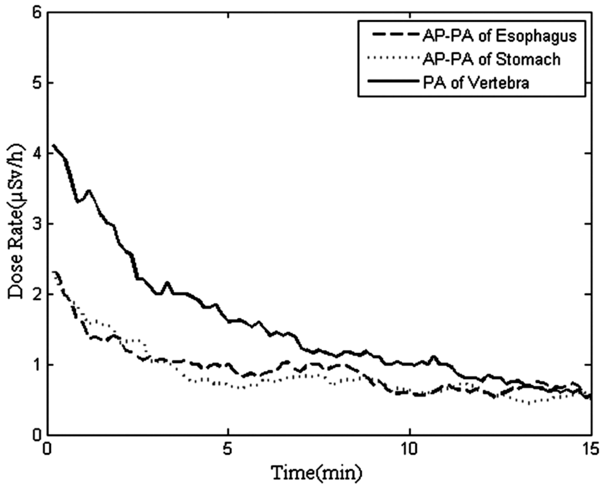

Figure 1. Dose rate versus time after the beam-off for trunk approaches.

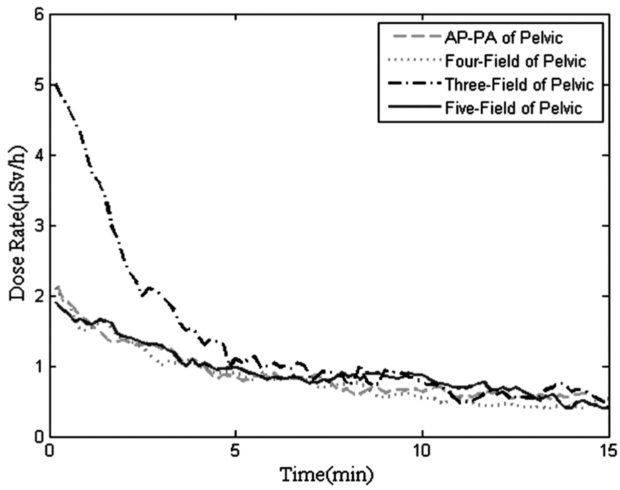

Figure 2. Dose rate versus time after the beam-off for pelvic approaches.

Table 2. Annual dose of a radiation therapist and total patient's treatment times.

Delay Entry Time (min)	Total patient treatment time in each fraction (min)							Worker's Annual Dose (mSv/y)
	Trunk			Pelvic				
	Vertebra	Esophagus	Stomach	2-field	3-field	4-field	5-field	
0.16	7	8	8.5	8	10	10	10.5	**5.9**
2	9	10	10.5	10	12	12	12.5	**4.1**
6	13	14	14.5	14	16	16	16.5	**2.8**
10	17	18	18.5	18	20	20	20.5	**2**
14	21	22	22.5	22	24	24	24.5	**0.3**

This value approximately agreed with previous studies that estimated radiation therapist's annual dose which were reported between 1- 5 mSv [3, 6-8]. By applying recommended delay times that were obtained from this study, the dose of a radiation therapist will be decreased to 2.4 mSv per year and the workload of the department will be 4.4 patients/hour. Therefore, the recommended times gave reasonable department's workload as well as a 60% reduction in dose to radiation therapists.

Conflicts of interest: *none to declare.*

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