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Measurement of Radiation Dose Emitted by 4 × 4 cm² and 10 × 10 cm² Aperture of Linear Accelerator[1]

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Abstract − The amount of the beam emitted from a linear accelerator's head can be adjusted by changing the jaw intervals of multi-leaf collimator (MLC) system. One of the parameters that are effective in delivering the prescribed dose to the patient is also the gantry angle. In this study, the jaw intervals of the linear accelerator in the Oncology Unit of the Tokat Gaziosmanpaşa University Faculty of Medicine have been determined as 4×4 cm^2 and 10×10 cm^2. The radiation dose emitted for both conditions has measured for 6 MV and 15 MV photon beams at different gantry angles. The measurements are taken at gantry angles of 0^o, 90^o, 180^o, and 270^o. The highest dose rate value is obtained in 10×10 cm^2 jaw interval for 15 MV photon energy at 0^o gantry angle. Then, the percentages of change between dose rate values measured at different portal angles are calculated. The obtained results are evaluated, considering other studies in the literature.

Keywords − *Linear accelerators, Gantry angles, Jaw intervals, Radiation dose*

1. Introduction

Various types of cancer rank second among the causes of death worldwide. For this reason, ways to deal with the disease are being explored. Today, methods of dealing with cancer develop over time. Radiotherapy, which plays a very important role in cancer treatment, is one of the comprehensive and fastest developing treatment methods. In radiotherapy, kilovoltage x-ray beams are useful in the treatment of skin lesions and shallow tumours. At the same time, they are not sufficient for tumours with deep localisation and are limited to high skin dose. Megavoltage beams not only more penetrating but is also of great benefit in delivering the maximum dose below the skin surface. In this context, one of the most advanced methods used to destroy cancer tissue is linear accelerators [1].

The principal radiation method for the treatment of deeply located tumours is x-rays of very high energy with penetrating power. In this regard, radiotherapy is applied through a radioactive source, typically Cobalt-60, or x-rays produced by stopping the electron beam with a tungsten target in a linear accelerator where electrons are accelerated. Alternatively, the electrons themselves may be used directly to treat more

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superficial cancers. Electron linear accelerator (linac) that accelerates charged particles in a straight line instead of circular or race track orbits such as cyclotron and synchrotron is mounted in a gantry that rotates on a stand containing electronic and other systems. For use in treatment, the linac can be rotated into position about the horizontal gantry axis, and the radiation beam emerging from the collimator is always directed through and centred on the gantry axis. The point where the centre of the beam intersects with the gantry axis in the space is called isocenter. The couch, which includes three linear movements along the isocenter and rotation around one or more axes, is centred such that the patient's tumour is at the isocenter. In the isocentric system, precise and reproducible treatment is provided by using multiple fields directed at the tumour from different gantry angles [2]. The beam spot displacement, collimator asymmetry, and movement of the collimator or slide rotation axis, which may cause misalignment of the x-ray beam, have been investigated by developing a test method [3] sensitive to these problems. Also, detailed information on developments in accelerator structures, variable energy connections, microtrons, beam transport systems and head design were examined, and numerical data related to them were evaluated [4]. Irradiation of healthy tissue with irradiation in the radiotherapy technique is an important limitation of radiotherapy treatment. Many organs that are sensitive to radiation damage (the spinal cord, salivary glands, lungs, and the eyes are common examples) should be especially considered during radiotherapy treatment planning. Advances in technology have led to design modifications in the collimating systems of modern accelerators.

In particular, MLCs are consisting of tungsten alloy leaves that can change shape and move independently according to almost any lesion and organ [5]. In a dynamic multi-leaf collimation system, the leaves are continuously in motion. At the same time, the beam is on to deliver optimum dose distributions which result in greater dose uniformity in the target and lower doses in the surrounding critical organs [6]. With this feature of the collimator system, healthy tissues are protected much better. Jaw intervals of collimators are determined according to the treatment plan. Jaws can be adjusted from 4×4 cm^2 to 40×40 cm^2. Previous studies have shown that effective doses can be given to the tumour with correct leaf positions [7, 8]. Thus, the correct dosage is given to the right volume. At the same time, it is protected by collimation in healthy tissue.

Radiation therapy aims to deliver the maximum dose to the tumour region while protecting the surrounding healthy tissues. To achieve this, various planning techniques have been carried out. In deeply located lesions, 4-6- and 15 MV x-rays, in superficial settlements, electrons with energies of 4-6-9-12-15 and 18 MeV are sufficient for all clinical applications [9]. In linear accelerators, to not to harm the healthy tissue while destroying the cancerous tissue, the treatment plan that contains the leaf positions for all control points (gantry angles) has been developed by changed the photon flux with the return of gantry [10].

Gantry angle is a very important parameter that is effective in dose reconstruction for precise and specific treatment. A simple measurement method and algorithm has been developed to calibrate the portal angle of a linear accelerator and test the reliability of portal angle measurements to prevent healthy tissue exposure to excessive radiation [11, 12]. To realise the mechanical quality assurance of linear accelerators, it is important to determine the actual zero degrees of the gantry angle [13]. The purpose of this work is to measure the scattered dose rate values at different gantry angles, to evaluate the changes between the measured the dose rates and is to determine the highest dose rate value in terms of radiation safety.

2. Materials and methods

In this work, the measurements have been performed using FLUKE Victoreen ASM 990 portable detector at the Nuclear Medicine Department, Medicine Faculty in Tokat Gaziosmanpaşa University. The ASM-990 series are designed to be detected alpha, beta, gamma, neutron, or x-ray radiation within a range of 1 μR/h to 1 R/h, depending on the selected probe, such as Geiger-Muller, neutron, proportional counter, scintillation. These detectors are used as a general survey meter with the proper probe combination [14]. The count rates and the dose rates are generally established through empirical calibration procedures. In this study, beam profile measurements were performed for 6 MV and 15 MV photon beams using the 4×4 cm^2 - 10×10

cm^2 field size applicators. Measurements were made at gantry angles of 0°, 90°, 180°, and 270°. The detector is located in the space between the surprising corridor and the front door in the section where the linear accelerator is located. The measurements were taken as cps (count per second), and the obtained values were converted to μSv/h. Here, the count rate is taken as about five cps per μSv/h [15]. By taking into account the measured time interval, the calculated values were converted to mSv/y.

3. Results

The dose rates values obtained according to the gantry angles varying in different jaw intervals for two different photon beams energies values are presented in Table 1.

Table 1. Dose rates values (mSv/y) according to gantry angle and jaw intervals for 6 MV and15 MV photon beams

	Dose rates for different gantry angels with 4 × 4 cm^2 and 10 × 10 cm^2 jaw intervals at 6 MV photon beam		Dose rates for different gantry angels with 4 × 4 cm^2 and 10 × 10 cm^2 jaw intervals at 15 MV photon beam	
Gantry Angle	**4 × 4 cm^2**	**10 × 10 cm^2**	**4 × 4 cm^2**	**10 × 10 cm^2**
0°	2.86	4.20	29.7	33.2
90°	1.88	2.43	13.2	16.6
180°	1.95	2.72	11.2	16.5
270°	1.14	2.03	17.7	23.8

The graphic representations of dose rates measured for 6 MV and 15 MV photon beams according to changing gantry angles, in 4 × 4 cm^2 and 10 × 10 cm^2 jaw intervals are given in Figure 1 and Figure 2, respectively.

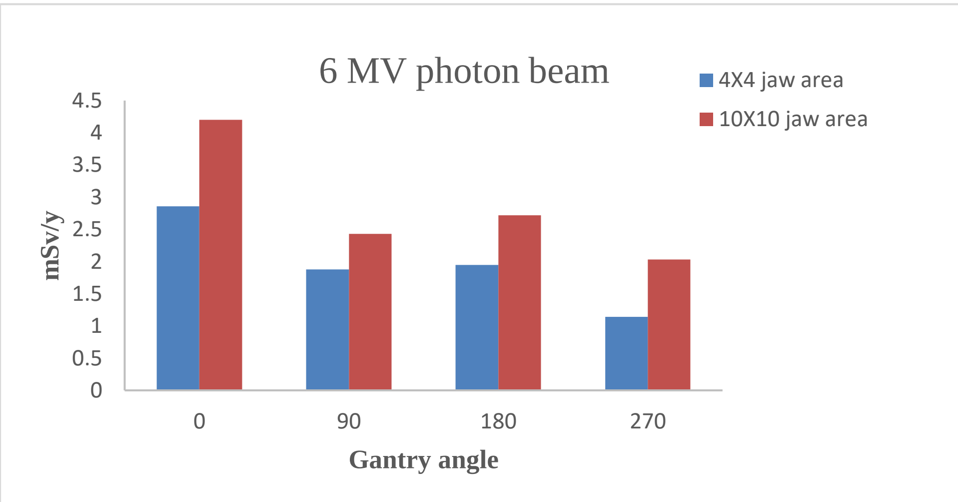

Fig. 1. Change of dose rates values according to gantry angle and jaw intervals in 6 MV photon beam

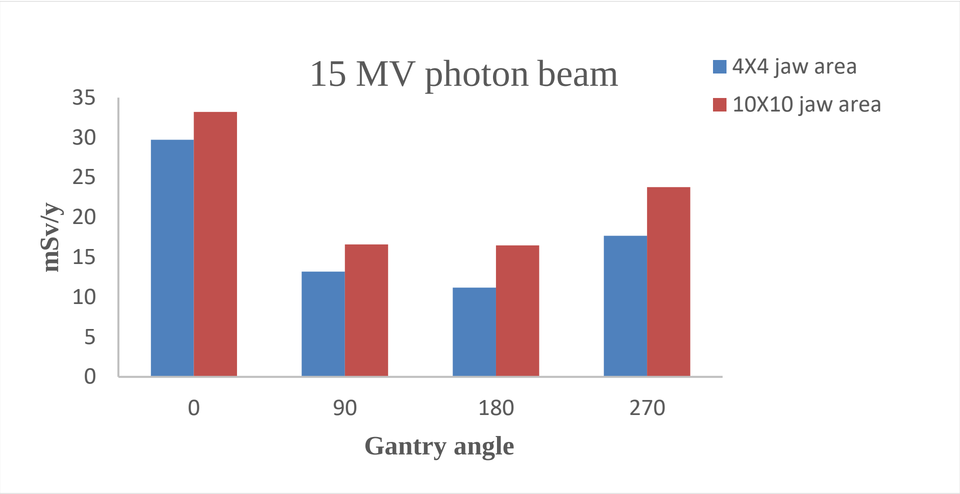

Fig. 2. Change of dose rates values according to gantry angle and jaw intervals in 15 MV photon beam

4. Discussion

In this study, the scattered dose rate values of the measured for the selected gantry angles of 0, 90, 180, and 270 degrees were presented in Table 1. The measurements were taken for each of the two different photon beams values (6 MV and 15 MV) and two different jaw intervals (4 × 4 cm^2 and 10 × 10 cm^2). From Table 1, it was observed that the dose rate increased when the collimator jaw intervals were increased from 4 × 4 cm^2 to 10 × 10 cm^2. The highest dose rates values have been measured for larger jaw interval in constant gantry angle values. An increase in the scattered dose rates with increases jaw interval is expected due to the change in the field size effects [16] the radiation output exiting the linac head. It was also observed that the amount of absorbed surface dose increased with increases jaw interval accordingly [17].

As can be seen in Figs. 1 and 2, when compared with other gantry angles, the highest value is observed where the gantry angle is chosen 0°. Also, at the same jaw interval and energy values, it is seen that the dose rates values measured at 90^o and 180^o gantry angles are close to each other. The maximum change between the dose rate values measured at different gantry angles in both 4 × 4 and 10 × 10 jaw intervals for 6 MV photon beam is taken at 0^o-270^o gantry angles. In contrast, the minimum change is taken at 90^o-180^o gantry angles. The rate of change between the external dose rates values measured at 0^o-270^o gantry angles in the 4 × 4 jaw interval is 60%, and the rate of change between the external dose rates values measured at 90^o-180^o gantry angles is 4%. In the 10 × 10 jaw interval, the rate of change between the external dose rates values measured at 0^o-270^o gantry angles is 52% while the rate of change between the external dose rates values measured at 90^o-180^o gantry angles is 11%.

For 15 MV photon beam, the maximum change between the dose rates values measured at different gantry angles in both 4 × 4 and 10 × 10 jaw intervals is observed at 0^o-180^o gantry angles, and the minimum change is observed at 90^o-180^o gantry angles. In the 4x4 jaw interval, the maximum change is found 55% and the minimum change is found 15%. On the other hand, in the 10 × 10 jaw interval, the maximum change is 51%, while the minimum change is very small and is less than 1%. The rate of change between measured dose rates values is between 1% and 60%. The greatest deviation among these values was observed at 0^o gantry angle.

During the irradiation, the linac is rotated around the horizontal gantry axis. Here the measurements have been performed in standard conditions where the gantry angle is moving in the direction of the clockwise. The beam is opposite in the vertical plane when the gantry is rotated from 0^o to 180^o. At gantry angle of 0^o, the linac head is towards the floor while at gantry angle of 180^o, the linac head is towards the ceiling. At gantry angles of 90^o and 270^o, the linac head is directed towards the opposite left and right walls in the horizontal plane.

In studies investigating the effects of gantry rotations using electronic portal imaging devices [18,19], it has been assumed that unless attenuation and scatter conditions changed, the number of particles per second coming to electronic portal imaging devices would ideally be invariant with gantry angle. However, it has been stated that the images taken at various gantry angles were dissimilar. One of the most important factors causing this difference is reported to be scattered from different environmental structures such as walls, floors and ceilings. It is also stated that the extent of the effect may depend on the construction materials used [18].

In our study, the difference between the measured dose rates values is predicted to could arise due to backscattering from the different surrounding structures depending on the position of the linac head at different gantry angles. Addition to this, for the maximum change at gantry angles of 0◦ and 180◦, the distance between the head of a linac and the floor/ceiling is also predicted to may have been effective on the backscattered radiation until it reaches the detector. For the minimum change, it is considered that the distance of the scattered beam from the detector may be affected. Besides, it is envisaged that the effect of energy on the scattered dose amount can be explained by obtained different maximum change percentage in different energy values. As seen in figure 2, the highest scattering dose rate is 33.2 mSv/y (33200 µSv/y) and is measured for 15 MV photon energy at a gantry angle of 0^o in 10×10 jaw interval. The maximum allowable yearly dose rate is 50000µSv/y [20]. Although the measured scattering dose rate value is small compared to the allowable annual dose value, it is a very high value considering the position of the detector.

5. Conclusion

In our study, scattered dose rate measurements in the clinical linear accelerator were made using the FLUKE Victoreen ASM 990 portable detector placed in the space between the surprising corridor and the front door in the section where the linear accelerator. The obtained dose rates were found to be high, although they were performed behind the confluence corridor. According to the data obtained, it is concluded that the patient is exposed to extra radiation due to secondary rays and radiation pollution occurs in the environment. This has shown that additional precautions can be taken to be protected from secondary radiation. The variation between the dose rates values obtained for different gantry angles was calculated. From the obtained results, it is concluded that deviations in values measured at different gantry angles may result from backscatters from surrounding structures depending on the position of the linac head. Besides, it was concluded that another important effect is the distance between the scattered beam and the detector and photon energy.

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