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Analysis of Small Field Dosimetry for 15 MV Photon Beams

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The aim of this study is to obtain the optimum measurement method to overcome the dosimetric problems in small field dosimetry which is very important in Intensity Modulated Radio Therapy. In this study, the relative dose factors obtained by Farmer, Semiflex, PinPoint, Marcus PP ionisation chambers and thermoluminescence dosimetry of the square fields between 1x1 - 15x15 cm generated by multi leaf collimator of Siemens Artiste linear accelerator (6-15 MV) were researched. For each field in d=10 cm, the measurements are performed thrice using 100 MU and averages are obtained. Same fields are created in computer treatment planning system and reference point doses are recorded. The measurement results obtained from different devices are compared. Then, relative dose factors are compared with data obtained by computer treatment planning system. In 15 MV, the data obtained by PinPoint ion chamber and thermoluminescence dosimetry were similar, but this data was higher dose response to other devices. However, all ion chambers have similar dose response in fields larger than 4x4 cm. Farmer ion chamber presents rapid dose decrease in fields smaller than 4x4 cm. As a result, usage of high resolution ion chambers and thermoluminescence dosimetry in dose efficiency measurement are shown appropriate. Furthermore, large sensitive measurement volume ion chambers such as 0.6 cm³ aren't suitable for using absorbed dose measurement in small fields. PinPoint ion chamber is a good choice for absorbed dose measurement in small fields.

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1. Introduction

The fundamental target in radiotherapy is to give the suitable homogeneous dose to the target volume by keeping the normal tissue dose minimum. It could not be possible with common conventional techniques nowadays. The most suitable (conformal) dose distribution in target could be obtained by Intensity Modulated Radio Therapy (IMRT) that has developed in recent years. Since this theory technique provides the opportunity to protect the healthy tissues in a better way, it allows to reach higher doses in tumor; thus, it provides improved tumor cure. The usage of IMRT has been very beneficial in terms of the optimization of radiotherapy (dose increase for complex shaped target volume, decrease of risky organ dose, providing the dose homogeneity, etc.) [1].

IMRT is an improved version of 3-D conformal therapy. Conformal dose distribution in IMRT is obtained with the help of multileaf collimator (MLC) in the head of linear accelerator. In contrast to the conventional or classical conformal therapy, dose intensity of each IMRT field is changed in a complex way. IMRT is applied in two ways: the first one is the dynamic IMRT (DMLC) technique formed by continuous movement of collimator leaves during irradiation, the second one is the step and shoot technique in which the beams are given by dividing into sub segments (SMLC) [1-3].

IMRT fields used to obtain conformal dose distribution comprise of small sub fields. The sizes of these fields might be $1 \times 1 \text{ cm}^2$ sometimes. These small fields cause dosimetric problems such as sudden dose declines inside the therapy field. These rapid dose declines bring about divergence in dose that is required to be given to tumor.

Another dosimetric problem in small field usage is that the detectors used to take measurements are rather big volumetrically for the fields used in therapy. Standard detectors cannot exactly measure the dose value because of dose fluctuations in small field. Therefore, the ion chambers having smaller volume should be used [4, 5].

When Wolfram and Wong [6] have compared the measurements they have done with 0.6 cc Farmer and 0.015 cc PinPoint ion chamber with the calculated values, they have seen that the ion chamber with 0.015 cc has shown closer readings to the calculated values.

When they have compared these values to Thermoluminescence dosimetry (TLD) and diamond detector readings, they have found that the best result is the one read by diamond detector because it is the tissue equivalent and it has the perfect spatial resolution.

As seen from the conducted studies, different dosimetry systems can be used for IMRT quality reliability process. The important thing in the verification of IMRT is to use the most appropriate and accurate system.

The aim of this study is to investigate the most appropriate measurement method to overcome the dosimetric problems encountered in small field dosimetry which has an important place in intensity modulated radiotherapy.

2. Material And Method

Relative dose factors (RDF) of square fields between $1 \times 1 - 15 \times 15 \text{ cm}$ formed by MLC in ARTISTE linear accelerator (6-15MV) device have been calculated by using different-volume ion chambers and TLD. The results obtained by the used methods have been compared. Relative dose factors have been

compared to the data of treatment planning system.

Whereas the primary dose constituting the dose in one point (primary dose+scattered dose) is independent from the field size, the scattered dose is dependent on the field size and beamed phantom size.

Therefore, relative dose factors have been found in order to show the dependence of the dose on field size. To find the factors, measurements have been made in 10 cm depth in 1x1, 2x2, 3x3, 4x4, 5x5, 6x6, 7x7, 8x8, 9x9, 10x10 ve 15x15 cm fields in 15 MV photon energy. The measurements have been made by giving 100 MU in RW3 solid water phantom in center line and they have been repeated at least 3 times. The reading values have been normalized to the reading value of 10x10 cm reference field and relative dose factors have been found and the graphic has been drawn to field width. Besides, dose efficiency measurement have been repeated in the same set-up conditions with TLD. Relative absorbed dose values have been examined according to the volumes of ion chambers. The results have been compared to the data of CMS XIO treatment planning system.

The measurements of solid water phantom have been made by using RW3 solid water phantom in center line for 15 MV photon energy in d= 10 cm ; 1x1, 2x2, 3x3, 4x4, 5x5, 6x6, 7x7, 8x8, 9x9, 10x10 and 15x15 cm field and using Farmer in SSD 100 cm (0,6 cm³), Semiflex (0,125 cm³), PinPoint (0,015 cm³), Markus PP ion chambers (0,055 cm³) and PTW Unidos electrometer. 100 MU has been given for each irradiation. The specially designed plate of solid water phantom has been used for each ion chamber in measurements. Each measurement has been repeated three times and the average has been calculated.

By placing TLD in center lines of , 2x2, 3x3, 4x4, 5x5, 6x6, 7x7, 8x8, 9x9, 10x10 and 15x15 cm fields in 15 MV photon energy, measurement has been made by giving 100 MU in 10 cm depth. The measurements have been repeated at least three times. The reading values have been normalized to the reading value of 10x10 cm reference field.

TLDs that have been grouped and given numbers have been placed in TLD reader by keeping at least 10 hours after irradiation without ruining the sequencing. After the process of reading done by entering the numbers of each TLD one by one, radiant curves have been formed.

Reference point doses have been recorded by forming 2x2, 3x3, 4x4, 5x5, 6x6, 7x7, 8x8, 9x9, 10x10 and 15x15 cm fields in d=1,5 cm and d=3 cm respectively in 15 MV photon energy in CMS XIO.

3. Findings

3.1. The results of measurements made by ion chamber

Measurements have been taken by giving 100 MU in d=10 cm in 1x1, 2x2, 3x3, 4x4, 5x5, 6x6, 7x7, 8x8, 9x9, 10x10 and 15x15 cm fields in 15 MV photon energy by using Farmer, Semiflex , PinPoint and Markus PP ion chambers. The plans of these fields have been formed in CMS XIO and reference point doses have been recorded.

3.2. The results of measurement made by TLD

Measurements have been taken by giving 100 MU in d=10 cm in 1x1, 2x2, 3x3, 4x4, 5x5, 6x6, 7x7, 8x8, 9x9, 10x10 and 15x15 cm fields in 15 MV photon energy by using TLD. The plans of these fields have been

formed in CMS XIO and reference point doses have been recorded.

3.3. The results of measurement made by BTPS

The results of reference point doses in 2x2, 3x3, 4x4, 5x5, 6x6, 7x7, 8x8, 9x9, 10x10 and 15x15 cm formed in CMS XIO in d=1,5 cm and d=3 cm respectively in 15 MV photon energy have been given in the table below.

Table 1.BTPS data in 15 MV photon energy in various square fields.

FIELD cm ²	ENERGY 15 MV	
	READINGS	RDF
2X2	73,3	0,949
3X3	74,5	0,965
4X4	75,5	0,977
5X5	75,8	0,981
6X6	76,4	0,989
7X7	76,9	0,996
8X8	77,1	0,998
9X9	77,2	1
10X10	77,2	1
15X15	77,9	1,009

When 15 MV photon energy has been examined for Relative dose factors, the results of measurement found by using Farmer, Semiflex, PinPoint and Markus PP ion chambers with TLD have been demonstrated in Figure 1. The measurements made in 10 cm depth (SSD=100cm) have been normalized to 10x10 field dose. The plans of the same fields have been formed in CMS XIO in order to compare relative dose factors.

Figure1. Different ion chambers for 15 MV, The relative dose values with TLD and BTPS

It has been seen that Farmer ion chamber has done the lowest reference dose in 15 MV. The reason of it depends on the fact that Farmer ion chamber has bigger precise volume and it is also because of the breakdown in electron flow.

The relative dose factors that the computer treatment planning system has given in 15 MV have been compared for the bigger fields than 2x2 cm because the smallest field entered in the system is 2x2 cm. relative dose factors of computer treatment planning system are compatible with TLD results and ion chambers except for Farmer ion chamber.

4. Results and Discussion

The dose defined by IMRT is given by using multi small sub fields. In IMRT based on MLC, most of the fields are given from as small fields as 1x1 cm. Accordingly, small fields and their dosimetric properties should be modelled appropriately in TPS for an accurate dose calculation in IMRT. This study has been conducted to research different dosimetric methods in the verification of dose distribution of which relative dose factors have been modelled in TPS and to compare them and to find the most effective verification method in terms of accuracy and process easiness.

In the study, relative dose factors for 15 MV photon energy in CMS XIO, TLD, Farmer, Semiflex, PinPoint and Markus PP ion chambers have been demonstrated in Figure 1.

Whereas PinPoint ion chamber and TLD readings have similar results in small fields for 15 MV photon energy, they give higher dose response than the other ion chambers. Semiflex ion chamber and Markus PP ion chamber are close to each other and they give lower dose response than PinPoint ion chamber and TLD readings. Farmer ion chamber shows severe dose decline than other ion chambers. This decline has some reasons. These are;

- (1) The precise volume of Semiflex, Farmer and Markus PP ion chamber is bigger.
- (2) Because of the breakdown in electron flow, the decline in electron flow ends in lower dose response by the decrease in ionization inside the ion chamber volume.
- (3) The decline in the number of photon reaching the detector because of the spreading of electrons moving away from the center line and the decline of scattered dose. Maximum field dependence is seen in larger fields than the maximum distance of reaching of secondary electrons.

As seen in the study, the main reason why RDFs have been found smaller than 4x4 cm is that the lateral electron unbalance has increased by the increase of the measurement volume of the detector. It has been shown by similar studies that this increase in lateral electron unbalance might cause errors in dose calculations [7].

According to these evaluations, it has been inferred that the adequate use of small volume ion chamber in small field dosimetry will give

compatible results with film dosimetry having high spatial resolution and tissue equivalent TLD not forming perturbation factor. Besides, while low dose measurement caused by small volume ion chamber and lateral electron unbalance has been decreased, effective measurement point has been provided to take place inside the measurement fields. This situation will bring less uncertainty than bigger volume ion chamber. Similarly, Wolfram and Wong [6] have stated that the effect of the volume of ion chambers increase as the irradiated area grows in absolute dose measurements they have made with PinPoint (0.015cc) and 0.125 cc ion chamber. They have noted that as the volume of the detector increases lateral electron unbalance increases and the read value decreases.

Martens et al. [8] have compared the measurements by using Markus PP ion chamber, PinPoint ion chamber and diamond detector. One of the findings of their study is that PinPoint chamber has given excessive reaction to low energy Compton scattering photons as in radiographic film. It depends on the fact that center electrode of PinPoint ion chamber is steel. They have recommended this ion chamber for output measurements in 1.5 cm and smaller fields.

The measurements of relative dose factors of small field photon beams depend on the efficiency of the detectors used [9]. It has been revealed in many studies that diode and diamond detectors in relative dose factor have given the best results for small fields in many studies [10-12]. Besides, diamond detectors are very precise and expensive. Diode type should be chosen carefully because it might affect diode armor measurements negatively. Sanchez et al. [13] have compared the measurements by using a large field Markus PP, PinPoint,

Semiflex, Farmer ion chambers, p type diode, diamond detector and Kodak X-Omat Vfilm. In the study, it has been seen that the volume precision of the detectors in output factors plays an important role. It has been reported that the precise volume of 0.6 cm^3 ion chamber falls short of measuring the absorbed dose in small fields. Calcina et al. [4] have reached the conclusion that high-resolution film and TLDs are appropriate for small radiation fields in their studies in which they have evaluated the dosimetric parameters and various dosimetries. It has been noted that large volume ion chambers are not appropriate in high dose gradient fields because of the perturbation of electronic balance and volume average. Similarly, Laub and Wong [7] have notified that 0.015 cm^3 volume PinPoint ion chamber has shown closer readings to the calculated values when they have compared the measurements they have made with 0.6 cm^3 Farmer ion chamber and 0.015 cm^3 PinPoint ion chamber with the calculated values. Westermarck et al. [15] have informed that TLD relative dose factor measurements have shown closer readings to the calculated values than big volume ion chambers.

Pappas et al. [12] have measured the output factors of the field with 5 mm radius by using gel dosimetry. the average dose value between one voxel and zero voxel has been calculated inferentially by using the effect of volume and different voxel sizes. These results have coincided with the data of PinPoint ion chamber. It has been found out that ion chambers used routinely (0.6 cm^3 volume) in our study falls short of measuring the absorbed dose in small fields of precise volume. TLD and PinPoint ion chambers in small field RDF have shown similar readings. These results have been found compatible with the literature [14-17].

Considering the results of our study and similar

studies in the literature, it is essential to choose the dosimetry volume as appropriate to field size and lateral electron unbalance we have encountered while evaluating the dosimetric parameters of small fields. It is necessary to choose the possible lowest volume and high spatial resolution dosimetry to decrease the effect of both factors. It should be paid attention that the dosimetries have high spatial resolution in the small field photon therapy.

Whereas the average volume of dosimetry size and the presence of lateral electronic uncertainties and the uncertainties have minimized, the precise volume of the detector should be low enough in terms of saving the dose on shard drop area of the distribution. Besides, dosimetry should provide a spatial map of dose distribution and the accuracy of conformal distribution than the dose in a single point.

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