Study and Comparison of Beam Characteristics of 6-MeV Photon of Two Linear Accelerators at Karachi Institute of Radiotherapy & Nuclear Medicine (KIRAN)

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Abstract: In this work the dosimetric characteristics of Siemens Primus Plus linear accelerator (LA-1) and Primus linear accelerator (LA-2) were analyzed. The similarity in photon dosimetry data was also investigated for nominal photon energy of 6-MeV of both linear accelerators at Karachi Institute of Radiotherapy and Nuclear Medicine (KIRAN). The relative depth dose or percentage depth dose (PDD), off-axis ratios or off-axis profile (OAR), field output factor (FOF), flatness (F), symmetry (S) were measured for each linear accelerator as per weekly and monthly Quality Assurance checks. Output constancy was also observed on these machines. The maximum positive and maximum negative percent deviations in PDD data were less than 2%, off-axis profile percent deviations were no more than 3%, output factors were varied no more than 2% and deviations in photon output constancy were no more than 3% in both machines. The similarity in the basic photon dosimetry data was found in current study among the linear accelerators with the same make, model and nominal energy. All tolerances are within the clinically acceptable tolerance limit. From clinical point of view this study supports the radiation oncology department to avoid any delay or interruption in the treatment of patient that is, the medical physicist can utilize the same treatment plan for treatment on the other machine of the same model and energy.

Key Words: Primus Plus linear accelerator, constancy checks, output factors, percentage depth dose, off-axis profiles.

1. INTRODUCTION

Quality assurance (QA) of clinical treatment machines is necessary for any radio therapy center. The purpose of QA clinical machines is to measure actual performance and compare it with existing standards, or reference value. QA procedures are designed to minimize the difference between prescribed and delivered dose, prevent the delivery of unintended dose and to minimize the time between occurrence of error and implementation of corrective action.

Medical Physicists have been playing a vital role to make use of linear accelerator and radiations for clinical use. The need of precision, data validation, a variety of testing methods etc. are the challenges faced by them [1]. The delivered dose to the patient depends on the accuracy of beam data used in the treatment planning process. These data are obtained from linear accelerator are treated as the standard data for clinical use. For quality assurance of clinical radiotherapy treatment planning these data should be verified periodically [2]. For this purpose medical physicists have studied dosimetric characteristics photon beam, having a range of energies, of a clinical accelerators [3-12].

In any radiotherapy centre the investigation of dosimetry characteristics of modern computer controlled LINACS is the main part of quality assurance program and to ensure that the dose delivered to the patient is more accurate and its value is within the tolerance limit. The purpose of this project was the dosimetric quality assurance of Siemens Primus Plus (LA-1) and Primus (LA-2) linear accelerators which were installed ten years before at KIRAN. LA-1 has photon beams of nominal energy 6-MeV and 15-MeV and electron beams of 6, 9, 12, 15, 18 and 21-MeV. Similarly LA-2 has photon beams of nominal energy 6-MeV and 10-MeV and electron beams of 5, 7, 8, 10, 12 and 14-MeV.

We investigated the dosimetric characteristics of the two LINACS for 6-MeV photon [2]. This study was divided into three parts. In first part the periodic output constancy of LA-1 and LA-2 was investigated, in second and third parts, beam characteristics such as percentage depth dose, off-axis profiles, field output factors were studied and compared with published data. The purpose of this statistical analysis was to verify that the standard behavior among the basic photon dosimetry data of same models.

2. MATERIALS AND METHOD

Siemens Primus Plus and Primus linear accelerators, PMMA phantom, PTW water phantom, Radiation Field Analyzer (Multidata 9850).

3. MEASUREMENTS AND DATA ACQUISITION

For output constancy checks simple plastic phantom slab which is made of PMMA having dimensions, 30cm×30cm×

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2.5cm was used. The constancy check was performed for both machines in alternate days. The periodic constancy check was performed mostly by using a Farmer type ion chamber, PTW30013 model No.0612 in a simple plastic phantom. The electrometer used was CNMC11.

Water phantom of dimensions, 30cm×30cm×30cm (PTW, Germany) for determination of absorbed dose was used. The cylindrical ionization chambers PTW30013, model No.0114, PTW30001, model No.1464 and PTW3006, model No.0065 having cavity volumes 0.6,cm^3. were used in absolute dosimetry.

Relative dose measurements were performed in a remote controlled water phantom Multi-data9850 (Radiation Field Analyzer, RFA) of dimension 50cm×50cm×50cm. Multi-data9732-2 model No.1007 and Multi-data 9732-2 model No.1006 chambers were used for relative dose measurements in this study.

For measurement of charges produced by photon in water and plastic phantom, CNMC11 electrometer, model No.5232 and Standard Imaging (SI) electrometer, model No.JO33532 were used in relative and absolute dosimetry. In constancy check mostly CNMC11 electrometer was used.

4. RESULTS AND DISCUSSION

4.1. Output Constancy

The maximum and minimum percent deviations in recorded data for a period from January, 2010 to July, 2010, in LA-1 and in LA-2, are given in Table **1**. For comparison the corresponding data for 2008 and 2009 are also given. The deviations were calculated with reference to previous and first value of each year.

Table 1. Percent Deviations in Photon Output Constancy in LA-1 and LA-2.

Year	Percentage Deviation (Previous)				Percentage Deviation (Reference)			
	Maximum		Minimum		Maximum		Minimum	
	LA-1	LA-2	LA-1	LA-2	LA-1	LA-2	LA-1	LA-2
2010	1.5	1.5	-1.5	-1.2	2.7	2.4	-0.6	-0.9
2009	1.5	1.2	-2.1	-1.5	0.6	1.7	-2.7	-0.5
2008	2.4	1.2	-2.4	-0.9	1.5	1.2	-2.7	-0.9

The output constancy for 6-MeV photon in Primus Plus and Primus accelerators were observed and recorded, the deviations were also calculated. These deviations were no more than, the tolerance limit of ±3% and ±2% recommended by American Association of Physicists in Medicine (AAPM), and International Atomic Energy Agency (IAEA) respectively. Over all result is that 94% data values in LA-1 and 99% data values in LA-2 are within the tolerance limit of ±2%. The deviations in constancy are caused by improper cooling in treatment room at the time of measurements, because the available time to cool the treatment room as well as to maintain the temperature of the phantom in the morning was insufficient.

4.2. Absorbed Dose

In second part of this study the absorbed dose to water at the depth of dose maximum and at the reference depth was calculated for 6-MeV photon in both LINACS by using the IAEA [12-13] protocol, TRS-398. Percent deviations in the absorbed dose at the depth of dose maximum was calculated and analyzed. In Table **2**, maximum and minimum percent deviations in absorbed dose for LA-1 and LA-2 are given.

Table 2. Percent Deviations in Absorbed Dose

LINACS	Percent Deviations (Maximum)	Percent Deviations (Minimum)
LA-1	1.1	-1.9
LA-2	0.5	-1.6

The current study shows that, the percent deviations in the absorbed dose are within the tolerance limit of ±2% as recommended by IAEA.

The absorbed dose to water was evaluated for different chambers. The results obtained for different chambers were the same and percent deviations were also within the tolerance limit as shown in Table **3**. Medical Physicists work in the same way to assure that the instruments which are used during quality assurance checks are working properly [14].

In weekly test, measurements are made for sufficient temperature due to this the deviations in absorbed dose are less as compared to periodic constancy checks.

Table 3. Percent Deviations in Absorbed Dose at, Z_{max}. by Using Different Chambers

Model #	Percent Deviation (Maximum)	Percent Deviation (Minimum)
0114	0.5	-1.9
1464	0	-1.3
0065	1.1	-1.6

The beam characteristics such as percentage depth dose, off-axis profile and output factor were analyzed in three months period. From off-axis profile beam symmetry and flatness were calculated for 10cm×10cm and 20cm×20cm field sizes. The flatness was calculated from off-axis profiles for 10cm×10cm and 20cm×20cm field sizes for in-plane and cross-plane profiles, the symmetry for in-plane and cross-plane profiles were analyzed. The tolerances in flatness and symmetry were found in the dosimetry data are within the IAEA recommended limit of ±3%.

4.3. Percentage Depth Dose

The percentage depth dose of both the LINACS were compared with the central axis depth dose data provided by BJR and maximum and minimum percent deviations in central axis depth dose data from BJR Supplement No.25 [15] were calculated these results are given in table **4** and **5**.

Table 4. Percent Deviations in PDD Data in LA-1

Month	Percent Deviation (Maximum)	Percent Deviation (Minimum)
1	0.33	-1.84
2	0.81	-0.6
3	0.89	-0.08

Table 5. Percent Deviations in PDD Data in LA-2

Month	Percent Deviation (Maximum)	Percent Deviation (Minimum)
1	0.96	-1.37
2	0.56	-0.43
3	0.27	-1.61

4.4. Output factors

In this study the output factors were measured at reference depth, 5cm for different field sizes. The reference field was 10cm ×10cm. Fig. (**1**) gives the dependence of output factor on field size for both LA-1 and LA-2. It is clear from the figure that both accelerators have same output factor for any field size.

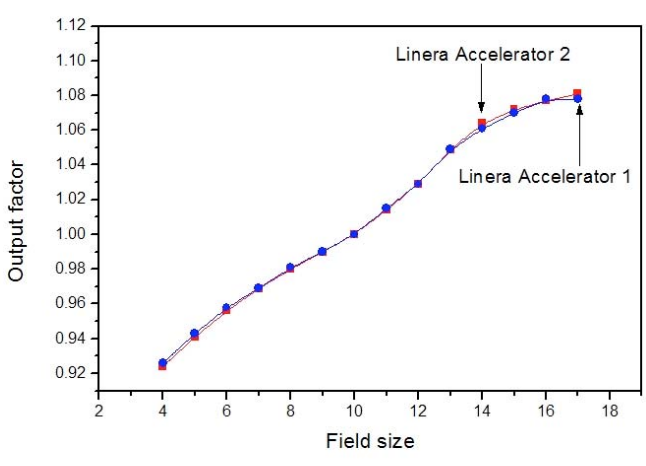

Fig. (1). Dependence of output factor on field size.

The tolerance limit for percentage depth dose (PDD), off-axis ratio (OAR), field output factor (FOF), Output constancy, and absorbed dose were recorded and compared with the Radiological Physics Center (RPC) pre-determined values. Fig. (**2**) gives the comparison of recorded and PRC values. The recorded tolerance limit for each factor is less than given in PRC.

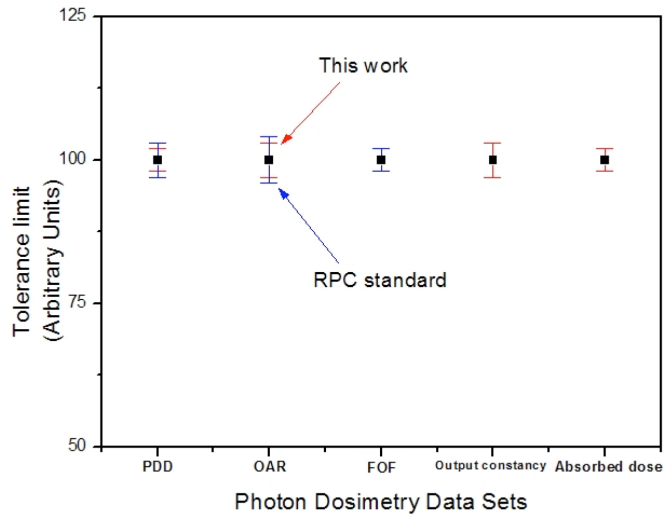

Fig. (2). Comparison of measured tolerance values with PRC values for various photon dosimetry data sets.

5. CONCLUSION

The dosimetric characteristics of Siemens Primus Plus linear accelerator (LA-1) and Primus linear accelerator (LA-2) were analyzed. The similarity in photon dosimetry data was also investigated for nominal photon energy of 6-MeV of both linear accelerators at Karachi Institute of Radiotherapy and Nuclear Medicine (KIRAN).

The dosimetry data that have been included in comparative study performed at KIRAN was photon output constancy, percentage depth dose, off-axis profiles, field output factors, flatness and symmetry for 6-MeV photon beams. Photon output constancy (periodic) data of three years period was investigated. The study shows that there is a similarity in the basic photon dosimetry data obtained for the linear accelerators with the same make, model and nominal energy.

It is concluded that the maximum positive and maximum percent deviations in PDD data were less than 2%, off-axis profile percent deviations were no more than 3%, output factors were varied no more than 2% and deviations in photon output constancy were no more than 3%.

The study also supports the Radiological Physics Centre's (RPC) measured values. All tolerances are within the clinically acceptable tolerance limit recommended by IAEA and AAPM. From clinical point of view the study also supports the radiation oncology department to avoid any delay or interruption in the treatment of patient that is, the medical physicist can utilize the same treatment plan for treatment on the other machine of the same model and energy.

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