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STUDY ON VARIATION OF QUALITY ASSURANCE DATA OF A LINEAR ACCELERATOR AFTER THIRTEEN YEARS OPERATION FOR CANCER TREATMENT.

[1*]Dr. Suvendu Kumar Sahoo and [2]Dr. Rabinarayan Mukharjee

[1]HCG Panda Curie Cancer Hospital, Telenga Pentha, NH-05, Cuttack, Odisha, India.
[2]School of Applied Sciences, KIIT University, Bhubaneswar, Odisha, India.

***Correspondence for Author: Dr. Suvendu Kumar Sahoo**

HCG Panda Curie Cancer Hospital, Telenga Pentha, NH-05, Cuttack, Odisha, India.

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ABSTRACT

Quality Assurance data is very much useful which had got during commissioning of a linear accelerator (LINAC) for clinical and research purposes. The commissioned beam data obtained are treated as references and ultimately used for radiotherapy clinical treatment for cancer patients. The scientific procedure used for measuring data of LINAC at HCG Panda Curie Cancer Hospital, Cuttack, India has been described in detail in this article. The maximum beam energy of this LINAC is 6 MV for photons and 10 MeV for electrons. The approximate flux of the source are of the order 10^{15} photons/sec and 10^{18}electrons/sec with a highest delivery dose rate of 300 cGy/min for photons and 200 cGy/min for electrons at the dose maximum point in the water phantom. Here we have measured a complete set of QA data as per present performance of LINAC and made a comparison with commissioned data which was got before thirteen years. Both complete set of measured data of the LINAC have been presented here. The current measured radiation data are within permissible limit as per Atomic Energy Regulatory Board (Mumbai), India guide lines. Hence this old linear accelerator can be used safely for clinical radiotherapy treatment for cancer patients and research purposes like material modification by irradiation.

KEYWORDS: Linear Accelerator, Water Phantom, Flux, Radiotherapy.

INTRODUCTION

Linear accelerator (LINAC) is a device can produce high energy X-rays (MV) and electron beams (MeV). This LINAC uses microwave technology to accelerate electrons in a part of the accelerator called the wave guide (WG). The WG structure is energized at microwave frequency most commonly at 3000 MHz (100 mm wave-length in free space)[1], then allows these accelerated electrons to collide with a heavy metal target as a result of which high-energy transmission X-rays are produced from the target. These X-rays are directed towards exist part of accelerator in different field sizes by collimator. The beam comes out of the accelerator through gantry, which rotates around the patient in 360^0. The patient lies on a movable couch. The treatment is being delivered to the tumor from any angle by rotating the gantry and moving the treatment couch. Now days in cancer care management, radiotherapy is an important modality for treatment. It is very easy now to treat any tumor even of irregular shape by sparing the surrounding critical organs by using modern radiotherapy techniques like three dimensional conformal radiotherapy (3D, CRT), intensity modulated radiotherapy (IMRT) and image guided radiotherapy (IGRT), etc. Response of radiation treatment is directly related to the precession in the delivered dose to the patient that is dependent on the accuracy of beam data used in the treatment planning process. These data are obtained during the initial commissioning of the LINAC and are treated as the standard data for clinical use and should be verified periodically as described by Task Group-40 protocol[2] by a qualified medical physicist to ensure that machine parameters have not changed during normal operation. The acceptance testing implies the verification process of the machine based on manufacturer's guidelines for a very small subset of beam data whereas commissioning[3] is a process where a full set of data is acquired that will be used for patient treatment and other research purposes.

MATERIALS AND METHODS

In our centre,we have Simens primus linear accelerator. This LINAC has single energy photon beam (6MV) and multi energy electron beam (5, 7, 8 and 10 MeV) and it was installed and commissioned before thirteen years. In this work we used some dosimetric equipments, like 2D water phantom scanner, with computer interface called as radiation field analyzer (Scan-o-plan), ionization chambers (two cylindrical and one flat), and Dose-1 electrometer (all instruments are from IBA, Germany), solid phantom (an assembly of tissue equivalent solid plates of different thickness), radiochromic films

(EDR2), film laser scanner, barometer, chronometer and thermometer for LINAC data measurement. The RFA consists of a cubic water tank with inner dimensions of 40 × 40 × 40 cm^3.Total measurements were done in the water medium as human body contains 80 % of water and it is a standard protocol worldwide. Film scanners are used to convert the film data to digital data by using computer soft ware, which gives finally the intensity of the incident beam at various points in the radiation field.The ionization chamber is the detector of choice for the radiation measurement, as its measurement response is independent of the fluence of the beam characteristics (beam quality, dose and dose rate) and shall possess good reproducibility and repeatability. The radio chromic film gives practical and rapid indications of the dose distribution in a plane. The advantage of the film lies in its high spatial resolution, which is particularly useful in regions where dose gradient is very high or very low.

LINAC Machine specific tests

The Machine specific testing method has been classified into two types as non- radiation specific testing methods of the accelerator is concerned. These tests are, a) Electrical tests and b) Mechanical tests. Electrical tests involve the testing and proper functioning of all interlocks and emergency cut-off switches and mechanical tests involve patient treatment couch movement, collimator rotation, gantry rotation, optical distance indicator (ODI) scale verification and position of isocentre mechanically.

LINAC Radiation specific tests

The basic parameters like percentage depth dose (PDD) and profiles (in-plane and cross-plane) of photon beams at various depths for open and wedge fields, energy stability verification.[4] However , PDD, profiles analysis and output factors for different applicator size (AS) are essential tests for electron beam in radiation specific test group.It is necessary to be ensured that for a given nominal beam energy, the radiation monitor response is independent of parameters like dose rate, the direction of the radiation beam, temperature and pressure of the LINAC. However, the variation of monitor response is related to the ion recombination in monitor chamber due to inadequate voltage supply to the chamber. Hence, monitor should be carefully calibrated for each dose rate in clinical use. For checking of monitor and chamber response, like reproducibility, linearity, dependence on gantry rotation, dependence on the field shape and stability with time have been properly checked before starting the detailed procedures.

It is important to measure the leakage radiation of LINAC installation bunker on the outside walls including top and bottom sides indicating clearly area occupied by radiation and non-radiation workers (including public) with gantry positions at 0°, 90°, 180° & 270°.[5] These tests were done for radiation safety integrity of LINAC installation by the use of water phantom and radiation survey meter with nominal photon energy. The measurements of radiation dose at various points of the outside walls of bunker were carried out using radiation survey meter (Victoreen, model-451P RYR, Fluke biomedical, USA). But as per Atomic Energy Regulatory Board (AERB) Mumbai,India recommended value of safety radiation level at outside area of the bunker is up to 2 mR/hr (maximum). Our measured values are well within this limit.

RESULTS AND DISCUSSIONS

The detailed commissioned QA data are given in Table Nos. [1(a), 1 (b) & 1(c)] what we had got during commissioning time before thirteen years. After completion of all scientific methods (procedures)[6], we got the complete QA data as per preset Status of the LINAC after operation of thirteen years for radiotherapy treatment to cancer patients. All the results have been presented in the Table Nos. [2(a), 2 (b) & 2(c)]

Table 1(a): QA Measured Parameters of radiation beams during Commissioning Time

11	Photon beam	Electron beam	Tolerance/ remark
Congruence	< 2 mm (upto FS 40×40 cm^2)	< 2 mm (upto FS,20×20 cm^2, AS)	≤ 2mm (all FS)
Depth dose d_{max} (cm)	1.5 cm (6MV)		1.5±0.2 cm (6MV)
PDD at 10 cm (D_{10})	67.5% (6MV)		67.1±1.5 % (6MV)
Flatness (10×10 cm^2) d_{max} (cm)	≤1.5% (6MV)		Upto 3%
D_{10} (10 cm)	≤1.8% (6MV)	≤102.1% (for all electron energies)	
Symmetry (10×10 cm^2) d_{max} (cm)	≤101.6%(6MV)		Upto 103%

Penumbra (20 ×20 cm^2) at d_{max} (cm)	≤ 7 mm(6MV)	≤12 mm (For all electron energies)	FS upto 15×15 cm^2 ≤ 7 mm and FS > 15×15 cm^2 ≤ 8 mm for photon, and for electron no specified value
Q.I	0.680 (6MV)		0.676±0.009 (6MV)
Energy stability	Measured for one week		< ± 0.002 MV
Wedge angle for 60^0	0.360 (6MV)		0.360 (6MV)
MLC intera leaf leakage	No MLC		
Movements of the patient table w. r. t. isocenter Horizontal displacement Vertical Displacement Angle between table and table top rotation axes Deviation of table top height with lateral displacement	 1.5 mm 2 mm 0.2° 3 mm		 2 mm 2 mm 0.4° 4 mm

Table 1 (b) : Calculated energy of the specific electron beam during Commissioning Time

Energy (MeV)	d_{max} (mm)	R_p (mm)	R_{50} (mm)	$E_{p,0}$ (MeV)	$\bar{E}_o$ (MeV)
5	1.2	24.0	18.8	4.99	4.40
7	16.5	33.4	26.5	6.86	6.18
8	20.6	47.1	38.1	9.61	8.88
10	25.2	61.7	49.9	12.54	11.63

Table 1 (c): The D_s, d_{min}, D_{10} & *QI* of photon beam in Commissioning Time

Energy (MV)	% D_s	d_{max} (cm)	d'_{max}*	D_{10}	D'_{10}	*QI*	*QI'*
6	60.3%	1.5	1.5±0.2	67.5%	67.1±1.5 %	0.680	0.676±0.009

* Recommended values (d'_{max}, D'_{10}, *QI'*), and observed values (d_{max}, D_{10}, *QI*)

Table 2 (a): Present Measured QA Parameters of radiation beams

Parameters	Photon beam	Electron beam	Tolerance/ remark
Congruence	< 2 mm (upto FS 40×40 cm^2)	< 2 mm (upto FS,20×20 cm^2, AS)	≤ 2mm (all FS)
Depth dose d_{max} (cm) PDD at 10 cm (D_{10})	1.6 cm (6MV) 67.6% (6MV)		1.5±0.2 cm (6MV) 67.1±1.5 % (6MV)
Flatness (10×10 cm^2) d_{max} (cm) D_{10} (10 cm) **Symmetry** (10×10 cm^2) d_{max} (cm)	 ≤1.5% (6MV) ≤1.8% (6MV) ≤102.0%(6MV)	≤102.1% (for all electron energies)	Upto 3% Upto 103%
Penumbra (20 ×20 cm^2) at d_{max} (cm)	≤ 7 mm(6MV)	≤12 mm (For all electron energies)	FS upto 15×15 cm^2 ≤ 7 mm and FS > 15×15 cm^2 ≤ 8 mm for photon, and for electron no specified value

Q.I	0.670 (6MV)		0.676±0.009 (6MV)
Energy stability	Measured for one week		< ± 0.002 MV
Wedge angle for 60^0	0.360 (6MV)		0.360 (6MV)
MLC intera leaf leakage	No MLC		
Movements of the patient table w. r. t. isocenter			
Horizontal displacement	2.0 mm		2 mm
Vertical Displacement	2 mm		2 mm
Angle between table and table top rotation axes	0.2°		0.5°
Deviation of table top height with lateral displacement	3 mm		4 mm

Table 2 (b): Present Calculated energy of the specific electron beam

Energy (MeV)	d_{max} (mm)	R_p (mm)	R_{50} (mm)	$E_{p,0}$ (MeV)	$\bar{E}_o$ (MeV)
5	1.3	24.0	18.8	4.99	4.40
7	16.4	33.4	26.5	6.86	6.18
8	20.7	47.1	38.1	9.61	8.88
10	25.3	61.7	49.9	12.54	11.63

Table 2 (c): Present parameters like D_s, d_{min}, D_{10} & *QI* of photon beam

Energy (MV)	% D_s	d_{max} (cm)	d'^{*}_{max}	D_{10}	D'_{10}	*QI*	*QI'*
6	60.3%	1.6	1.5±0.2	67.6%	67.1±1.5 %	0.670	0.676±0.009

* Recommended values (d'_{max}, D'_{10}, QI'), and observed values (d_{max}, D_{10}, QI)

From above present measured tabulated data , it gives the clear idea that all radiation parameters and mechanical checks are well within permissible limit as per AERB guidelines. If will compare with commissioned data there is no much more difference with tolerance value. So there is no discrepancy between recommended[7] and measured value.

CONCLUSIONS

The scientific methods used here for measurement present status of linear accelerator is really a time consuming procedure and needs dedication in work. In this study we measured a complete set of data of linear accelerator with all respects dosimetrically and mechanically and got all data are within permissible limits as per our regulatory authority specification. Hence this old linear accelerator can be used safely for clinical radiotherapy treatment for cancer patients and research purposes like material modification by irradiation.

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