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Dosimetric verification of radiotherapy treatment planning system at TMSS Cancer Center, Bogura, Bangladesh

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Abstract

Authentication of TPS is the component of the QA program for RTPS and planning process. So, verification of dose calculation algorithm is essential to measure the efficiency of the dose calculations. The goal is to assess how far the dosage measured deviates from the dose predicted by the treatment planning system (TPS) algorithm using a CIRS Thorax phantom. It has been done to measure the dosimetric variations of 6MV, 10MV and 15MV photon beams. The phantom was initially scanned using a CT-simulator, and the raw data from the gated scans were then exported to TPS to perform the planning. Using this planning, the phantom was irradiated for four different cases. The computed dose was then compared with the measured dose to ensure TPS validity. The findings demonstrate that the variation between the measured doses in altered holes of the CIRS thorax phantom and the calculated doses by TPS was within the allowed limit except few points of four cases. Max. and Min. deviations for 6MV were 3.87% and 0.05% respectively. On the other hand, Max. and Min. deviations for 10MV were 7.87% and 0.12% respectively and that for 15MV are 4.44% and 0.02% respectively. Satisfactory results were obtained for lung and bone substitute. The results demonstrate the accuracy of the doses determined by the treatment planning system algorithm using a thorax phantom, and they also demonstrate the competency of using the phantom for regular verification. In case of external beam radiation therapy with AAA algorithm, the CIRS Thorax Phantom is suitable for dose computation in heterogeneous medium. However it is more compatible for 6MV than 10MV and 15MV.

Keywords: Vital-Beam LINAC; Radiotherapy; Commissioning; Eclipse Treatment Planning System

1. Introduction

Among various treatment modalilities, radiotherapy is very sophisticated technique and plays vital role in the cancer treatment. To secure the accurate treatment, the phantom is an essential tool for dosimetry conformation and Quality Assurance routine cheek up. Quality Assurance (QA) in any treatment modality is essential to ensure that the dose distrtibution is performed correctly i. e. to obtain maximum dose to the tumorous cell and minimum dose to the normal cell. In radiotherapy procedure, computerized treatment planning systems (TPS) are employed to make a plan using patient anatomical information like CT or MRI. Treatment planning is an impotant phenomena for any external beam radiotherapy practice, beacuse it deals with the precise dose distribution to the patient using patients information provided by physician. The precision of treatment planning dose calculation depends on types and properties of algorithms which were used in the in different steps of the planning process. Now- a- days there are a lots of algorithms are using in the treatment planning process. My study is deals with the Anisotropic Analytical Algorithms (AAA), due to

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its availability in my system. Several reports, including AAPM TG-53, IAEA TRS 430, and NCS Report 15, make recommendations regarding the verification and commissioning of the dose calculation algorithms used in TPS [1, 2].

Patients received radiation therapy with their treatment plans designed and calculated using computer-based Treatment Planning Systems (TPS). The commercial TPS are developed and tested by the manufacturer before implementation. Before the application of TPS to execute a plan for a patient to provide treatment in a radiation therapy center, lots of parameters should have checked by medical physicists like commissioning and the system's calculation check up. Medical Physicists also carry out additional checks when updates are deployed and ongoing quality assurance (QA) of a TPS. The extensive significance of the accuracy of TPS calculations, however, necessitates the employment of additional QA measures because no check can completely cover all aspects of the system [3,4].

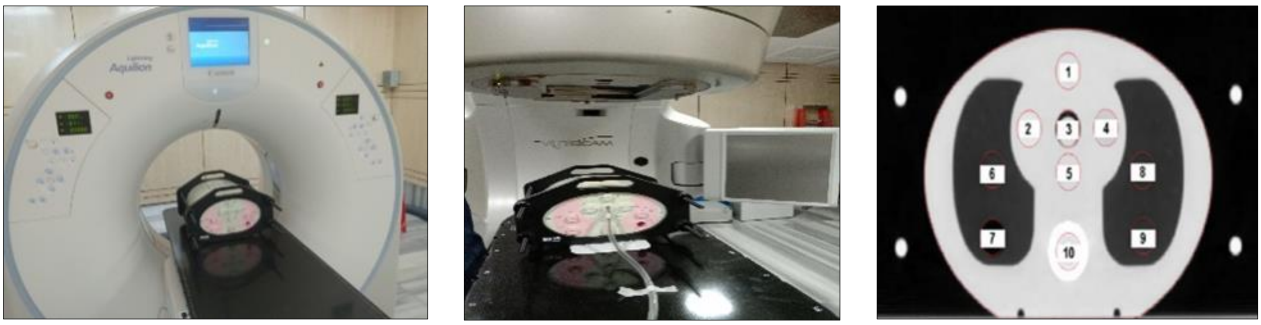
There are several international documents on the aforesaid subject, like International Atomic Energy Agency Technical Reports Series 430 (IAEA TRS430), which suggest categorizing the verifications into benchmark, generic beam, and user's beam data verifications. The American Association of Physicists in Medicine (AAPM) Report 85 and the European Society for Therapeutic Radiology and Oncology (ESTRO) brochure No. 7 are additional materials from different groups. To assist users in confirming the dosimetric accuracy of their systems, the IAEA produced a series of useful clinical tests for TPSs based on the TRS 430 in its TEC-DOC 1583 [5].

The main goal of this study is to Verification of the ability of the dose calculation algorithms to reproduce measured dose calculations using the IMRT Thorax Phantom (CIRS-002LFC) and hence to investigate the deviation between the calculated and measured dose.The current study examined the accuracy and reliability of TPS that followed IAEA TECDOC 1583 while calculating photon doses of various energies during external beam radiotherapy.

2. Materials and methods

2.1. Materials

The study was conducted using a CIRS Thorax phantom (Model 002LFC) at the TMSS Cancer Center in Bogura, Bangladesh. The dosage was measured using a Farmer Type Ionization Chamber (FC65-P). The Canon-Lightning Aquilion CT-simulator has taken four separate scans while holding the chamber in various phantom holes. The Eclipse treatment planning system has been used to implement 46 distinct treatment programs. In this system for treatment planning, anisotropic analytical algorithm (AAA) has been used of Linac, (Varian: true Beam). Additionally, a DOSE-1 Reference Class Electrometer (IBA) was engaged to measure the dose directly into the Gray scale [6].



(a) (b) (c)

Figure 1 a) Thorax Phantom (CIRS Model 002LFC) on CT simulator Couch, b) Linac Couch & c) Plug 1-water equivalent, plug 2- muscle substitute, plug 3 - syringe filled with water, plug 4 - adipose substitute, plug 5 - water equivalent, plug 6 - lung substitute, plug 7 - should be empty to represent air, plugs 8 & 9 - lung substitutes, plug 10- bone substitute

2.2. Protocol

The TECDOC-1583 protocol from the International Atomic Energy Agency has complied with all planning requirements. All test plans have been carried out in accordance with IAEA-TECDOC-1583, Commissioning of Radiotherapy Treatment Planning Systems: Testing for Typical External Beam Treatment Techniques. A variety of fundamental therapeutic methods used in clinical practice have been validated using a set of clinical tests recommended by IAEA TECDOC-1583.

It has been determined how many monitor units are required to deliver the suggested dose of 200 cGy to the reference site.

2.3. Dosimetric test cases

According to IAEA TECDOC, there are eight dosimetric test cases to check the reliability of the TPS algorithm. Generally one dosimetric test case covers the check of several parameters. The position of the measuring point, gantry angle, collimator angle, and field size vary depending on the situation. Due to some unavoidable situations, only four cases have been studied here. For each case, a dose of 200 cGy has been estimated at the reference site.

2.3.1. Case 1: Testing for reference conditions based on CT data

This test's objective is to validate the reference field calculation. The basic beam data has been verified using a 10 cm × 10 cm field with a gantry angle of 0° and a collimator angle of 0°. The center of holes 1, 3, 5, 9, and 10 as well as reference point hole 3 have been designated as the measurement sites.

2.3.2. Case 3: Significant blocking of the field corners

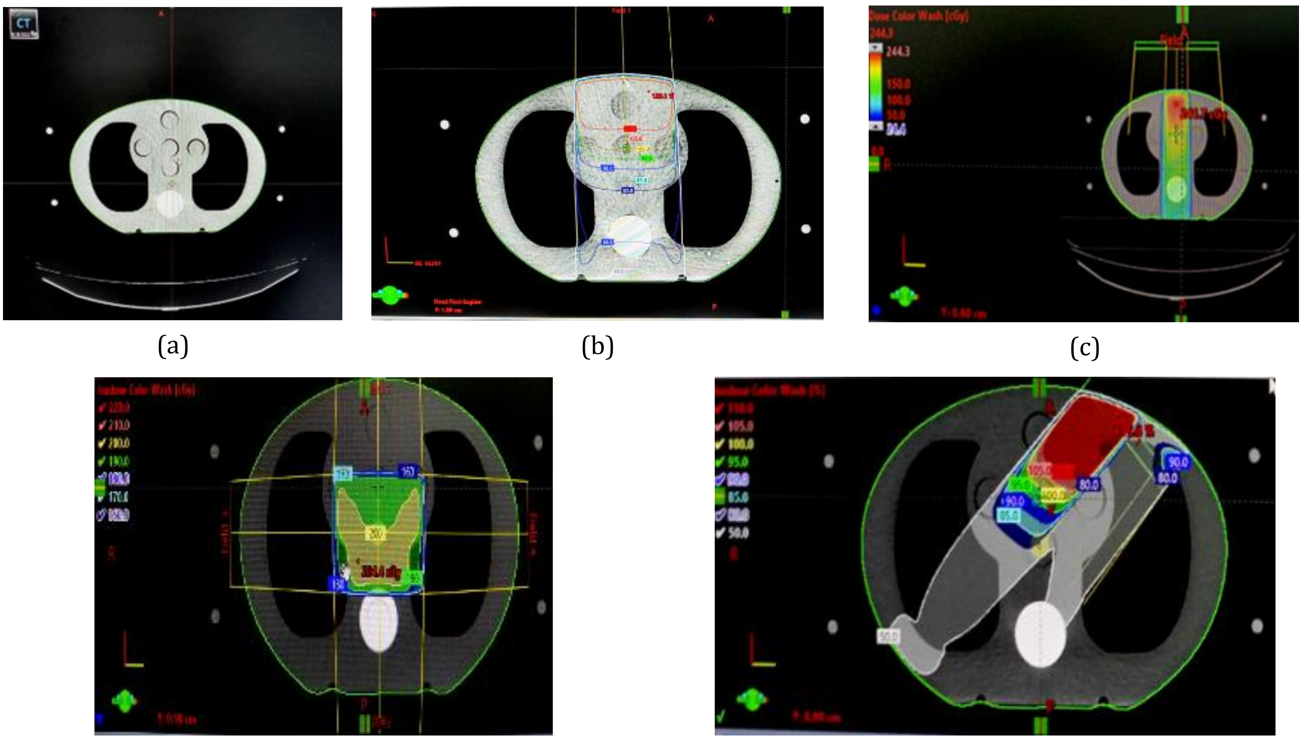
The aim of this test is to validate the blocked field calculation. The MCL has been applied to a field of 14 cm × 14 cm with a collimator angle of 45^0 blocked. When hole 3 is used as the reference point, the measurement point is set in the centre of that hole.

2.3.3. Case 4: Four field box

Many radiotherapy hospitals employ this method, and the goal of this test is to confirm the calculation of the dose delivered by a single beam and the sum of four fields. The middle of holes 5, 6, and 10 have been designated as the parameters and measurement locations, and the four fields are equally weighted.

2.3.4. Case 6: Oblique incidence with irregular field and blocking the centre of the field

This test aims to validate calculations for a field with an irregular field with a field center that has been blocked. The center of hole 5 has been selected as the ISO-Centre. A 20 cm × 10 cm field with a 45° gantry angle and a 90° collimator angle was employed. By enclosing a 6 cm × 12 cm field, an L-shaped field has been formed [7].



(a) (b) (c)

(d) (e)

Figure 2 a) CT Image of CIRS Phantom, Treatment Planning for: b) Case-1, c) Case-3, d) Case-4 & e) Case-6

2.4. Dose and error calculation equation

Dose has been measured by the following equation [8, 9]:

Absorbed dose

$$D_{W,Q} = M_Q \times D_{W,Q} \times K_{T,P} \times Ks \times Kpol \times K_{QQ} \quad \text{...(01)}$$

Where
M_Q=Monitor reading,
$N_{D,W}$=Calibration factor in terms of absorbed dose to water,
K_{TP}=Temperature Pressure correction factor,
K_S=Ion recombination correction factor of an ionization chamber,
K_{Pol}=Voltage polarity correction factor,
$K_{Q,Q}$=Beam quality correction factor

Error has been measured by the following equation [5]:

$$\text{Error [\%]} = \frac{(D_{cal} - D_{meas})}{D_{meas}} \times 100 \quad \text{...(02)}$$

Where
D_{meas} = the measured dose value
D_{cal} = the calculated dose value

3. Results

The findings of the clinical test cases are reported in the sections that follow, with a comparison between measured and computed values in each case. In the majority of four cases, the reference point has been taken into account at hole-3 (body tissue equivalent material), while in case-4, the reference point has been taken into consideration at hole-5, where the applied dose is always 200 cGy. The dose deviations in different points for different cases at different energies are shown graphically in figure 3 for several test situations.

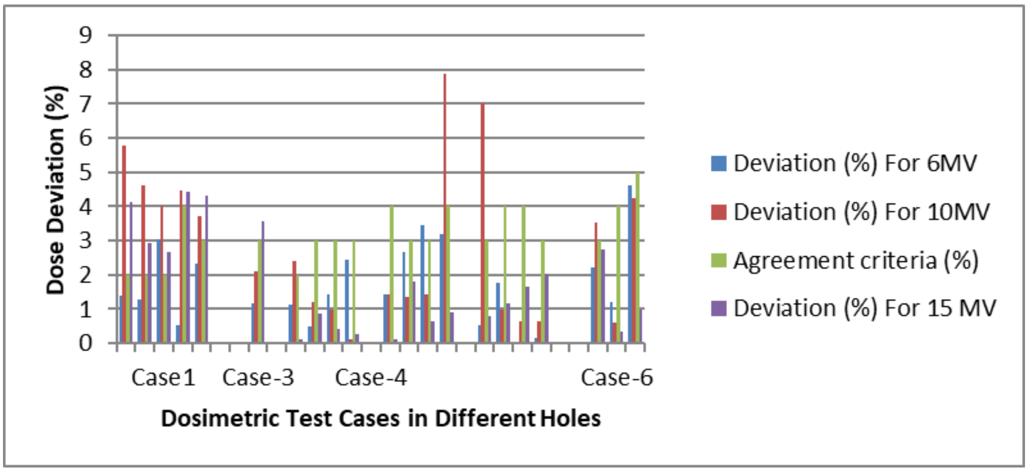


Figure 3 Dose deviations in different points for different cases

Table 1 TPS verification data for case four at point 10 (In the middle of Bone substitute/plug)

6 MV						10 MV			15 MV		
		Cal. Dose (Gy)	**Meas. Dose (Gy)**	**Dev. (%)**	**Cal. Dose (Gy)**	**Meas. Dose (Gy)**	**Dev. (%)**	**Cal. Dose (Gy)**	**Meas. Dose (Gy)**	**Dev. (%)**	**Agreement Criteria (%)**
Four Field Box	F_1	36.3	36.57	-0.53	36.2	39.80	-7.02	40.8	41.20	-0.77	3
	F_2	70.6	69.72	1.77	70.8	71.29	-0.97	68.6	69.19	-1.16	4
	F_3	3.6	3.573	0.05	3.5	3.17	0.65	3.8	2.96	1.64	3
	F_4	3.5	3.573	-0.15	3.5	3.19	0.62	4.0	2.97	2.03	4
SUM		114	113.43	2.5	111.4	102.4	4.25	117.2	116.32	1.4	3

Table 2 TPS verification data for case four at point 6 (In the middle of Lung substitute/plug)

6 MV						10 MV			15 MV		
		Cal. Dose (Gy)	**Meas. Dose (Gy)**	**Dev. (%)**	**Cal. Dose (Gy)**	**Meas. Dose (Gy)**	**Dev. (%)**	**Cal. Dose (Gy)**	**Meas. Dose (Gy)**	**Dev. (%)**	**Agreement Criteria (%)**
Four Field Box	F_1	4.10	3.38	1.42	4	3.28	1.41	3.6	3.59	0.02	3
	F_2	5.60	4.27	2.66	5.6	4.91	1.35	4.6	5.516	-1.80	4
	F_3	64.50	66.21	-3.47	64.5	63.78	1.43	36.5	36.17	0.65	3
	F_4	31.10	32.66	-3.20	31.1	35.04	-7.87	61.6	62.06	-0.90	4
SUM		105.3	106.52	2.69	105.2	107.01	-0.89	102.9	108.25	0.84	3

4. Discussions

Dosimetric characteristics are the most important parameter of a linear accelerator (LINAC) which is a prerequisite before patient treatment by utilizing the Linac beam. Most of the developed countries are using linear accelerator for the treatment of cancer patient according to their socioeconomic status. So, dosimetric verification is necessary to establish the equivalence and minimal discrepancy between the data derived from each treatment system and the data obtained through practical measurements. It has been observed that the discrepancy between estimated and measured doses is in good agreement after comparing dosimetric test cases. The IAEA-TECDOC 1583 protocol states that variations have mostly been shown to be below permissible limits, but sometimes it has been found to be above the acceptable limit [10]. According to figure 3, the cases (Case1-Case 6) are described as follows:

- **Case-1:** In case-1, dose reference point was hole-3 and measured points were hole-3, hole-1, hole-5, hole-9 and hole-10. In that case, for 6MV, all the deviations were found within agreement criteria except hole-5. For only hole-5, deviation was found to be -3.03% which exceeds allowed limit 2%. For 10MV and 15MV, all calculated values were slightly deviated from measured value.
- **Case-3:** In that case, reference point and measured point was hole-3. The deviations (-1.18% & 2.10%) were within agreement criteria (3%) for 6MV and 10MV respectively. For 15MV, deviation (3.55%) slightly exceeds allowed limit (3%).
- **Case-4: T**he differences between the measured and calculated doses were reported on Table 4 for that case. Based on reported data, the deviation between calculated and measured dose was in an acceptable level of accuracy and just in case four (four-field box) in 15MV was slightly exceed the allowed limit (4.2%).
- **Case-6:** In case – 6, all deviations for hole-3, hole-7 and hole-10 were within allowed limit for 6MV. However, for 10MV, only at hole-3 deviation was 3.54% which is slightly greater than permissible limit (3%). For 15MV, all deviations were within the limit.

TPS audit data for case four at point 10 (in the middle of Bone substitute/plug) were shown in Table 1. For 6MV and 15MV, all the deviations were within the agreement criteria for but for 10MV, some deviations have occurred as 7.02% (allowed limit 3%) and 4.25% % (allowed limit 3%). Among four fields, Table 2 shows deviation of 3.47% (allowed limit 3%) was found for gantry rotation 270^0 with fixed collimator angle 0 degree at the energy of 6MV. Most of the cases, dose deviations have been found within the acceptance limit; but in few cases deviations have been found beyond the acceptable level. It may be due to the exact positioning of ionization chamber in the phantom or air gap outside the chamber, scattered dose, field converse or field size, effective point of measurement of ionization chamber in the phantom. However, Algorithm of TPS may need to be updated. The Dosimetric validation of the Radiotherapy Treatment Planning System (RTPS) utilizing the IMRT Thorax Phantom (CIRS - 002LFC) was the main focus of this study, which examined the deviations between the estimated dose and measured dose distribution in the phantom. The process is based on International Atomic Energy Agency TECDOC-1583. In the verification of TPS based on Protocol, the CIRS Thorax phantom is satisfactorily executed.

5. Conclusion

In radiotherapy practices, the computerized treatment planning system's commissioning is crucial. It is an essential phase in the entire radiotherapy procedure. In this study, the absolute dose of each plan is verified along with the dose distribution in the CIRS Thorax phantom (Model 002LFC). It is also calculated and studied how the measured dose differs from the calculated dose. Every piece of data has been properly measured. Four Cases have been selected for this investigation. In the majority of these circumstances, the agreement requirement outlined in IAEA TECDOC 1583 is met with excellent outcomes. The agreement condition has only been violated in a few number of situations. In the discussion segment, the reasons for this inconsistency have been discussed. The dose deviations between measurement and AAA algorithm computation must be within accepted limits according to the IAEA TRS 430 and TECDOC-1583 recommendations. The AAA method of TPS is appropriate for dose computation in heterogeneous media and regions of high density gradient (Lung , bone etc) when using the CIRS Thorax Phantom for external beam radiation. Dose computation of TPS was more accurate for 6MV compared to 10MV and 15MV photon beam. Further study is needed to find out the cause of inaccuracy of dose computation. Finally, this study will help the users to better understand the operational features and limitations of their TPSs i.e. to perform complete QA from CT imaging to dose verification of the Radiotherapy Treatment Planning System of their centers.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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