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Dosimetric Validation of Commissioning Data Validation of Xio Treatment Planning System on a Philips Linear Accelerator

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Abstract

Treatment planning is one of the main steps in radiotherapy. It includes dose, isodose and monitor units (MUs) calculations. The dose calculation is based on algorithms implemented in the treatment planning system (TPS). For a suitable clinical use, these algorithms must calculate the dose as accurately as possible. The aim of this work is the assessment of treatment planning system installed in Aswan Oncology Institute to perform dosimetric validation of various parameters.

Measurements have been performed using existing Elekta linear accelerator, (scanditronix-wellhofer dosimetry) system, and water phantom. A variety of 3D conformal fields were created in Xio TPS on a combined Polymethyl methacrylate (PMMA) phantom and validated against measurements with a calibrated ion chamber. Some of the parameters such as (Tissue phantom ratio (TPR), surface dose, buildup, flatness, symmetry, penumbra, contamination dose) varied including source to surface distance, field size, gantry angle, and depth for all photon and electron energies. The difference between measurements and calculation of flatness and symmetry values at different electron energies were between -0.4% to 1.7% and 6 MV didn't exceed ± 0.8%. The mean difference in value of penumbra of electron beams was -4.97% and 6 MV was ± 5%. TPR and surface dose at 6 MV increased with the field size (FS) increasing. All the resulted difference of measurements and calculation were in agreement with IAEA-TRS430 and Venselaar et al. which didn't exceed ± 2% at flatness, symmetry and ±15% at penumbra. This investigation on dosimetric validation ensures accuracy of Xio TPS thereby improving patient safety.

Keywords: Flatness; Radiotherapy; Penumbra; Dosimetry; Surface dose; Build up

Introduction

Radiotherapy physics is very important for clinical response of tumours and normal tissues exposed to photon beams and electron beams. The treatment planning systems use computation methods to determine dose distribution in patients from external photon beams and electron beams. Advance algorithm is needed in order to achieve quick and accurate calculation of dose distribution for radiation beams. Depending on treatment modality, an optimum algorithm should be selected. Dose calculation algorithms are the most critical software component in a computerized Treatment Planning System. These modules are responsible for the representation correct of dose in patient, and maybe linked to beam time or monitor unit (MU) calculations.

The dose calculation is based on algorithms implemented in the treatment planning system (TPS). For a suitable clinical use, these algorithms must calculate the dose as accurately as possible. The radiotherapy department at Aswan Oncology Institute combines the Clarkson algorithm and the Pencil Beam (PB) algorithm to measurement. It was necessary to verify that algorithm will not introduce the unexpected results in the clinical practice. So, this study is made to compare the two algorithms with measurements (wellhofer-dosimetry system) and reference protocol. The comparisons between algorithms and measurements include from where Beam quality, Surface dose, build-up, flatness, symmetry, penumbra, Contamination dose, buildup region and Absolute dose at different energy (6 MV, 4 MeV, 6 MeV, 8 MeV, 10 MeV, 12 MeV, and 15 MeV) and different field size.

Materials and Methods

In the present study, a Philips-Elekta SL-15 linear accelerator is used. It has two independent tungsten jaws with maximum field size of 40 cm. It provides two photon energies: 6 and 10 MV. The distance from the target to the (X) jaws isSource Collimate Distance (SCDX)=40.9 cm and (SCD y)=27.6 cm for the (Y) jaws. The flattening filter is located at a distance (SED)=15.8 cm from the target (Vendor reference manual) [1,2]. These parameters are used to model the Treatment Machine in the Elekta Xio TPS.

Measurements have been performed using the Scanditronix-wellhofer relative and absolute dosimetry system [3]. Percentage depth dose (PDD) and beam profiles at 6 MV and available electron beams (4 MeV, 6 MeV, 8 MeV, 10 MeV, 12 MeV, and 15 MeV), TPR then calculated, mean energy, surface dose, Symmetry, Flatness, Penumbra, build up region and contamination dose are evaluated.

Dosimetric measurement tools

Beam data were acquired using a computer-controlled radiation field analyzer (Scanditronix-Wellhofer AB, Sweden), a water phantom having the scanning area of dimensions 495 mm × 495 mm × 495

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mm (X/Y/Z) and positional accuracy of ± 0.5 mm [4]. The detectors used in this study were parallel Plate, and CC13 thimble ion chamber (Scanditronix-Wellhofer AB, Sweden) [5,6]. It is recommended to position parallel plate, and thimble ion chambers perpendicular tocentral axis CAX of the beam. OmniPro Accept (Version 6.1) software (Scanditronix-Wellhofer AB, Sweden) was used to control the movement of detectors in water phantom and to analyze the acquired PDD and beam profiles [3].

Experimental setup

In photon measurements, PDD and beam profiles were acquired using different detectors oriented both in parallel and perpendicular direction to central axis (CAX) of the beam for square fields varying from 5 cm × 5 cm to 30 cm × 30 cm defined at 100 cm source to surface distance (SSD) [7]. At the nominal depth of zero, the effective point of measurement of detectors was positioned parallel to the water surface. In electron measurements 6 × 6, 10 × 10, 14 × 14, and 20 × 20 applicators were used, defined at 95 cm SSD (Figure 1)

Percentage depth dose

Photon PDDs were normalized at the Depth of 10 Cm (D10) with 10 cm × 10 cm field after measurement with each detector. Where the electron PDDs were normalized at depth of maximum dose (Zmax) The thimble chamber was positioned accurately in the detector holder and PDDs were obtained by scanning the detector from a depth of 30 cm to the surface of water tank in discrete of 0.5 mm steps for all field settings as mentioned in the previous section. The photon percentage D10, and the value of Zmax, and electron Zmax in water were analyzed using thimble ion chamber.

Beam profile

Beam profiles for different field settings mentioned in experimental setup were measured across the center of the field using thimble ionization chamber in cross-line with a target-to-surface distance of 100 cm. The acquired profiles were normalized at 100% on the CAX of the beam. Cross-line plane profiles for each field along the center of the beam were acquired at Zmax for 6 MV photon beam and 6,8,10, and 12 MeV electron beams. The cross-line profiles acquired using various thimble chamber were analyzed to find the variation in flatness, symmetry, and penumbral width (20% to 80%).

Absolute dose

Electron absolute dose was measured using parallel plate ionization chamber and PMMA (Scanditronix-Wellhofer AB, Sweden) in Zmax and 10 cm under them. IAEA TRS 398 protocol was used to obtain the dose, the ion chamber correction factor (ND,w) was defined by National Institute of Standards(NIS) using Co-60.

Calculating XIO TPS data

A QA water phantom was created on XIO TPS. The phantom's dimensions were set up as 40 × 40 cm^2 and the slices step as 1 cm. Dose Profiles and planar doses from the scanned phantom were exported. Beams data for photon and electrons were set up as in previous measurements, in Figure 2a. Dose Profile can be evaluated across a plane and then exported, in Figure 2b. The dose profiles were used in absolute Normalization mode. The cross-line profiles were analyzed to find the variation in flatness, symmetry, and penumbral. The parameters data were extracted from the Xio planning system, and compared with the same parametersmeasurements. The Analyzed difference is considered as (∂) [8,9].

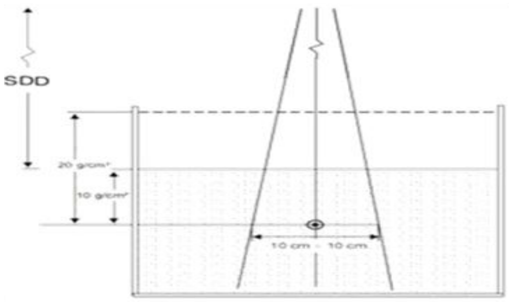

Figure 1: Experimental set-up for the determination of the beam quality index (TPR20,10) , PDD, and beam profile.

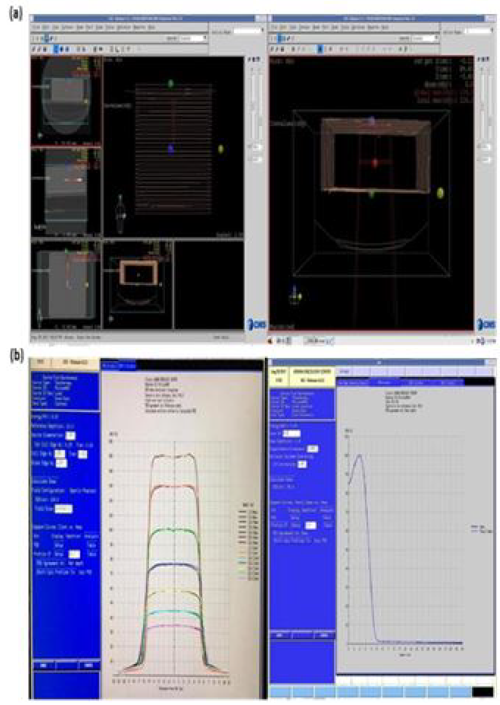

Figure 2: Illustrated - (a) 3-D phantom set up in Xio TPS; (b) Calculation of PDD and beam profile in Xio TPS.

∂=100% (Dcalc.–Dmeas.)/Dmeas.

Dcalc is the calculated dose at a particular point in the phantom; Dmeasis the measured dose at the same point in the phantom. The difference between measurements and calculationcheck with IAEA-TRS430 and Venselaar et al. which was Determining the extent of agreement.

Results and Discussion

One of the major contributions in TPS is the accuracy of dose calculation algorithm. Therefore, it is important to perform various tests to understand the algorithm's limitations. Such tests aim to identify problems and decrease errors in overall patient treatment process. In this study, comparison between dose calculation algorithms (Clarkson and Pencil beam) in common used TPS and measurement (wellhoferdosimetry system) in Aswan Cancer Center was evaluated using TRS430 protocol and Venselaar et al.

The parameters of calculations and measurements are tabulated

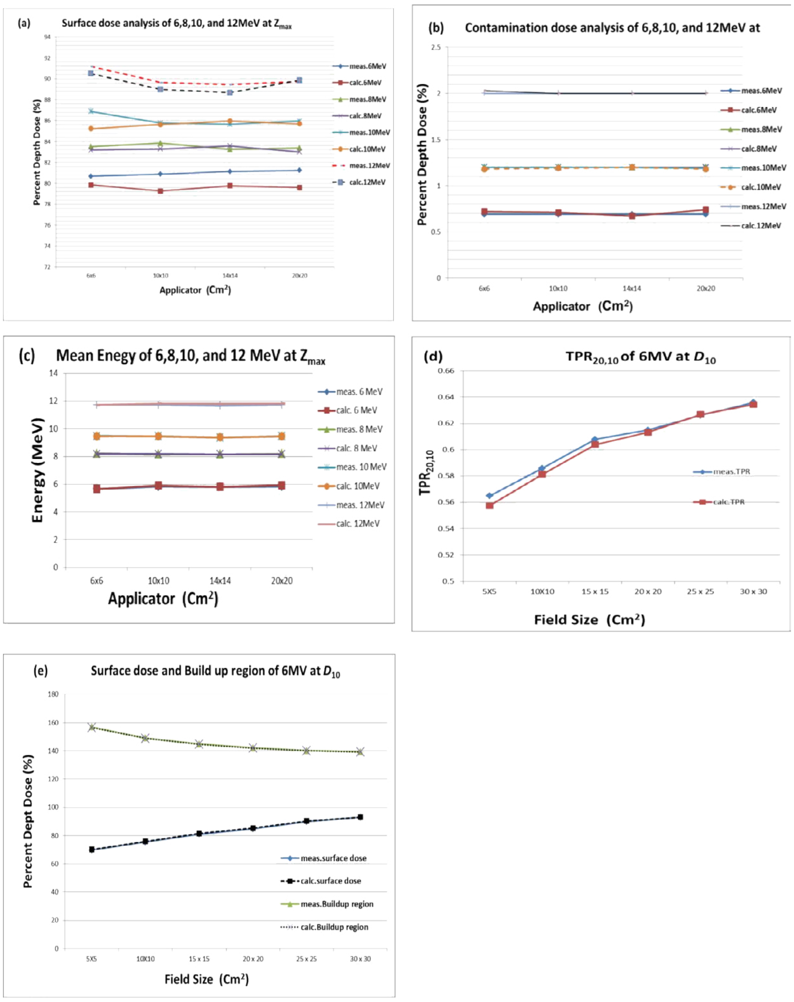

Figure 3: Comparison between measured and calculated by TPS data: (a) surface dose analysis of 6, 8, 10, and 12 MeV at Z_{max}; (b) contamination dose analysis of 6, 8, 10, and 12 MeV at Z_{max}; (c) mean energy of 6, 8, 10, and 12 MeV at Z_{max}; (d) TPR20, 10 of 6 MV at D_{10}; (e) surface dose and build up region of 6, 8, 10, and 12 MeV at D_{10}, respectively.

in Table 1 for all electron energies at Zmax and applicator (6 × 6, 10 ×10, 14 × 14, and 20 × 20). The symmetry data of calculations and measurements was between 98.29% to 100.39%, the average values of difference in measurements and calculations for 8 MeV, 10 MeV, and 12 MeV energy equal 0.67%, 1%, 0.25%, and 0.37%, respectively. But 10 MeV energy at FS (10 × 10) is low to 0.1%, 4 MeV energy at FS (6 × 6 and 20 × 20) equal 1% and FS (10 × 10 and 14 × 14) equal 0.1%, 6 MeV energy at FS (6 × 6 and 14 × 14) equal 1.7% and FS (10 × 10 and 20 × 20) equal 0.2% (Figure 3) (Table 1). With regard to the flatness and penumbra, the values of flatness and penumbra for measurements and calculations were 99.98% to 100.92%, 0.86 Cm to 1.25 Cm, respectively. The average values of difference in Flatness for 6 MeV, 8 MeV, 10 MeV, and 12 MeV energies equal -0.2%, - 0.1%, -0.23%, and -0.43, respectively. 8 MeV energy at FS (10 × 10), the difference value was up to -0.9%. The average values of difference in Penumbra for 6 MeV, 8 MeV, 10 MeV, and 12 MeV energies equal - 8.93%, -9.2%, -8.95%, and -4.8%, respectively. But 6 MeV energy at FS (20 × 20), the value was even to 2.4% (Table 2). All difference in symmetry and Flatness between measurement and calculation of all electron energies were between -0.4% to 1.7% and all difference didn't Exceed ± 2%. As for penumbra, the difference was between -9.8% to 2.4% and all difference didn't Exceed ± 15% (Table 3). The absolute dose data of measurements and calculations was tabulated in Table 2 at FS (10 × 10) for all electron energies. The absolute dose of measurements and calculations was between 99.26% to 101.41% and the difference of absolute dose between them was in ± 2%. When looking at other parameters such as (surface dose, mean energy and contamination dose) of all electron energies at Zmax and applicators (6 × 6, 10 × 10, 14 × 14 and 20 × 20) were illustrated in Figure 3. Shown in Figure 3a was comparison of surface dose values between measurements and calculations of all electrons, the surface dose of measurements and calculations at 6 MeV, 8 MeV, 10 MeV, and 12 MeV was 79.2 to 81.2, 82.8 to 84, 85.2 to 86.8, and 89.2 to 91.6, respectively. The surface dose difference between measurements and calculations for all applicators, maximum difference of 12 MeV were observed in the smaller FS and minimum differences were observed in the larger FS, at 6 MeV, 8 MeV, and 10 MeV were close to each other. But the difference of 10 MeV at FS 6 cm × 6 cm raised. In Figure 3b, the contamination dose of measurement and calculation at 6 MeV was below 1%, 8 MeV and 10 MeV between 1% to 1.2% and 12 MeV was close to 2%. The dose in a patient is contributed by bremsstrahlung interactions of electrons with the collimation system (scattering foils, chambers, collimator jaws, etc.) [3]. This photon contamination creates various doses in electron beams. Typical x-ray contamination doseto a patient ranges from approximately 0.5% to 1% in the energy range of 6

Type	Energy / Applicator	6MeV			8MeV			10MeV			12MeV		
		Meas.%	Calc.%	Diff %	Meas.%	Calc.%	Diff %	Meas.%	Calc.%	Diff %	Meas.%	Calc.%	Diff %
Flatness	6x6	100.36	99.98	-0.4	100.16	100	-0.2	100.12	99.99	-0.1	100.09	100	-0.1
	10x10	100.17	100	-0.2	100.92	100	-0.9	100.29	100	-0.3	100.38	100	-0.4
	14x14	100.07	100	-0.1	100.05	100	0.0	100.06	100	-0.1	100.82	100	-0.8
	20x20	100.12	100	-0.1	100.10	100	-0.1	100.41	100	-0.4	100.39	100	-0.4
Symmetry	6x6	98.29	99.93	1.7	99.38	99.75	0.4	99.1	100.08	1.0	99.5	100.03	0.5
	10x10	99.9	100	0.1	99.50	100	0.5	100.1	100.01	-0.1	100.1	99.97	-0.1
	14x14	99.01	99.98	1.0	99.11	100	0.9	99.2	100.06	0.9	99.78	100.39	0.6
	20x20	99.7	100	0.3	99.1	100	0.9	98.9	100	1.1	100.01	99.99	0.0
penumbra	6x6	0.95	0.86	-9.4	1.08	0.98	-9.3	1.19	1.08	-9.2	1.05	1.03	-1.9
	10x10	0.97	0.89	-8.2	1.07	0.97	-9.3	1.2	1.11	-7.5	1.08	1.02	-5.6
	14x14	0.98	0.89	-9.18	1.05	0.96	-8.6	1.22	1.1	-9.8	1.15	1.07	-7.0
	20x20	0.85	0.87	2.4	1.03	0.93	-9.7	1.18	1.07	-9.3	1.25	1.19	-4.8

Table 1: Comparison of values between measurements and calculations at some parameter for all electron energies.

Energy	Depth	SSD	PDD	N_{DW}	Dose meas.	Dose calc.	Diff. %
4mev	0.9 PMMA	100	98	5.141	101.19	100	-1.1
6mev	1.1 PMMA	100	99.3	5.141	101.08	100	-1.06
08 Mev	1.6 PMMA	100	100	5.141	99.26	100	0.74
10 Mev	1.8 PMMA	100	100	5.141	100.74	100	-0.73
12 Mev	2.1 PMMA	100	100	5.141	101.41	100	-1.4
15 Mev	2.8 PMMA	100	99.9	5.141	101.17	100	-1.2

Table 2: Shows parameters and absolute dose for all electron energies at 10 × 10 field size.

Type / Field size	Flatness			Symmetry			Penumbra		
	Meas.%	Calc.%	Diff %	Meas.%	Calc.%	Diff %	Meas.	Calc.	Diff %
5X5	100.47	100.16	-0.3	100.39	100.09	-0.3	0.66	0.7	6.1
10X10	100.97	100.56	-0.4	100.32	100.02	-0.3	0.72	0.75	4.2
15 x 15	100.88	100.93	0.05	99.58	99.97	0.4	0.78	0.72	-7.7
20 x 20	100.98	100.94	0.04-	99.75	100	0.3	0.73	0.7	-4.1
25 x 25	101.45	101.46	0.01	99.58	99.98	0.4	0.75	0.73	-2.7
30 x 30	101.68	101.61	-0.1	99.17	100	0.8	0.69	0.72	4.7

Table 3: Comparison of values between measurements and calculations at some parameter for 6 MV.

to 12 MeV; 1%to 2%, from 12 to 15 MeV; and 2% to 5%, from 15 to 20 MeV [10,11]. The difference between measurement and calculation was venial. Figure 3c shows that the difference between measurement and calculation at energy of electron beam was venial. The values of electron energies were very near to required value for energy. TPS calculations and measurements were yielded to some test toward photon which were tabulated in Table 3 and figured in Figure 2 at Zmax and different field size. In Table 3 the values of measurements and calculations of flatness, symmetry and penumbra were from 100.16% to 101.68%, 99.17% to 100.39%, and 0.66 cm to 0.78 cm, respectively. The difference values of flatness between measurement and calculation were from -0.04% to 0.05%, symmetry was from -0.3% to 0.8% and penumbra was -7.7% to 6.1%. In Figure 3d, the TPR was between 0.56 to 0.64, it is small in small field size and it increases with increasing field size, due to Challenges with small field dosimetry including lack of charge particle equilibrium, partial volume averaging, and positioning accuracy [12]. The difference between measurement and calculation was maximum in small field size and minimum in large field size. Figure 3e shows, the surface dose and build-up region of measurements and calculations at Zmax for 6 MV, surface dose values increase with increasing field size, Due to Photons scattered from the collimators, flattening filter, air and High-energy electrons produced by photon interactions in air [1]. The difference of surface dose between measurement and calculation was slight. The dose of measurements and calculations in build-up region was large in small field size and small in large field size and the difference between measurement and calculation was very small.

Conclusion

All results of difference of flatness, symmetry penumbra and contamination at 6 MV and electron beams were less than ± 2%, ± 2%, ± 15%, and ± 30%, respectively.2.4 TPR and surface dose increase with increasing field size.1 Thus, Xio TPS commission was successfully verified on dosimtric measurements.

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