Characterization and Dosimetry of 15-MeV Electron Beam from Elekta Synergy Platform Linear Accelerator Using Square Field Applicators

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Abstract

Background: Ionizing radiations from linear accelerators to deliver radiation therapy for cancer patients in India are being used for more than five decades. The study involves the use of various recommendations and protocols for dosimetric verification and characterization of the electron beam of 15-MeV from the Elekta Synergy platform linear accelerator.

Introduction: This study aimed to present the dosimetric characteristics of the absolute dose to water from the Elekta Synergy platform linear accelerator using the reference dosimetry technique with plane-parallel ionization chambers for an electron beam of energy 15-MeV. This article describes the verification of the percent depth dose (PDD) and beam profile (In-plane and Cross-plane) of the electron beam.

Methods and materials: The experimental setup comprise an Elekta Synergy platform linear accelerator and a dosimetry system containing water phantom and assembly of reference dosimetry. The plane-parallel ionization chamber and digital electrometer were coupled with the experimental phantom. The measurements were performed using the radiation field analyzer (RFA) system under AERB-Mumbai protocols.

Results and Discussion: It was the inference that the Elekta Synergy platform linear accelerator is more efficient and reliable rather than other conventional linear accelerators because of its online imaging technology to perform intensity-modulated and image-guided radiation therapy. The value of R_{50} for the 15 MeV electron beam obtained from the PDD curve is found to be 59 mm. The TPS calculated value of absolute dose to water for 15 MeV electron beam was 1.0000 NC/MU.

Conclusion: It is concluded that the clinical utilization range of 15 MeV electron beam from Elekta Synergy platform linear accelerator was 2-5 cm.

Keywords: Ionizing Radiation, Percent Depth Dose, Beam Profile, Absolute Dose.

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INTRODUCTION

Ionizing radiations from linear accelerators to deliver radiation therapy for cancer patients in India are being used for more than three decades [1]. There was a long journey of radiation therapy from a commercial x-ray machine assembled by Emil Herman Grubbe to Elekta Synergy platform linear accelerators capable of online imaging technology [2]. A medical electron linear accelerator is an important piece of equipment in radiotherapy departments clinically worldwide. Elekta Synergy Platform Linear Accelerator is released by Elekta Oncology Systems, Crawley, the UK which can deliver Photon and Electron energies. Elekta Synergy platform linear accelerators are capable to operate in both photon and electron beam mode with three (6, 10, and 15 MV) photon energies and six (4, 6, 8, 10, 12, and 15 MeV) electron energies with online imaging of the target volume to deliver radiation therapy for patients [3].

The basic principles of radiation therapy are based on the understanding of radio-biological properties i.e. radiosensitivity of cancer cells and administration of radiation dose within uncertainties ±5% to the treatment site. The requirement that must be full-filled in radiation therapy is the accuracy in the delivery of the dose. As per ICRU reports, IAEA and TRS-381 recommendations all uncertainties in the treatment should be less than ±5% for all treatment techniques. In this regard, the machine has to be

calibrated for all radiation beams to verify the dose before starting the treatment of patients [4-5].

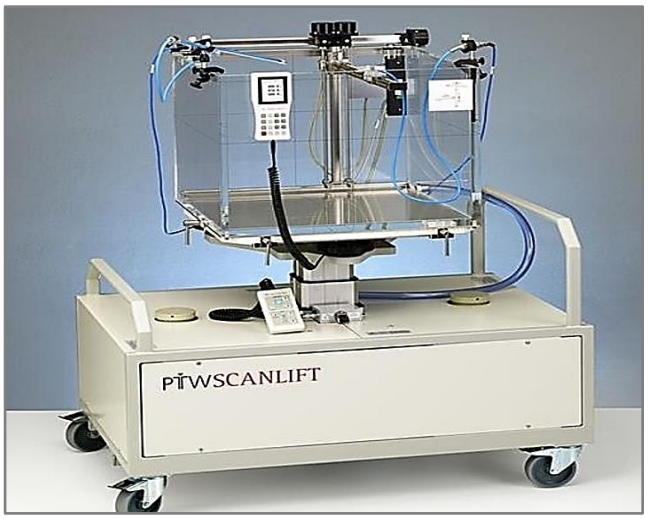
This study is based on the dosimetric characterization of the electron beam from a linear accelerator to determine the parameters absorbed dose to water and beam profile using quality of beam and correction factors. However, the measured dose is influenced by several other factors such as measuring instruments, various protocols, and environmental conditions [6]. This article deals with the percent depth dose (PDD) curve, dose profile, absolute dose, and its analysis for an electron beam of 15 MeV from the Elekta Synergy platform linear accelerator [7].

Methods and Materials

The experimental set-up used for measurements comprised a linear accelerator (make and model: ELEKTA, Synergy platform) shown in figure 1(a) and a water phantom designed for reference dosimetry as shown in fig 1(b). The measurements for percent depth dose and beam profile were performed at SSD 100 cm at the dose rate of 100 MU using an electron beam of 15 MeV and square field applicators of sizes 6x6 cm^2 to 20x20 cm^2 [8].

The process of dosimetry has been carried out using a radiation field analyzer (RFA) through reference dosimetry. A PTW-Freiburg parallel plate ionization chamber (waterproof with cap, Model TM 23343) with a sensitive volume of 0.055 cm^3 and a semi-flex chamber (waterproof with cap, Model TM 30010) with a sensitive volume of 0.125 cm^3 both coupled with a digital electrometer (PTW UNIDOSE) were used [9, 10]. The experimental water phantom was assembled in a cubical box of transparent glass measuring 50x50x50 cm^3 filled with water and placed on the treatment board. However, to fulfill the protocols of TRS 381 some other devices such as an alignment system, ionization chamber holders with scale, and water level adjusting water supply are also fitted with the chamber box [5].

Figure 1(a): Elekta Synergy Platform Linear Accelerator



1(b): Experimental phantom with Dosimetry system

Results and Discussions

The percent depth dose (PDD) curve for the relative dose of the beam obtained from the measurements shows that at a depth of 59 mm the value of the absorbed dose in the phantom is reduced to 50% as given in figure 2. The percent depth dose data presented in table 1 form of build-up region, D_{max} region, slope region, and tail region depending upon the variation of dose with depth [8].

Table 1: Output factors for the electron beam of 15 MeV using applicator size 10x10 cm2, dose rate 100 MU, and SSD 100 cm in an experimental water phantom

Build-up Region		D_{max} Region		Slope Region		Tail Region	
Depth (mm)	Dose (%)	Depth (mm)	Dose (%)	Depth (mm)	Dose (%)	Depth (mm)	Dose (%)
2	92	6	96	40	95	68	20
5	95	26	100	59	50	72	10 %

The relative dose in the build-up region up to a depth of 5 mm increases to 95% due to the scattering effects, however, the depth for the maximum dose is 26 mm after that dose drops off linearly in the slope region up to 65 mm [11]. The value of R_P, is the depth of practical range of the dose delivered in the tail region of 72 mm as shown in figure 2 for the electron beam under consideration.

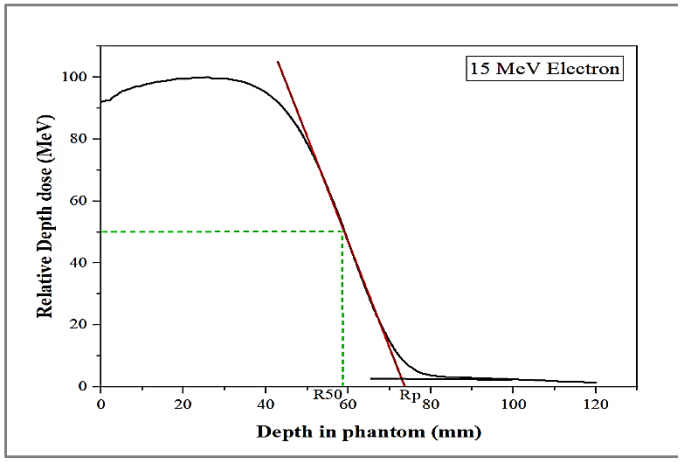


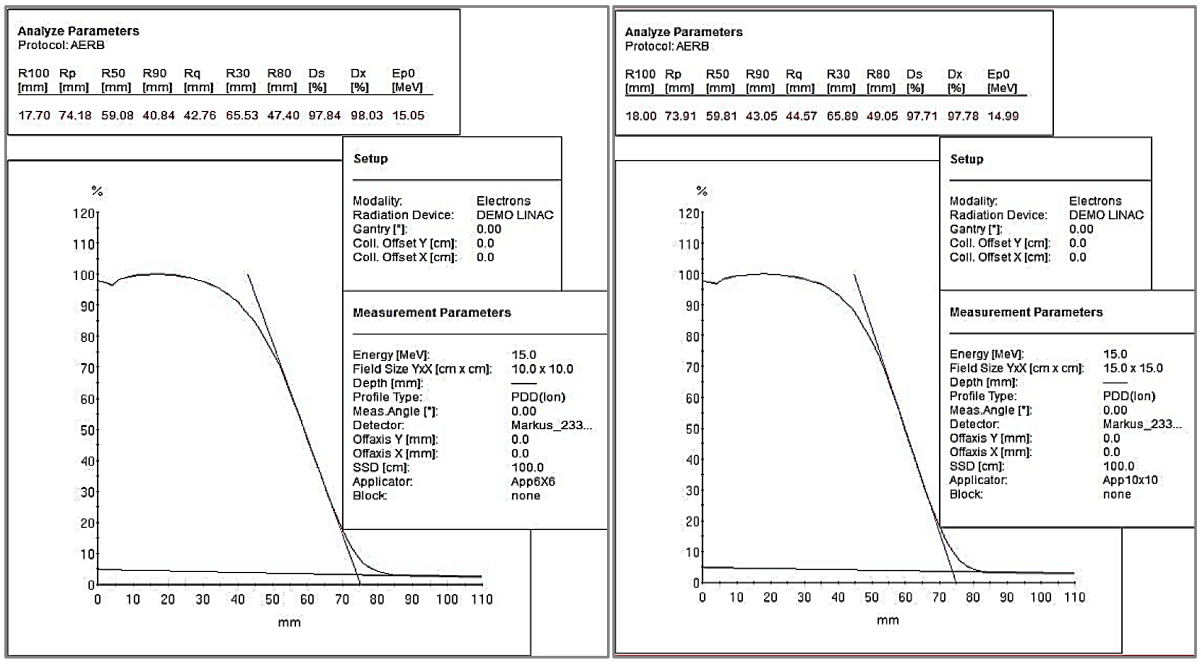
Figure 2: Percent Depth Dose (PDD) curve for electron beam of 15 MeV using applicator size 10x10 cm2, dose rate 100 MU, and SSD 100 cm in water phantom

The measured values of the percent depth dose for the electron beam of 15-MeV using the square field applicators of sizes 6x6, 10x10, 14x14, and 20x20 cm^2 tabulated in table 2 show the variation in the different parameters. The values of R_{100} are 17.70 mm, 18.00 mm, 19.80 mm, and 16.30 mm for the field sizes from 6x6 to 20x20 cm^2 found to be highest for the applicator of size 14x14 cm^2 and least for the applicator size of 20x20 cm^2.

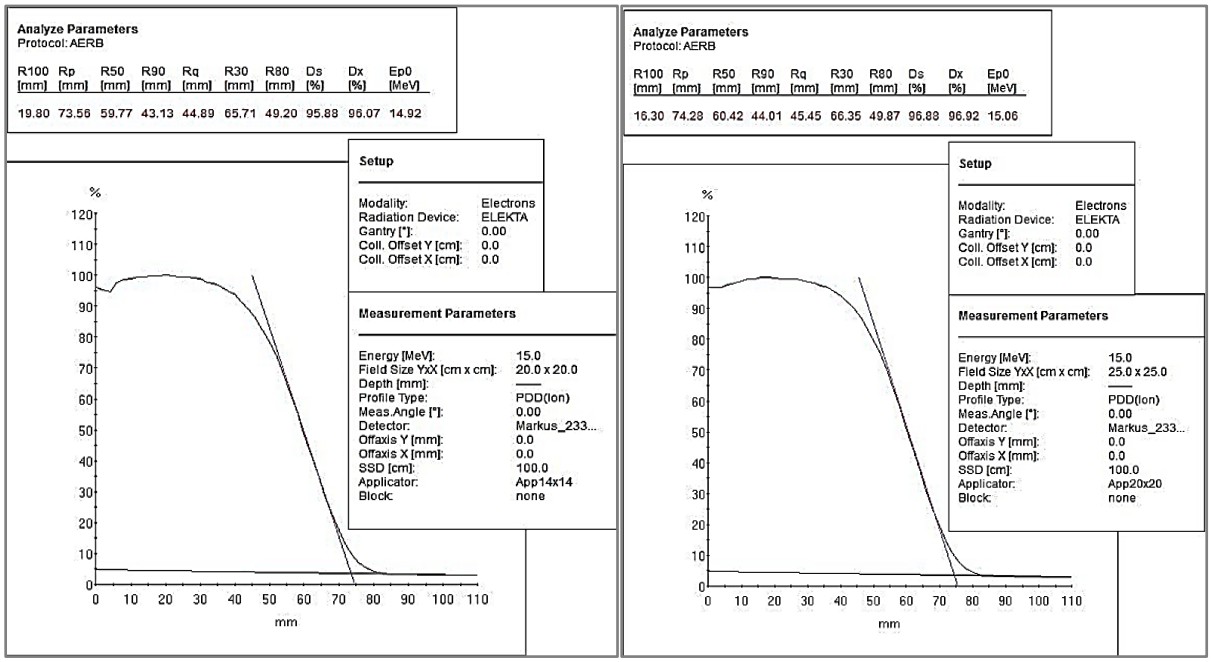
Table 2: Representation of the different measured values of range for the electron beam of 15-MeV with the variation of applicator size using AERB Protocols.

Applicator Size (cm^2)	R_{100} (mm)	R_p (mm)	R_{50} (mm)	R_{90} (mm)	R_q (mm)	R_{30} (mm)	R_{80} (mm)	D_s (%)	D_x (%)	E_{p0} (MeV)
6x6	17.70	74.18	59.08	40.84	42.76	65.23	47.40	97.84	98.03	15.05
10x10	18.00	73.91	59.81	43.05	44.57	65.89	49.05	97.71	97.78	14.99
14x14	19.80	73.56	59.77	43.13	44.89	65.71	49.20	95.88	96.07	14.92
20x20	16.30	74.28	60.42	44.01	45.45	66.35	49.87	96.88	96.92	15.08

However, the values of Rp, R_{50}, R_{90}, R_q, and R_{30}, and change in an irregular manner with increasing the applicator sizes from 6x6 cm^2 to 20x20 cm^2, the values of R_{80} increase in a regular manner with increasing the applicator sizes from 6x6 cm^2 to 20x20 cm^2.



(a) (b)



(c) (d)

Figure 3: Representation of percent depth-dose (PDD) for 15-MeV Electron Beam in a water phantom for the square field applicators of size (a) 6x6, (b) 10x10, (c) 14x14, and (d) 20x20 cm^2

The values of the relative surface dose (D_s), relative dose at a depth (D_x), and E_{p0} do not vary linearly with changing the applicator sizes from 6x6 cm^2 to 20x20 cm^2 and the least values of the relative surface dose (D_s), relative dose at a depth (D_x), and E_{p0} are 95.88%, 96.07%, and 14.92 MeV for the applicator of size 14x14 cm^2 and highest values are 97.84%, 98.03% and 15.08 MeV for the applicators of sizes 6x6 cm^2 and 20x20 cm^2 respectively.

The percent depth dose curves shown in figure 3(a-d) for the electron beam of 15-MeV are plotted using the field sizes of 10x10, 15x15, 20x20, and 25x25 cm^2 using the external field applicators of sizes 6x6, 10x10, 14x14, and 20x20 cm^2.

The absolute dose for the electron beam for the reference depth of maximum dose at 34 mm is 1.0009 NC/MU for the dose rate of 100 NC/MU as shown in table 3. However, TPS calculated value was 1.0000 NC/MU for the applicator of size 10x10 cm^2 [12]. The deviation of the observed value from the TPS calculated value of the dose is very small and less than ±2% as recommended by the protocols of TRS-381 [5, 10].

Table 3. Experimental results for absorbed dose to water using reference dosimetry for 10x10 cm2 applicator at 100 cm SSD.

Field size (cm^2)	Z_{ref} (mm)	Absolute dose (NC/MU)	TPS Calculated dose (NC/MU)
10 x10	34	1.0009	1.0000

The beam profile for the electron beam with field applicators of sizes 6x6 cm^2 to 20x20 cm^2 plotted as shown in figure 4 was symmetrical [12]. The variation of relative absorbed dose to the water phantom using the field applicators 6x6 cm^2 10x10 cm^2, 14x14 cm^2, and 20x20 cm^2 is uniform which indicates that throughout the clinical range the percent depth dose was uniform and useful for the clinical applications [13].

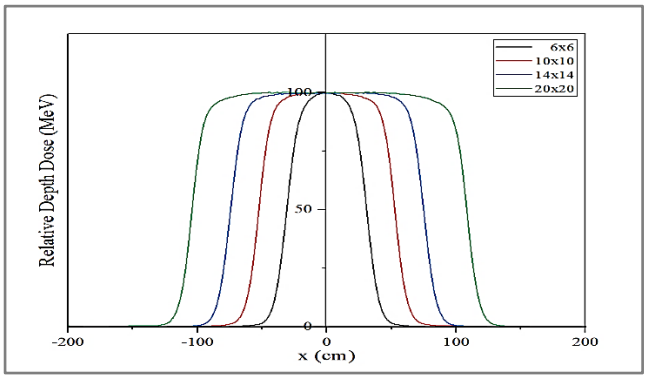


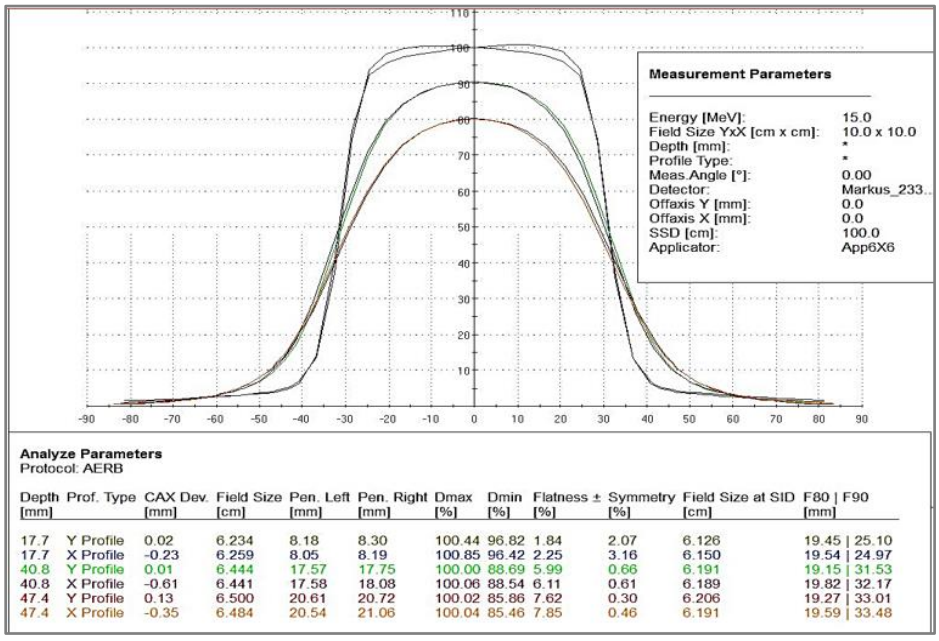
Figure 4. Beam profile for electron beam of 15-MeV at SSD 100 cm and applicator 10 x10 cm^2 at a dose rate of 100 MU

The dose parameters of cross-plane and in-plane beam profile of the electron beam of 15-MeV for the applicator sizes of 6x6, 10x10, 14x14, and 20x20 cm^2 are described in table 4 and plotted in figure 5. The dose parameters of beam profile CAX deviation, beam penumbra of left and right side, maximum and minimum dose, beam flatness, beam symmetry, and field size at SID are evaluated and tabulated in table 4.

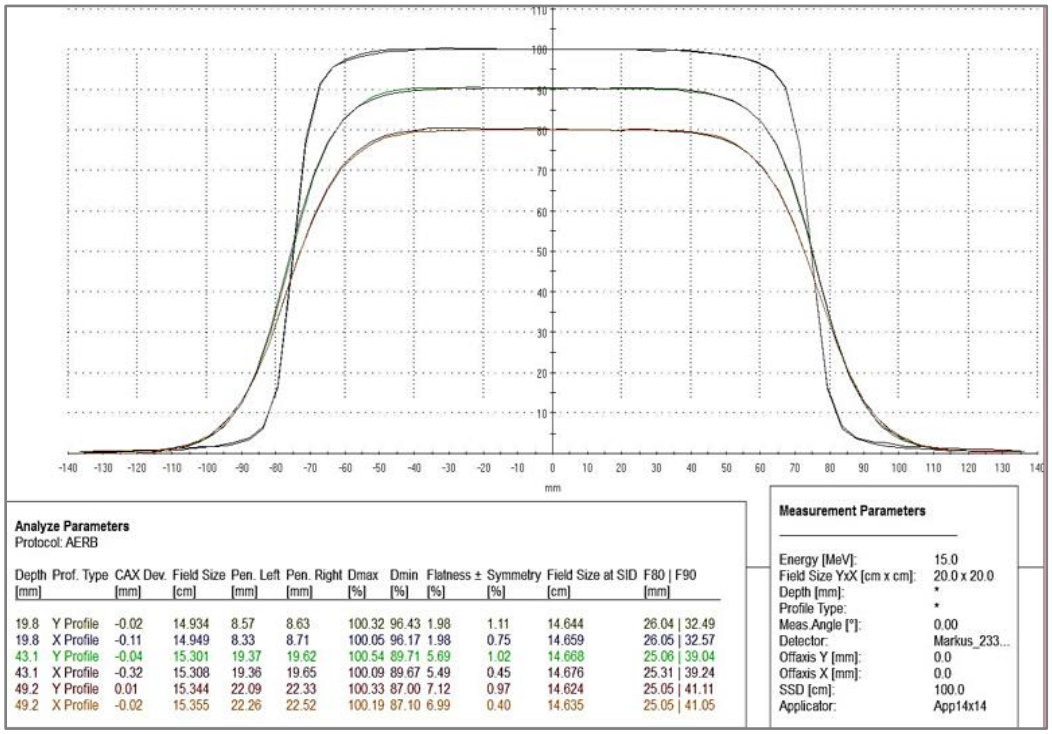
Table 4: Representation of the different measured variables for the electron beam of 15 MeV at the depth of 43 mm with the variation of applicator size using AERB Protocols.

Applicator Size (cm^2)	Profile Type	CAX Dev. (mm)	Pen. Left (mm)	Pen. Right (mm)	D_{max} (%)	D_{min} (%)	Flatness (%)	Symmetry (%)	Field Size at SID (%)
6x6	Y Profile	0.01	17.57	17.75	100.00	88.69	5.99	0.66	6.191
	X Profile	-0.61	17.58	18.08	100.06	88.64	6.11	0.61	6.189
10x10	Y Profile	0.32	18.61	18.78	100.41	89.54	3.44	0.38	17.645
	X Profile	-0.25	18.97	18.99	100.32	90.31	3.25	0.29	18.121
14x14	Y Profile	-0.04	19.37	19.62	100.54	89.71	5.69	1.02	14.668
	X Profile	-0.32	19.36	19.65	100.09	89.67	5.49	0.45	14676
20x20	Y Profile	0.42	19.80	19.92	100.75	95.22	2.82	0.49	21.085
	X Profile	-0.26	19.72	20.05	100.48	95.09	2.76	0.30	21.122

The beam flatness and symmetry values in x-profile and y-profile are not changing in a definite manner with the highest and lowest values of 6.11%, 2.76%, and 1.02%, 0.30%. However, the field sizes at SID are increasing with increasing the applicator sizes in both x-profile and y-profile from 6.189% to 21.122% and 6.191% to 21.085 respectively. There are no appreciable changes in the left and right beam penumbra with increasing the filed applicator sizes from 6x6 to 20x20 cm^2.



(a)



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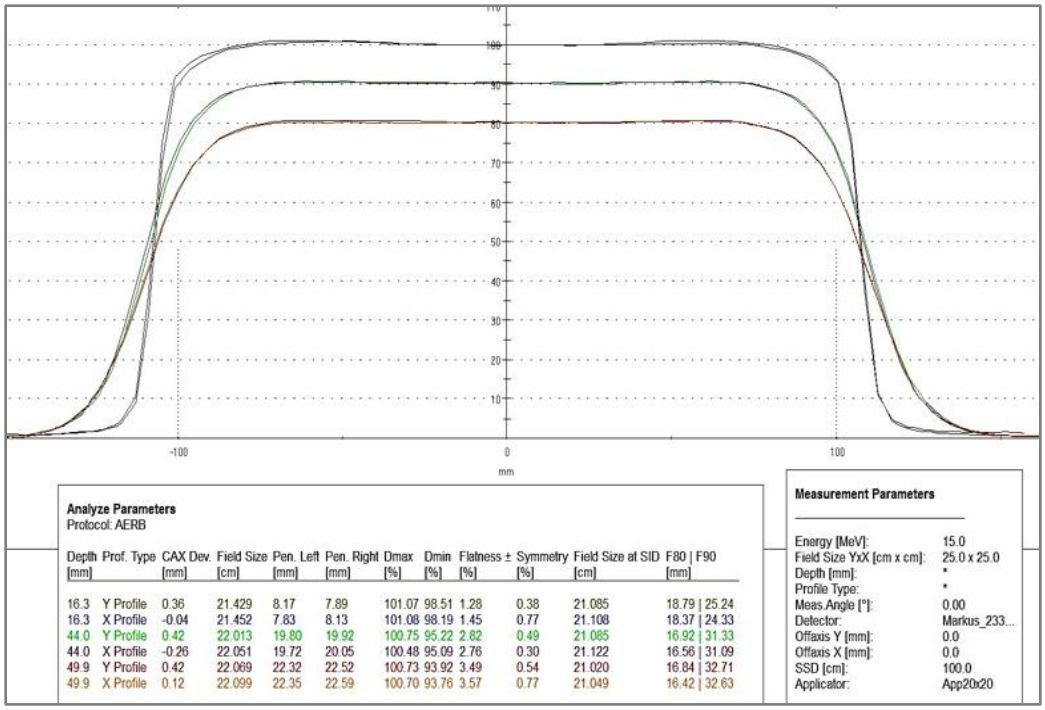

(c)

Figure 5: Representation of measured in-plane and cross-plane beam profile for 15-MeV Electron Beam for square field applicators of sizes (a) 6x6, (b) 14x14, and (c) 20x20 cm^2 at D_{max}, R_{90}, and R_{80} in water

Conclusions

In this study, the authors have presented the commissioning and verification of a 15-MeV electron beam from the Elekta Synergy platform linear accelerator. The values of relative surface dose (D_s) are 97.84%, 97.71%, 95.88%, and 96.88%, and phantom doses at the depth are 98.03%, 97.78%, 96.07%, and 96.92% with the least values for the applicator size of 14x14 cm^2 and highest on the surface of the phantom with values 97.84% and 98.03% respectively. However, the values

of E_{p0} do not vary appreciably the applicator size. All the measurements are taken for the depth of 43 mm and it is found that the highest values of D_{max} in x-profile and y-profile are 100.48% and 100.75% for the applicators of sizes 20x20 cm^2 respectively. The lowest values of D_{min} in x-profile and y-profile are 88.64% and 88.69% for the applicators of sizes 6x6 cm^2 respectively. The dosimetric characterization of the beam for PDD and beam profile have been analyzed using reference dosimetry. It was concluded that the clinical utilization range of 15 MeV electron beam from Elekta Synergy platform linear accelerator was 2-5 cm.

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