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Dosimetry of absolute dose to water from elekta synergy platform linear accelerator using clinical electron beam

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***Abstract*---**The use of electron beams in external beam radiation therapy started in 1930 but was limited to very few medical centers due to manual calculations of dose. The development of Van de Graaff generators, Betatrons, and various generations of commercial linear accelerators led to Elekta Synergy platform linear accelerators which were capable of performing dose calculations using computer software. In the present paper, we present a study on dose calculations for electron energies in the range of 4-15 MeV. This study was pursued following the recommendations of the International Commission on Radiation Units and Measurements (ICRU) and International Atomic Energy Agency (IAEA) reports and protocols of the international code of practice TRS-381. It is based on an experimental setup using a radiation field analyzer (RFA). This comprises of PTW-Freiburg Parallel plate ionization chamber (waterproof with cap, Model TM 23343) with a sensitive volume of

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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). The measurements were performed on a linear accelerator (Make & Model: ELEKTA, Synergy Platform). The applicator sizes were 6x6 cm^2, 10x10 cm^2, 14x14 cm^2 and 20x20 cm^2 for the measurements of all-electron energies. Electron beams of energies 4 MeV–15 MeV were acquired for specific reference depths of measurements for specific energies and recorded for further analysis. A rapid drop-off was recorded in the absorbed dose after a certain depth for the electron beams of energies 4 MeV-15 MeV. Relatively greater absolute doses were recorded for the 10x10 cm^2 field applicator at the reference depths of measurement for electron energies in the range 4 MeV-15 MeV.

***Keywords*---**Electron beam, Absolute dose, Percent depth dose, Ionization chamber, Water phantom.

Introduction

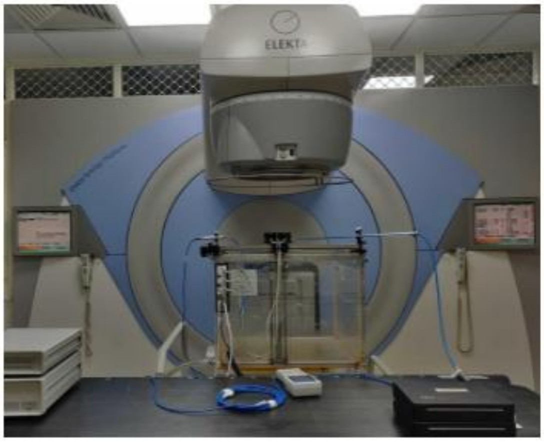
External Beam Radiation Therapy (EBRT) remains one of the most common treatment modalities for curing patients suffering from various types of cancers from the beginning. At present, more than 50% of cancer patients around the world suffering from various types of malignancies are treated with radiation therapy [1, 2]. The basic requirement that must be fulfilled in radiation therapy is the accuracy in the delivery of the dose. International Commission on Radiation Units and Measurements (ICRU) Report No. 24 that uncertainties in the determination of absolute dose to the tumor site in a patient's body should be ±5% in delivery of external beam radiation therapy to the target volume [3]. Emerging modern technologies of radiation therapy have fulfilled the need for high accuracy in the delivery of doses because of their diagnostic tools. [4-8].

Here we present a water phantom study based on TRS-381 recommendations to determine the absolute dose of clinical electron beams using reference dosimetry techniques for various energies of electrons available in the Elekta Synergy platform linear accelerator [9]. Elekta Synergy platform linear accelerator is an advanced version capable to operate in photon beam as well as electron beam modes. It delivers three photon energies 6, 10, and 15 MV, and six electron energies 4, 6, 8, 10, 12, and 15 MeV. Elekta Synergy platform linear accelerator can be operated with different applicators up to the size of 26x26 sq. cm [10]. The present study deals with percent depth dose (PDD) curves, dose profile, absolute dose, and their analysis [11].

Materials and Methods

The measurements were performed on a linear accelerator (Make & Model: ELEKTA, Synergy Platform). The applicator sizes were 6x6 cm^2, 10x10 cm^2, 14x14 cm^2 and 20x20 cm^2 for the measurements of all-electron energies. The experimental setup for the study uses a radiation field analyzer as shown in Figures 1(a) and 1(b).

This comprises of PTW-Freiburg parallel plate ionization chamber (waterproof with cap, Model TM 23343) with a sensitive volume of 0.055 cm^3 (figure 2(a)) and a semi-flex chamber (waterproof with cap, Model TM 30010) with a sensitive volume of 0.125 cm^3 as reference chamber (figure 2(b)), both coupled with a digital electrometer (PTW UNIDOSE) (figure 2(c)) [9, 11] The parallel plate chambers are used to measure radiation dose up to the surface in solid phantoms and the protection cap enables it for the measurements in water phantoms [12].
The semi-flex chamber (Model TM 30010) is the most common ionization chamber due to spatial resolution and precise dose measurements in water phantoms. It gives a flat angular response and uniform spatial resolution about the geometrical axes of the water phantom due to its spherical sensitive volume [9].



(a) (b)

Fig. 1(a) Elekta Synergy Platform Linear Accelerator and (b) Experimental Phantom with Ionization chamber

(a)

(b)

(c)

Fig. 2(a) Parallel Plate Ionization Chamber, (b) Semi flex Ionization Chamber and (c) UNIDOS® E Universal Dosimeter

The measurements were taken under the protocols of international codes of practice TRS-381 [9, 13]. The source to surface distance (SSD) was kept as 100 cm. The applicator size varied from 6x6, 10x10, 14x14 to 20x20 cm^2 for arbitrarily chosen reference depth of measurements 9, 13, 18, 22, 28 to 34 mm. Absolute doses were measured for the electron beams of energies 4, 6, 8, 10, 12, and 15 MeV in a water phantom to finally verify the measured PDD [14-16].

Results and Discussion

The doses deposited to the water phantom by electron beams generated from the Elekta Synergy platform linear accelerator are measured and analyzed by RFA. The PDD curves and hence absolute dose at the reference depths of measurements Z_{ref} are chosen under the protocols of TRS-381. The variation in absolute dose measured from the medical linear accelerator was within the tolerance limits of TRS-381 protocols [9, 17]. The PDD curves thus obtained for various energies of electrons are shown in figure 3 which illustrate a rapid drop off in absorbed dose after the depth of 5 mm for 4 MeV and approximately 35 mm for 15 MeV energies of the electron beams.

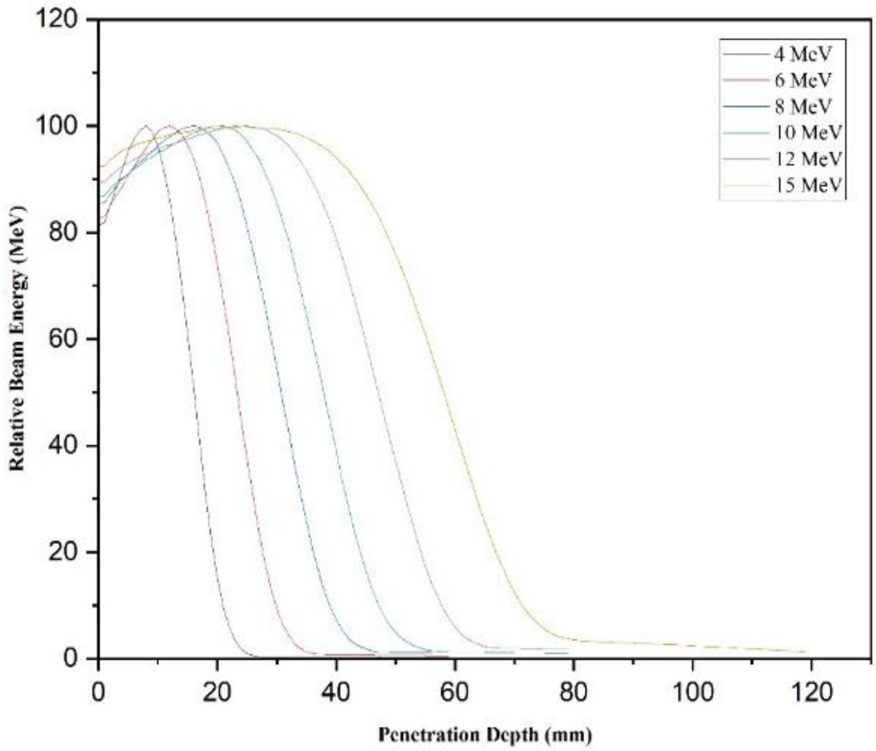


Fig. 3 Percent Depth Dose (PDD) curves for Electron Beam of 4-15 MeV from Elekta Synergy Platform Linear Accelerator

However, the depths of maximum dose for electron beams of higher energies were also higher [18]. It is also evident from the PDD curves that as beam energy increases, the flatness of the curve also increases, which shows an increase in penetration depth.

Table 1
Experimental data for calibration of clinical electron beam for SSD 100 cm for field size 6x6 cm^2, 10x10 cm^2, 14x14 cm^2, and 20x20 cm^2 at the dose rate of 100 MU

Sl. No.	Beam Energy (MeV)	Ref. Depth Z_{ref} (mm)	Absolute Dose (Gy) 6x6	Absolute Dose (Gy) 10x10	Absolute Dose (Gy) 14x14	Absolute Dose (Gy) 20x20
1.	4	9	1.0123	1.0008	1.0005	0.9977
2.	6	13	1.0006	1.0005	0.9955	0.9854
3.	8	18	0.9872	1.0005	0.9879	0.9779
4.	10	22	0.9702	1.0001	0.9970	1.0004
5.	12	28	0.9212	1.0003	0.9927	0.9987
6.	15	34	0.8175	1.0009	1.0369	1.0337

The electron beams of energies 4 MeV and 6 MeV at the reference depth of measurement Z_{ref} 9 mm and 13 mm, absolute doses vary from 1.0123 Gy to 0.9977 Gy and 1.0006 Gy to 0.9854 Gy respectively for square applicators of size 6x6 cm^2 to 20x20 cm^2. The electron beams of energies 8 MeV and 12 MeV gives the maximum absolute dose of 1.0005 Gy and 1.0003 Gy respectively for a 10x10 cm^2 applicator at a reference depth of measurement Z_{ref} 18 mm and 28 mm rather than the other applicators for the same reference depths of measurement Z_{ref} values as shown in table 1 [9, 19]. The electron beam has been calibrated at 1cGy/MU for all calculation purposes.

This study presents the investigation of the parameters of dose profile in detail for exposure to electron beams of energies 4 MeV to 15 MeV in water phantom (20). The maximum absolute dose of 1.0004 Gy for the applicator of 20x20 cm^2 for the electron beam of energy 10 MeV was delivered to the phantom at the reference depth of measurement Z_{ref} 22 mm. [9].

However, the highest absolute dose of 1.0369 Gy is deposited by the electron beam of energy 15 MeV at the reference depth of measurement Z_{ref} 34 mm for a 14x14 cm^2 field applicator. It is observed that the value of absolute dose decreases on increasing the value of Z_{ref} for the electron beams of energies 4-15 MeV for the applicator of size 6x6 cm^2 [21].

The statistical analysis of the absorbed dose shows that the mean value of the absolute dose at a confidence level of 95% was 0.9524, 1.0005, 1.0017, and 0.9990 Gy with the standard deviation of 0.0737, 0.0003, 0.0177, and 0.0192 respectively for the applicator of sizes 6x6 cm^2, 10x10 cm^2, 14x14 cm^2, and 20x20 cm^2 as shown in table 2 [19].

Table 2
Statistical parameters of the absolute dose for the electron beam of energies 4-15 MeV field size 6x6 cm^2, 10x10 cm^2, 14x14 cm^2, and 20x20 cm^2 at SSD 100 cm and dose rate of 100 MU at a confidence level of 95%

S.N.	Measurement	6x6	10x10	14x14	20x20
1.	Mean	0.9524	1.0005	1.0017	0.9990
2..	Median	0.9787	1.0005	0.9962	0.9982
3.	Standard Deviation	0.0737	0.0003	0.0177	0.0192

The histogram shown in figure 4 represents the variation of dose with beam energy for the field sizes 6x6 cm^2, 10x10 cm^2, 14x14 cm^2 to 20x20 cm^2 at SSD 100 cm at the dose rate of 100 MU also predicts that a field size of 10x10 cm^2 is rather suitable for external beam radiation therapy [22].

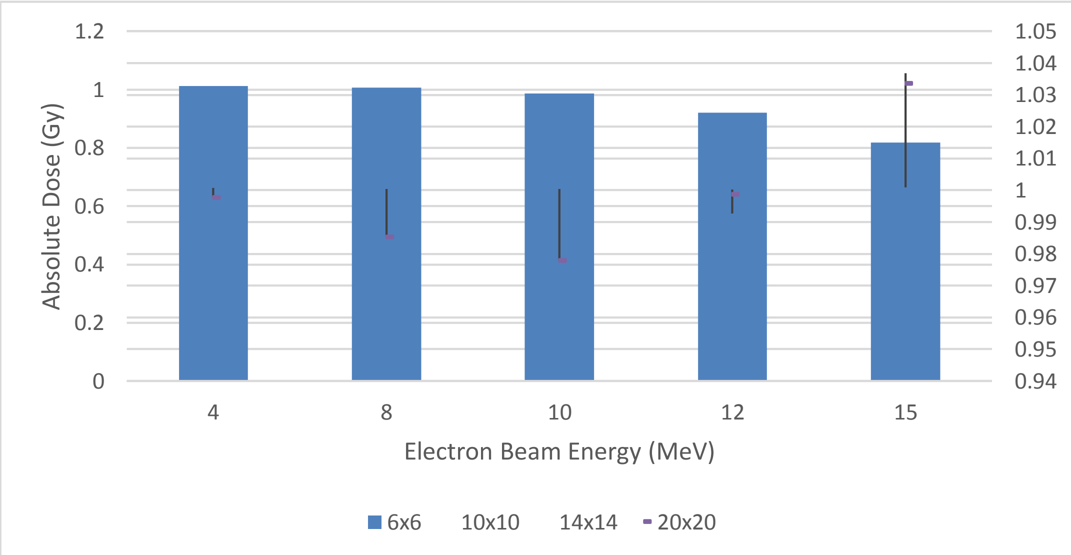


Fig. 3. Histogram representing variation in Absolute Dose to water for electron beam of energy 4-15 MeV with field size 6x6 cm^2, 10x10 cm^2, 14x14 cm^2, and 20x20 cm^2 at SSD 100 cm and dose rate of 100 MU from Elekta Synergy Platform Linear accelerator

Conclusion

Relatively greater absolute doses were recorded for 10x10 cm^2 field applicator at the reference depths of measurement Z_{ref} 9 mm - 34 mm for electron energies 4 MeV-15 MeV. It is also observed that for the electron beams of energies 4 MeV – 15 MeV there is a very rapid drop off in absolute dose to the water phantom. This indicates that the nearby normal tissues of the sensitive organs like nasal nodes, head, and neck can be escaped from the radiation effects using the electrons beams in radiation therapy.

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