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Technical Note

Photon beam commissioning of an Elekta Synergy linear accelerator

Md Abdullah AL MASHUD[1], M TARIQUZZAMAN[2,a], M JAHANGIR ALAM[3], GA ZAKARIA[4]
[1]*Dept. of Applied Physics, Electronics & Communication Engineering, Islamic University, Kushtia-7003, Bangladesh*
[2]*Dept. of Information and Communication Engineering, Islamic University, Kushtia-7003, Bangladesh*
[3]*Medical Physics Division, Dept. of Radiation Oncology, Ahsania Mission Cancer & General Hospital, Uttara, Dhaka*
[4]*Dept. of Medical Radiation Physics, Gummersbach Hospital, Academic Teaching Hospital University of Cologne, Gummersbach, Germany*
[a]*E-mail address: mtareq@ice.iu.ac.bd*

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Abstract

The aim of this study is to present the results of commissioning of Elekta Synergy linear accelerator (linac). The acceptance test and commissioning were performed for three photon beams energies 4 MV, 6 MV and 15 MV and for the multileaf collimator (MLC). The percent depth doses (PDDs), in-plane and cross-plane beam profiles, head scatter factors (Sc), relative photon output factors (Scp), universal wedge transmission factor and MLC transmission factors were measured. The size of gantry, collimator, and couch isocenter were also measured.

Key words: commissioning; accuracy; output; LINAC; transmission factor; in-plane and cross-plane.

Introduction

Elekta Synergy accelerator is produced by Elekta (Elekta Oncology Systems, Crawley, UK). A few hundred of such accelerators are now used clinically. The Elekta Synergy can deliver photon and electron beams. The accelerator may be used to irradiate a very complex targets in 3D conformal and Intensity Modulation mode. Before first clinical use according to international recommendations the acceptance and commissioning tests have to be performed. Later the quality control test have to be performed regularly. In this study, we present the results of dosimetric and mechanical tests for Elekta Synergy accelerator installed in Ahsania Mission Cancer & General Hospital in Dhaka, Bangladesh. In our study, we proposed the systematic steps of commissioning of Elekta Synergy linear accelerator for high energies photon beam only.

Materials and Methods

The Elekta Synergy is a digital linear accelerator that has capable of delivering 4 MV, 6 MV and 15 MV photon beams. It has a pair of sculpted diaphragms mounted orthogonal to the multileaf collimator with maximum field size of 40×40 cm^2. The thickness of tungsten MLCs in the Agility collimator is 9 cm and the leaf speed is 3.5 cm/s. The accurate position of the leaves ensures the Rubicon optical tracking system [1,2]. The primary collimator speed of Agility collimator is 9 cm/s. The clearance of isocenter is 45 cm [3]. All measurements were made at gantry and collimator angle of 0°.

The measurements were performed according to the AAPM TG-106 recommendations [4]. A PTW MP3-M water tank (PTW, Freiburg, Germany) with a scanning capacity of 50×50×40 cm^3 was used. The PDD measurements were made using PTW Semiflex 31010 chamber with a 0.125 cc active volume. As a reference detector the PTW Semiflex 31010 ion chamber was used. For larger field sizes 0.6 cc Farmer type ion chamber SN 009016 and for very small field sizes PTW p diode with active volume 0.03 mm^3 was used. The acquisition sampling times have been set to 0.3 s and 0.6 s for PTW Semiflex and PTW p diode respectively.

The PTW's MEPHYSTO mc^2 navigation software was used for processing all scanned PDD and profile scans. The PDD data have been interpolated to 0.2 mm spacing and normalized to 100% at the depth of maximum dose (d_{max}).

A. Mechanical tests

The mechanical check is a part of linac commissioning. The coincidence of light field and digital readout has been checked by aligning graph paper at 100 cm SSD to the crosshairs. TG-142 recommends the tolerances of 2 mm for symmetric jaws and 1 mm for individual asymmetric jaws [5]. The coincidence between mechanical front pointer and the optical distance indicator was measured at several SSDs in the range between 85 cm, 90 cm and 100 cm. According to the TG-142 recommendation the tolerance for optical distance indicator is 1 mm with a resolution of 1 cm. The collimator and gantry were fixed at zero degree [6].

B. Radiation/mechanical isocentricity

The coincidence of radiation and the mechanical isocenters of the gantry, collimator and couch was measured using star short analysis. A Gafchromic film was used. The film was exposed to five or to six nonoverlapping fields of 0.5×20 cm^2 that defined by the secondary collimator and MLCs respectively using 100 monitoring units (MU). For various gantry, collimator and couch angles the process has been repeated. The film was scanned with Vidar scanner. The scanning procedure was based on the recommendations given in TG-55 [7]. TG-142 recommended the tolerance of congruence of radiation and mechanical isocenter of 2 mm diameter.

C. Characterizations of PDDs and profiles

The photon PDDs and profiles were measured for square fields sizes of 1 cm, 2 cm, 3 cm, 4 cm, 5 cm, 7 cm, 10 cm, 15 cm, 20 cm, 30 cm and 40 cm per side. The in-plane and cross-plan profiles were measured for the same set of field sizes as PDDs at depth of d_{max}, 5 cm, 10 cm and 20 cm. The MEPHYSTO mc2 (PTW) software was used to process the raw profiles' scans. The smoothing filter was used and the data were interpolated in steps of 0.2 mm. Flatness, symmetry and penumbra were measured within the central 80% of the full width at half maximum (FWHM) of the processed profile [8]. The flatness, symmetry and penumbra were measured as a maximum ratio between any two points ($100 \times D_{max}/D_{min}$), the maximum ratio between any two symmetric data points $(100 \times D_{(x)}/D_{(-x)})_{max}$ and the spatial distance between 80% and 20% of the profile for flattened beam respectively [9,10].

D. Output factors

Head scattered factors (S_c) were measured in air using PTW Semiflex 31010 chamber with brass buildup caps. The wall thickness of build-cup was sufficient to ensure the charged particle equilibrium [11,12]. The HSFs were measured for different clinical field sizes. The output factors (S_{cp}) were measured at d_{max}. For the smallest field sizes the measurements of output factors were made with PTW p diode. For larger field sizes the PTW Semiflex 31010 chamber was used. The output factors were measured at 90 cm SSD and at 10 cm depth. The 100 MUs were delivered. The output factors were normalized to 10×10 cm^2 field size [13].

E. Measurements for the universal wedge

Elekta Synergy was equipped with 60 degree universal wedge mounted in the gantry head that moves in effective wedge angle [14]. In the wedge field the largest field size is 30×40 cm^2. The PDD curves, in-plane and cross-plane profiles have been measured for the filed sizes 5×5 cm^2, 10×10 cm^2, 15×15 cm^2, 20×20 cm^2, 20×30 cm^2 and 30×40 cm^2 at 90 cm SSD, 10 cm depth and 100 MUs. The relative wedge factors were measured in relation to 10×10 cm^2 field.

F. MLC characterization

The MLC transmission was measured using PTW Semiflex chamber (active volume 0.3cc) and PTW MP-3 water tank. The gantry was set to zero degree and collimator set at 90° and the tank surface was at 100 cm distance. The chamber was placed at a depth of d_{max} and open field profiles were measured perpendicularly to CAX of 10×10 cm^2 field size. The in-plane and cross-plane was scanned at the identical setup but the MLCs closed at a distance of 15 cm away from the CAX [15]. The maximum transmission for MLCs is 1% recommended by IEC [16].

The spoke shot of MLC was performed using a Gafchromic film for five to six non-overlapping field of 0.5×20 cm^2 which defined by the MLCs and secondary collimator, respectively, using 100 MUs. For all energies the process was repeated. RIT software was used to perform the analysis. The acceptable tolerance is 2 mm in diameter [5].

Results

A. Mechanical test

The largest deviation in digital readout of the gantry and collimator angles was 0.2°, which is lower than 0.5° tolerance. The couch movement deviations along the three axes were 0.8 mm which is less than 1 mm tolerance. The lateral and sagittal lasers were verified within the 1 mm tolerance. For the field sizes 5×5 cm^2 up to 40×40 cm^2 were found the largest deviation between light field and digital readout to be 1 mm. The optical distance indicator was verified from 85 cm to 100 cm against the mechanical front pointer. The largest deviation was 0.8 mm which is less than 1 mm tolerance. The coincidences of light field and radiation field were within 1 mm for symmetric jaws and 0.5 mm for asymmetric jaws settings.

B. Radiation/mechanical isocentricity

The congruence of the radiation and mechanical isocenter for gantry, collimator and couch were 1 mm, 0.8 mm and 0.8 mm diameter respectively.

C. Characterizations of PDDs and profiles

In **Figure 1** the measured PDDs for 10×10 cm^2 field size for 4 MV, 6 MV and 15 MV are shown. The photon beam parameters including d_{max}, PDD at 5 cm, 10 cm and 20 cm depth for a 10×10 cm^2 field of three energies are summarized in **Table 1**. It shows that the value of D_{20}/D_5 is increased with energy. In **Figure 2** in-plane profiles for 2, 5, 10, 15, 20 and 30 cm square fields acquired at 90 cm SSD and at 10 cm depth and collimator angle and gantry of zero degree for all three energies are shown. The characteristics of in-plane and cross-plane profile included flatness, symmetry and average penumbra values for 10×10 cm^2 field are summarized in **Table 2**. It shows that the cross-plane penumbra values were higher than the in-plane penumbra values by 1.6 ± 0.4 mm. The values of flatness and symmetry were almost identical.

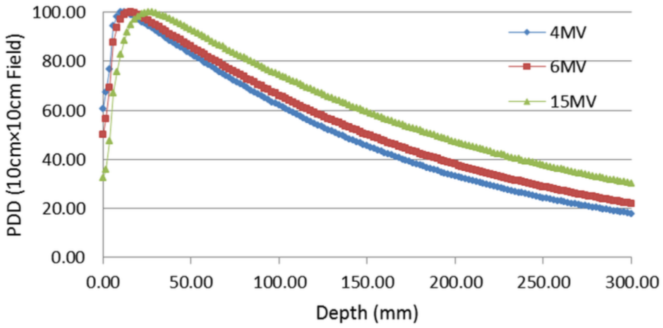

Figure 1. PDD curves for 4 MV, 6 MV and 15 MV photon beams for 10×10 cm^2 field at 90 cm SSD.

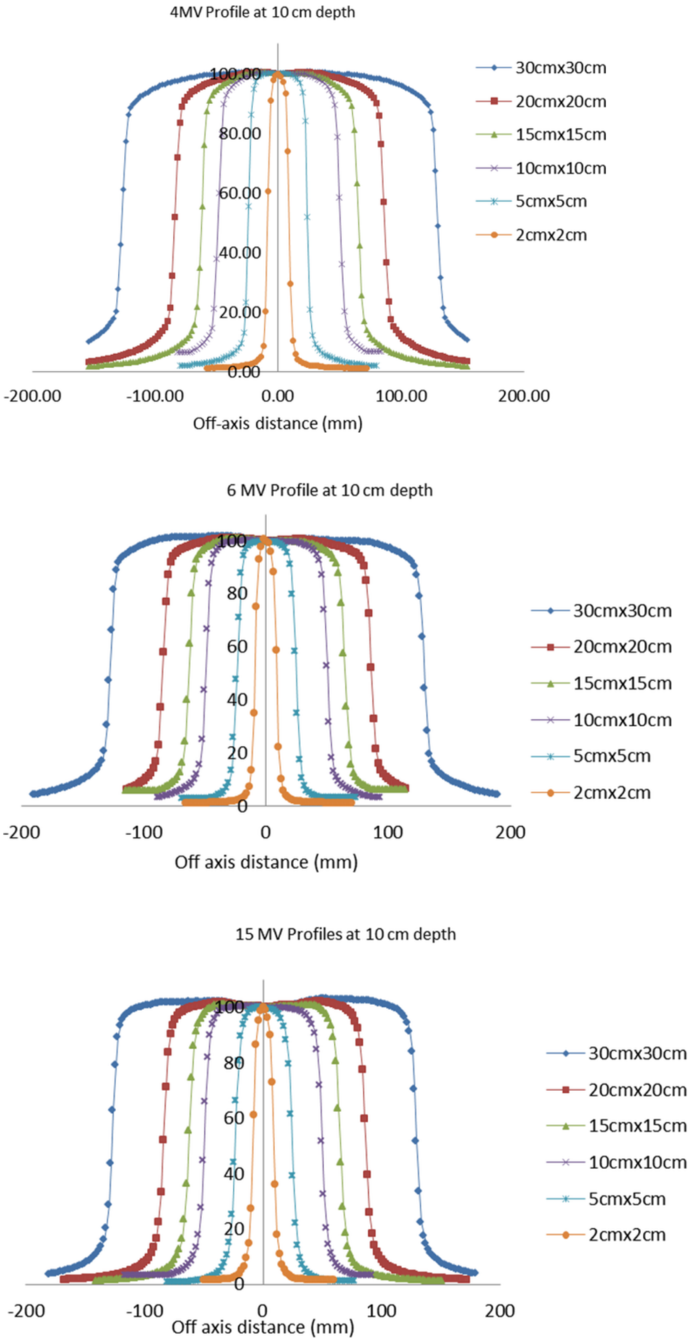

Figure 2. In-plane profiles for 4 MV, 6 MV and 15 MV photon beams for square field sizes 2, 5, 10, 15, 20 and 30 cm measured at a depth of 10 cm.

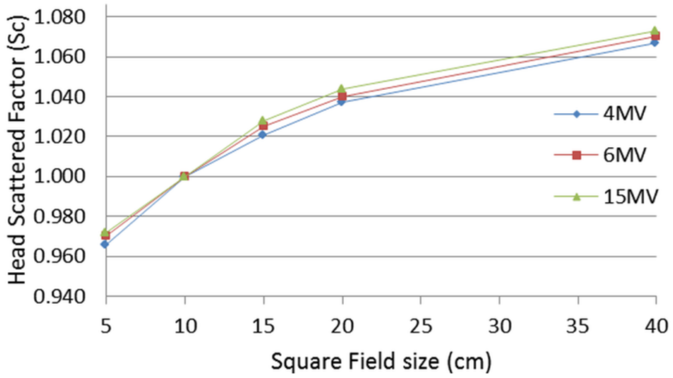

Figure 3. Head scattered factor (S_c) for square field sizes from 5 cm up to 40 cm for the three photon energies.

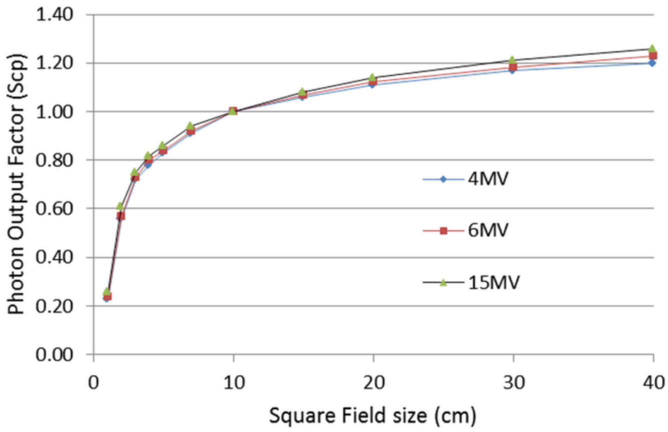

Figure 4. Phantom output factor (S_{cp}) for square field sizes from 1 cm up to 40 cm for the three energies.

Table 1. Photon beam parameters: d_{max}, PDD at 5, 10, and 20 cm depths and D_{20}/D_5 ratio for 10×10 cm^2 field for three photon energies.

Energy (MV)	d_{max} (cm)	PDD (5 cm)	PDD (10 cm)	PDD (20 cm)	D_{20} / D_5
4	1.2	83.00	61.90	33.10	0.40
6	1.5	86.10	66.00	37.90	0.44
15	2.7	92.90	74.50	47.20	0.50

Table 2. Flatness (%), symmetry (%) and penumbra (mm) obtained from measurements of in-plane and cross-plane profiles for 10×10 cm^2 field at a depth of 10 cm.

Energy (MV)	Flatness (%)		Symmetry (%)		Average Penumbra (mm)	
	In-plane	*Cross--plane*	*In-plane*	*Cross--plane*	*In-plane*	*Cross--plane*
4	105.5	106.42	100.01	100.13	6.18	8.08
6	104.21	105.21	100.21	100.00	6.37	8.22
15	105.30	107.40	100.37	100.92	7.26	8.33

Table 3. Relative wedge factors for field sizes 5×5cm^2 up to 30×40 cm^2 for 4, 6 and 15 MV beams

Energy (MV)	Field Size (cm^2)					
	5x5	10x10	15x15	20x20	25x30	30x40
4	0.87	1.00	1.09	1.17	1.23	1.27
6	0.89	1.00	1.08	1.15	1.20	1.23
15	0.89	1.00	1.07	1.13	1.16	1.19

D. Output factors

The S_c value ranges from 0.968 to 1.046 for 4 MV, 0.97 to 1.06 for 6 MV and 0.976 to 1.072 for 15 MV.

Figure 4 shows the photon output factors (S_{cp}) for square field sizes from 1 cm up to 40 cm. It shows that the output factor ranges from 0.45 to 1.20 for 4 MV, 0.47 to 1.29 for 6 MV and 0.50 to 1.35 for 15 MV.

E. Universal wedge - relative wedge factors

The wedge transmission factors were 0.24, 0.26 and 0.28 for 4 MV, 6 MV and 15 MV photon beams respectively.

The measured relative wedge factors ranged between 0.87 and 1.27, between 0.89 and 1.23, and between 0.89 and 1.19 for 4 MV, 6 MV and 15 MV photon beam respectively as tabulated in **Table 3**. It shows that the range of relative wedge factors decreases with increasing photon beam energy.

F. MLC characterization

The average transmissions were 0.5%, 0.6% and 0.6% for 4 MV, 6 MV and 15 MV photon beams respectively.

Discussion

The dependence of the measured PDDs and beam profiles on energies were consistent with the data for Varian True Beam [17]. The depth of maximum dose for 10×10 cm^2 field size increases with energy. The D_{20}/D_{10} values for 10x10 cm^2 field size increases with energy. Similar results were obtained by Kragl et al. [18]. The symmetry, flatness and penumbra were similar to obtained for Varian True Beam [20]. The range of head scattered factors, output factors and relative wedge factors agree with the observation obtained in studies [21,22]. The MLC transmissions agreed with Thomson's et.al. results [15].

Summary

In this study we present the results of commissioning of Elekta Synergy accelerator. This work may help others for efficient commissioning of any type of accelerator.

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