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Review

Installation and Commissioning of TrueBeam™ SVC 3. o Medical Linear Accelerator: An empirical measurement and comparative analysis of comprehensive Dosimetric parameters for flattened and unflattened photon beams

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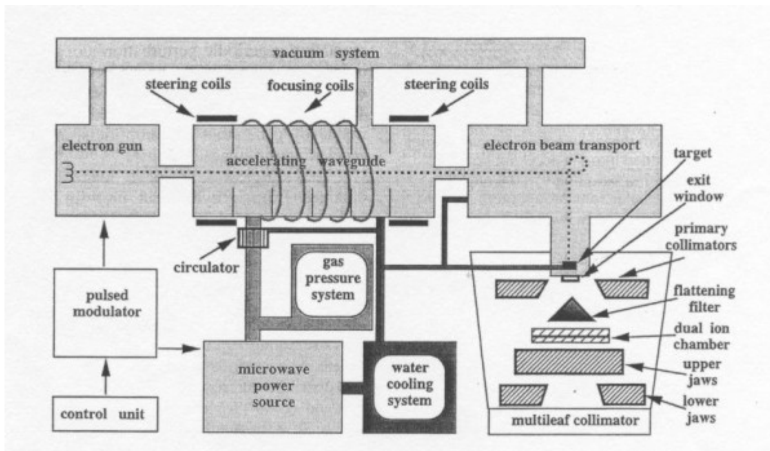
Abstract

This study aims to present a report on the commissioning results of the Varian TrueBeam™SVC Medical Linear Accelerator with available Flattening filter (FF) and Flattening filter free (FFF) photon beams and to compare their dosimetric differences and advantages. This study intends to benefit medical physicists and biomedical engineers during installation and commissioning. All evaluations followed TG-106 guidelines and regulations from the Atomic Energy regulatory board. Determination and comparison of parameters involved PDD (Percentage depth dose), Depth dose profile, Symmetry, Flatness, Quality index, Relative output factor, Penumbra, Transmission factor, DLG (Dosimetric leaf gap), in addition to the degree of Un-flatness and the off-axis ratio of and mechanical test such as Gantry, collimator, couch isocentric check. The 6MVFFF and 10MVFFF beams had the same average energy as the flattened beams and exhibited fewer PDD differences with varying field sizes. The depth of maximum dose (Dmax) was greater for FFF beams across all field sizes compared to their flattened beam counterparts. The symmetry values were almost identical while the flatness values of 6 MV FFF and 10 MV FFF normalized profiles were expected to be higher than the corresponding flattened beams. The surface doses for all beams increased linearly with the field size. For field sizes up to 10 ×10cm2, the 6MVFFF and 10MVFFF beams exhibited increased surface doses compared to the flattened beams, whereas for larger fields, the surface doses were lower. Additionally, both FFF beams had reduced average MLC transmissions in comparison to the flattened beams.

Keywords: Medical Linear accelerator, commissioning, dosimetry, Flattening Filter, Flattening Filter Free

INTRODUCTION

The Linear accelerator (LINAC) is a device that uses high-frequency electromagnetic waves to accelerate charged particles such as electrons to high energies through a linear tube. It accelerates electrons using a tuned-cavity waveguide, in which the RF power creates a standing waveguide. Medical LINAC uses monoenergetic electron beams between 4 and 25 MeV, giving an X-ray output with a spectrum of energies up to and including the electron energy when the electrons are directed at a high-density (such as tungsten) target. The electrons or X-rays can be used to treat both benign and malignant diseases. The LINAC produces a reliable, flexible, and accurate radiation beam. In addition, the device can be powered off when not in use. There is no source requiring heavy shielding, although the treatment room itself requires considerable shielding of the walls, doors, ceiling, etc. to prevent the escape of scattered radiation [1].



Installation and commissioning of the Varian TrueBeam SVC with HD 120 leaf Medical Linear Accelerator were carried out in the Bangalore Baptist Hospital, Bangalore (India) fromSeptember to November 2023.

Varian (P) Ltd. typically provides the TrueBeam^{TM} machine in two versions: one includes the millennium 120-leaf MLC (Multi-Leaf Collimator) designed for general use, and the other is the TrueBeam with HD (High Definition) 120-leaf MLC, tailored for stereotactic radiotherapy. The TrueBeamwith HD features a specialized MLC with 32 leaf pairs at the center with a 2.5 mm leaf thickness and 28 leaf pairs on the outer part with a 5 mm leaf thickness, aimed at achieving precise targeting and reducing the penumbra effect. Table 1 illustrates the specification of TrueBeam SVC specifications. Both versions of the TrueBeam^{TM} machine come equipped with FF (Flattening Filter) and FFF (Flattening Filter Free) modes and electron energy.This paper describes installing and commissioning the Varian TrueBeam SVC 3.0, the latest edition of the TrueBeamSTx platform. Figure 1 illustrates the typical medical LINAC's key components and beam generation system.

Table 1: Varian TrueBeam SVC 3.0 Specifications

Name of the Manufacturer	**Varian Medical systems**
Model	TrueBeam SVC 3.0
Photon Energy	6 MV, 10 MV, 15 MV, 6 FFF, 10 FFF
Electron Energy	6 MeV, 9 MeV, 12 MeV, 15 MeV, 18MeV
Maximum Field Size	40 x 40 cm^2
MLC	HD MLC
Number of leaves in MLC	120 leaves (60 pairs)
Leaf width	Outer – 28 leaves of 0.50 cm
	Inner – 32 leaves of 0.25 cm
Field size range	40 x 22 cm^2
Treatment Planning System	Eclipse 17.00.00
Treatment Technique	3D-CRT, IMRT, IGRT, RapidArc, SBRT, SRS, SRT, TSET, TBI
Imaging	KV, MV, CBCT

True beam system generates the beam by activating an electron gun, bunching the released electrons, accelerating them through the waveguide, and then steering them through a 270˚ achromatic bend magnet. 3 mm width of incident electron beam strike target and continuous deceleration of electron inside target generates X-ray radiation. True beam system utilizes the triode gun design capable of high-speed electron source. Buncher coil helps properly center the electron beam and form electron bunching. The Accelerator's large solenoid focusing coil along the length of the tube maintains electron bunching focus and narrow energy spectrum at the output of the guide. Position steering and angle steering coil are used to angle the beam at the end of the guide tube and inside the bending magnet respectively. Multiple target system with target materials is optimized for different energy ranges. A flattening filter is placed on the carrousel just below the target assembly to achieve beam uniformity. The output of the beam is continuously monitored by an ion chamber placed below the flattening filter. The beam is continuously steered by a feed-back servo control system that responds to ionization chamber monitoring of beam position, angle, symmetry, flatness, and beam output [2]. At the end, the collimator assembly consists of independent X and Y jaw along with MLC to define the field geometry.Figure 2 shows the front view of the Varian TrueBeam™ Medical Linear accelerator and Figure 3 shows the actual Varian TrueBeam SVC 3.0 Linear Accelerator installed in the Bangalore Baptist Hospital.

Fig 2: Front view of Varian TrueBeam Linac

In a typical clinical linear accelerator, the flattening filter (FF) is positioned in the path of the photon beam between the main collimator and the monitoring ion chamber. Its purpose is to address the uneven distribution of photon intensity across the field. The FF, typically cone-shaped and composed of high Z material, flattens the forward peaked bremsstrahlung spectrum of high-energy photon beams. Its presence in the Linac significantly decreases the dose rate of the photon beam and is a major contributor to head scatter and radiation leakage. Recently, there has been a growing interest in the clinical practice of eliminating the flattening filter to enhance the natural peak of the beam profile compared to traditional photon beams, resulting in what is known as a flattening filter-free (FFF) or unflattened photon beam. Removing the flattening filter alone, without making changes to other beam control parameters, results in a higher dose rate and reduced beam quality [3,4].The flattened and unflattened photon beams are available in the following dose rates: 6MV and 10MV are available at dose rates of 100, 200, 300, 400, 500, and 600 MU/min; 6FFF is available at dose rates of 400, 600, 800, 1,000, 1,200, and 1,400 MU/min; and 10FFF is available at dose rates of 400, 800, 1,200, 1,600, 2,000, and 2,400 MU/min.

Fig 3: Varian TrueBeam SVC 3.0 Linear Accelerator installed at Bangalore Baptist Hospital

MATERIALS AND METHOD

Commissioning of TrueBeam Linear Accelerator is performed with the help of the IBA dosimetry system (GmbH, Germany) in water phantom (RFA-Blue Phantom, with myQA Accept 9.0 software). All data collection and testing were conductedby international practice and guidelines such as AAPM Task Group TG-142 and TG-106 [5,6]. Photon beam data collection and evolution and mechanical and safety checks were carried out as per AERB (Atomic Energy Regulatory Board, INDIA) and Varian recommendations. A procedure such as MLC DLG (Dosimetric Leaf Gap) is carried out according to Varian's guidelines.

Detectors and phantom setup

All the measurements were performed using the IBA dosimetry system, the relative dosimetryi.e., Percentage depth dose (PDD), cross-line profile, diagonal profile, output factor) was measured in the IBA Smart ScanRadiation Field Analyzer (RFA). The absolute dosimetry for all the photon beam energies was performed using the 1D water phantom (IBA, GmbH, Germany). The MLC leaf transmission, secondary jaw transmission, and dosimetric leaf gap for all the available photon energies were measured using the Solid water-equivalent SP34 made up of RW3 is a white Polystyrene. The Smart Scan RFA has a measurable dimension of 480 mm x 480 mm x 410 mm (length x width x height) with a position accuracy, reproducibility, and position within 0.1 mm. It has a maximum scanning speed of 50 mm/sec. The RFA is connected to the common control unit using a custom trigger interface of RS 485 cable, which has a bias voltage range from ±50 V to ±500 V. The Radiation field analyzeris also connected to a water reservoir of a 220-liter capacity system.

The chambers used for beam data collection and dosimetric measurements and their physical properties are listed in Table 2. The additional instruments were laser test tools, self-developed film (gafchromic films),afluke ionization-based survey meter, and a Neutron contamination REM meter. The FC 65 and CC13 ionization chambers were used for the absolute dosimetry measurements and in the relative measurements for PDD and profile measurements for the field size larger than 5 x 5 cm^2. These ionization chambers may overestimate the beam penumbra compared to the actual, particularly in small fields, hence Razor chamber (CC01) was used for the smaller field measurements. Before collecting data, a radiation beam centralization check was carried out to align the chamber with the radiation's central axis (CAX) in the horizontal plane.

Table 2: The specifications of the Ionization chamber

Detector	Active Volume (Cc)	Active Length (Mm)	Central Electrode (Mm)			Wall Material	Wall Thickness (Mm)	Waterproof Material
			Length	Diameter	Material			
FC65-G	0.65	23.0	20.5	1.0	Aluminium	Graphite	0.4	Silicone
CC13	0.13	5.8	3.3	1.0	Shonka (C-552)	Shonka (C-552)	0.4	Silicone
RAZOR-CC01	0.01	3.6	2.8	1.0	Graphite	Shonka (C-552)	0.5	Silicone

The beam data measurement is done in AAA (Anisotropic Analytical Algorithm) for the photon beam and tocommission the Eclipse (Version: 17.0.0) Treatment Planning System(Varian Medical Systems, Palo Alto, CA)

[7]. Beam data measurement was performed for standard photon energies 6 MV, 10 MV, 15 MV flattening filter beam and 6MV-FFF, 10MFFF flattening filter free beams.

Pre- and post-installation verification

Procedure to check the Serial number of the machine

The first step in verifying the machine's serial number (SN) is to inspect the serial number on the commercial invoice and then cross-reference it with the packing list of the shipment. The serial number for the Varian Linear accelerator consists of four digits and remains consistent for on-board imaging systems. Finally, the number will be validated by checking the print on the shipment box.

Preliminary Software and License Check

From the supplier-provided service laptop, a copy of the license from the Varian folder is taken from the WordPad and this has been compared to the machine sales order. Apart from the basic license, some additional optional features set of licenseshave also been verified.

Safety interlock

The safety interlock is designed to stop X-ray beam production when the room door is open. This notification must appear on the workstation. The evaluation was carried out in service mode. Initially, the door is opened and the X-ray photon switch button must be activated. The beam remains inactive, and the workstation displays the open-door status. Consequently, the evaluation meets the requirements.

Couch sag

Couch sag at the isocenter was measured by placing a few water gallons above the couch distributed over 2 m through the isocenter. The vertical shift and tilt with and without weight aremeasured with the help of spirit level and visually inspected in the workstation.

Target to surface distance verification

This test is performed with the help of an instrument called a front pointer. The front pointer rod along with the tray has to be inserted accurately in the Linac head and the rod is adjusted in such a way that kept at a 100cm index line. The couch is kept at 0° and the couchis moved to the isocenter. Then rotate the gantry position to 90°. A small strip of white tape is attached to the front edge of the couch. The couch is moved to the axes accurately to the end of the front pointer tip to the taped line. Then rotate the gantry to 270° and verify that the tip of the front pointer is again aligned to the taped line. The measured variation is less than 2mm. The tolerance limit for this test is ±5mm.

Measurement of Mechanical alignment

Isocentre Verification

As part of commissioning, a mechanical verification process was conducted to ensure the alignment between the light field and the digital readout. This was done by placing graph paper at a distance of 100 cm from the source-surface distance (SSD) and aligning it with the crosshairs using an Optical Distance Indicator (ODI). The couch position was adjusted manually using a hand pendant, and the corresponding movement was checked on the digital readout located on the wall. According to TG-142 guidelines, the acceptable tolerance for the field size is 2 mm for symmetric jaws and 1 mm for asymmetric jaw settings. The alignment between the mechanical front pointer and the ODI was assessed at various SSDs ranging from 85 cm to 110 cm, with a recommended tolerance of 1 mm according to TG-142. The congruence between the light field and the radiation field is measured by placing a Gafchromic film (EBT2) at the isocenter perpendicular to the beam axis. The edges of the field light were marked on the film and then irradiated with opaque markers placed at the field boundaries. TG-142's recommended tolerance is 2 mm.

Radiation Isocentre

The alignment of the radiation isocenter with the mechanical isocenters of the gantry, collimator, and couch was evaluated through star shot analysis. A Gafchromic film (EBT2 film, Kodak, Rochester, NY) was irradiated with five to six separate fields measuring ~~0.5 × 0.5 cm2~~ each, defined by the secondary collimator and MLCs, using 500 monitor units (MU). This procedure was repeated for different angles of the gantry, collimator, and couch, encompassing a full 360° revolution.

Measurement of Dosimetric Indices

Beam Quality Index

The aim of this measuring quality index is to ensure that the radiation energy delivered consistently determines the beam's qualityhas not changed significantly. The quality index is defined as the ratio of the dose at 20cm depth to the dose at 10cm depth measured in the phantom in an isocentric setup for a 10 x 10 field size and source-to-axis distance (SAD) of 100cm (TRS-398) [8]. A calibrated 0.6cc Ionization chamber is used to measure and an exposure of 100MU is delivered, this is repeated three times to ensure the reading consistency. The base value for the index for this particular machine is measured from the formula given by the TRS-398 protocol. This is measured from the PDD curveusing $TPR_{20/10} = 1.2661 \times PDD_{20,10} - 0.0595$. Where $PDD_{20,10}$ is the ratio of PDD at 10 cm & 20 cmdepth. This base value will be checked daily and this test is included in the daily QA measurements**.**This initial value is repeated several times a day with periodic time intervals for commissioning to ensure the consistency of the quality index.

Depth of Dose Maximum (d_{max})

This is the region where the dose builds up as the electrons liberated in the preceding layers deposit their dose and reach a maximum depth below the surface. This value is measured at a standard field size of 10x10cm2 at 100cm SSD for both FF and FFF photon beams.

Output Calibration

Beams were calibrated following the American Association of Physicists in Medicine Task Group-51 formalism [9] which delivers 100MU corresponds to1Gy at the depth of maximum dose (*d*max) for source-surface distance (SSD)100cmandfield size of 10x 10cm^2

Commissioning parameters

Percentage Depth dose

The PDD is defined as the dose at a certain point Dx of the central axis over the maximum dose Dzmax on the central axis multiplied by 100. Furthermore, the PDD depends on the beam quality which is defined mainly by energy, radiation field size and shape, SSD, and collimation of the beam. It is crucial to ensure that the scanning direction of PDD measurements is consistent from the bottom to the top to prevent any disturbances in the water surface. The measurements were conducted with a Source-to-Surface Distance (SSD) of 100 cm at the water surface, focusing on depths ranging from 30 cm. The reference detector is positioned in a holder at the corner of the phantom.

All PDDs were standardized at the maximum dose depth using a 10 x 10 cm beam. The detector was accurately placed in the detector holder and aligned to the central axis using the holder cap. A measurement increment of 2mm was utilized. The changes in PDD at different depths (0.5 cm, 10cm, and 20 cm), as well as the maximum dose depth and beam characteristics for various energies, were investigated and compared between flattened and FFF beams. Ensuring the reproducibility of the PDD is crucial for confirming the consistency of a newly installed machine. Therefore, the consistency of the PDD was assessed by comparing it to the baseline PDD value for a 10x10cm2 field at a depth of 10cm. Three successive measurements were conducted, followed by the baseline measurement, to determine the percentage of variation in comparison to the baseline value. Additionally, for the FFF beam, the stability of the Dmax across different field sizes was evaluated to detect any changes in Dmax when increasing the field sizes for both 6 FFF and 10 FFF energies.

Beam dose profiles

Flatness, symmetry, and penumbra were defined within the central 80% of the full width at half maximum (FWHM) of the processed profile. Flatness is defined as the maximum ratio between any two data points F= 100 *(Dmax – Dmin) /(Dmax+Dmin).

Where, Dmax and Dmin are the dose maximum and dose minimum values in the central 80% of the dose profile, usually specified at a depth of Dmax cm or 10 cm.

Symmetry evaluations were done as per the recommendation of the International Electrotechnical Commission (IEC 60976, 2008)[10]

Transversal and diagonal beam profiles were measured for all available beam energies for different field sizes and different depths. The diagonal was determined only for the largest field size (i.e. 40×40cm2). The flatness of the field is calculated as a maximum deviation from the average dose intensity administered in 80% of the full width at half maximum (FWHM) of the profile in a plane transverse to the beam axis measured at 100cm SSD. At a depth of 10cm, the mean corresponds to the average of the maximum and minimum intensity points in 80% of the FWHM area.

The flatness parameter for FFF beams is discussed consecutively.

Penumbra

Penumbra is defined as the spatial distance between 80% and 20% of the CAX value in the profile scan of a flattened beam.The traditional description of penumbra for a regular beam does not apply to an FFF beam.

Relative Output factor

The Output Factor (OF) can be defined as the ratio of the corrected dosimeter readings of the absorbed dose in water Dw (x, y) at a specific depth Zref along the beam axis for a certain field size, to the absorbed dose in water at the same depth for the reference field size of 10x10 cm^2. The OF values were determined for both square and rectangular field sizes ranging from 1×1cm2 to 40×40cm2 across all photon energy levels. The relative OF measurements were conducted at a depth of 10 cm (100 cm SSD) for all photon energies. A Razor ionization chamber was utilized for measurements and positioned perpendicular to the beam following IAEA TRS 483 guidelines [11].The overall output factor readings were standardized to 10×10 cm2 for all field sizes tested. A consistent approach of 100 monitor units was applied for the OF measurements, with a minimum of three readings taken for each data point.

Head scatter factor

The head scatter factor (Sc) was determined under standard air conditions using anFC65 Farmer ion chamber equipped with a buildup cap. Measurements were taken for all square fields. Both Sp and Sc values were standardized based on the 10 × 10 cm2 reference field. Subsequently, the phantom scatter factor (Sp) was computed by subtracting the head scatter contribution from the total scatter.

Surface Dose

The measurement of the surface dose (Ds) was conducted using a CC01 Razor chamber at a Source-to-Surface Distance (SSD) of 100 cm for square fields 10 × 0 cm2, 20x20 cm2 for FF and FFF beams, and their corresponding differences were measured. This research describes the surface dose as the [(Ds=D0.5mm /Dmax) *100] a depth of 0.5 mm.
Table Summary of surface doses for 6MV &10MV flattened and unflattened photons and the ratio between them.

Difference in % surface dose		Phantom = IBA Smartscan; SSD = 100 cm; Chamber CC01 Razor			
Sr.No	**Energy (MV)**	**F.S = 10x10 cm2**		**F.S = 20x20 cm2**	
		Ds (%)	**Difference (%)**	**Ds (%)**	**Difference (%)**
1	6	47.72	9.10	56.72	4.80
	6 FFF	56.32		61.52	
2	10	31.51	7.66	42.93	1.45
	10 FFF	39.17		44.38	

Dosimetric Leaf Gap (DLG)

The dosimetric leaf gap is the effective leaf shift caused by the curved design of most MLCs. It represents the gap between the light and radiation fields, measured by estimating the size of fields created by MLC leaves until the dose matches the MLC leakage. This parameter considers the impact of rounded leaves on dose accuracy and is relevant for both dynamic and static MLC treatment modes.The value is calculated by analyzing Varian DICOM MLC files to record the doses at the isocenter for various widths of sliding gaps. The Varian DICOM file consists of sections containing MLC gaps that slide. It includes gap sizes of 2, 4, 6, 10, 14, 16, and 20 mm. The gap shifts from -60 mm to +60 mm at a consistent speed per Monitor Unit (MU). A control point defines the leaf's position every 10 mm [12]. The resulting beam intensity is consistent across a field area of 10 x 10 cm2. Record and document the measurements from the different gap configurations.

Leaf speed measurement

In this test, the speed of the leaf is preset at 2.5cm/s in the workstation then the leaf moves at 10 cm. The time taken for 10cm is measured in the timer and the speed/sec is measured with simple mathematical calculation. This test is repeated for three to verify the consistency.

Acceptance test for Unflattened Photon beams

Field size

FFF high-energy photon beams exhibit radial intensity patterns with a peak at the center that decreases gradually towards the edges. The field size for these photon beams is determined at the 50% intensity level along the central axis. The radiation field size is identified in the profile by the lateral distance between inflection points on the central axis. This research measures the basic physical concept of the inflection point with a new method proposed by G. Sahani et al. [13]

Degree of unflateness

The lateral distance from the central axis at 90%,75%, and 60% dose points on one side of the beam profile is measured for 6FFF and 10FFF photon beams.

Penumbra

For measuring radiation beam penumbra, the dose value at IP is taken as the reference dose value (RDV). Points Pa and Pb, which are located at 1.6 and 0.4 times RDV identified. Lateral separation between Pa and Pb on either side of the profile is measured as the radiation beam penumbra.

Picket fence test

A picket fence test was done for leaf position accuracy with the field pattern provided by Varian. The fields were verified by an electronic portal imaging device and analyzed with the Varian analysis tool.

Beam modelingin TPS

The measured depth dose curves, transverse profiles, diagonal profiles, and output factors were imported into Eclipse TPS to calculate beam data for the anisotropic analytical algorithm (AAA version 17.0.00). Profiles and depth dose curves were modeledby the configured AAA with the calculation grid of 1.5mm and exported.

Radiation Safety Measurements

Measurement of Radiation levels in and around the installation

Leakage radiation through secondary collimator at 100 SSD

1. The ionization chamber was positioned with its buildup cap along the central axis of the beam at 100 cm SSD and the Field size of 10 cm × 10 cm was opened and exposed for 100 MU and meter reading was noted.
2. A graph sheet was placed and aligned with the crosshair and marked. Radius $R_{\circ}$ can be calculated from A = πr2. Two circles of radii (R1 and R2) can be calculated from $R_{\circ}$ using R1 = 0.5 $R_{\circ}$ and R2 = 0.866 $R_{\circ}$ For the machine maximum jaws 40 cm × 40 cm, the value of $R_{\circ}$ = 22.5 cm, R1 = 11.3 cm, R2 = 19.4 cm.
3. Twenty equally spaced points of measurement were selected for leakage radiation at each of the circles. Y jaws were fully open and X jaws were fully closed. By placing the chamber at each of the points, the meter readings were noted for the above-mentioned MU. The same procedure was repeated
4. with X jaws fully open and Y jaws fully closed.

Leakage radiation inside and outside of the patient's plane

The ionization chamber was positioned with its buildup cap on the central beam axis at a Source-to-Surface Distance (SSD) of 100 cm. A 10 cm × 10 cm field size was used for an exposure of 500 Monitor Units (MU), and the meter reading was recorded. Subsequently, a 40 cm × 40 cm field size was set up to coincide with the crosswire at the center at the same 100 cm SSD. A circle was outlined around the 40 cm × 40 cm field at the isocenter with radii R1, R2, and R3 calculated as follows: R1 = $\{R + 0.25\,(2 - R_{\circ})\}$m, R2 = $\{R_{\circ} + 0.50\,(2 - R_{\circ})\}$m, R3 = $\{R_{\circ} + 0.75\,(2 - R_{\circ})\}$ m. Meter readings were then taken at 24 evenly distributed points for scattered radiation around each circle.

Measurements outside the patient plane were conducted at a distance of 1 m from the target, corresponding to the path electrons traveled between the electron gun and the target. A 0.6 cc ionization chamber equipped with its buildup cap was positioned on the central beam axis at a Source-to-Axis Distance (SAD) of 100 cm, with a 10 cm × 10 cm field opened for an exposure of 500 MU, and a meter reading was recorded as a reference. Subsequently, the Gantry was turned to 180°, and the chamber was situated 1 m away from the gantry at the electron travel path level. The chamber was exposed to the same MU, and readings were taken at six measurement points around the gantry.

Ambient dose equivalent

This test assesses the ambient dose equivalent resulting from induced activity in the accelerator parts located 5cm and 1m from the gantry head surface. The process begins by exposing the maximum field size and delivering 2000 MU. Subsequently, once the beam is deactivated, the survey meter is taken into the specified places, and the induced dose is measured.

Couch transmission

In this test, a Farmer chamber was positioned in a phantom on the treatment couch at 100cm from the source to the detector, while the gantry and collimator remained at 0° angles. The chamber was placed in uniformly spaced slabs above and below. Initially, the chamber was exposed to 100 MU, and the measurement taken was considered as the baseline reading without the treatment table. Next, the gantry was rotated to 180°, and the same number of MUs was delivered. Subsequently, the beam passed through the treatment couch, and the readings were recorded to determine the transmission with the couch. The ratio between the readings with and without the treatment table was calculated as the transmission through the couch. This procedure was conducted for all photon energies.

RESULTS

Percentage Depth Dose

Table 3 illustrates the measured depth dose parameters for 10x10 field size at SSD 100cm. The PDD for 10x10cm2 reference field size at 10cm depthfor the photon beams 6MV,6FFF,10MV,10FFF, and 15MV were 66.2%, 63.43 %, 73.3%,71.0%, and 76.5% respectively. This value is 1.5% less than *Karthick Raj etal* published value with the millennium MLC set up [14]. Hence it shows HD MLC depth dose values are 1.5% less than millinium MLC field size. TheDmax value for the 6MV photon is 8% greater than the 6FFF beam whereas the Dmax value for the 10MV photon is 7% greater than 10FFF. This indicates that the removal of the flattening filter causes a significant rise in the surface dose. The dose ratio D20/D10 increases with energy, and there is a negligible decrease in going from a flattened beam to an unflattened beam. Figures 4(a), and 4(b) illustrate the PDD curve for different field sizes for 6MV and 6FFF photon beams and Figures 4(c) and 4(d) illustrate the PDD curve for different field sizes for 10MV and 10FFF photon beams. Beam softening was observed for the 6FFF (4%) and 10FFF(3.2%) beams compared to the 6MV and 10MV beams for the field size 10x10 field size at 10cm depth.

Table 3: Measured Depth Dose parameter for photon energies.

PDD for 10cmX10cm F.S at SSD=100cm					
Energy (MV)	Dmax (cm)	D5cm (%)	D10cm (%)	D20cm (%)	D20/D10
6	1.50	85.94	66.22	37.96	0.666
6FFF	1.38	84.66	63.43	34.52	0.630
10	2.34	91.39	73.37	46.20	0.738
10FFF	2.18	90.43	71.04	42.90	0.705
15	2.95	94.09	76.56	49.75	0.763

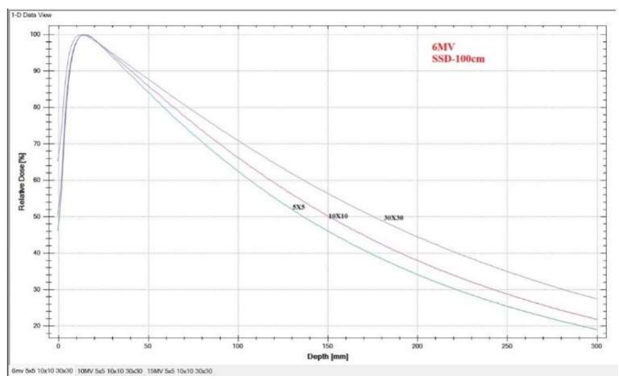


Fig4 (a):6MV PDD for 5x5, 10x10, 20x20 field sizes

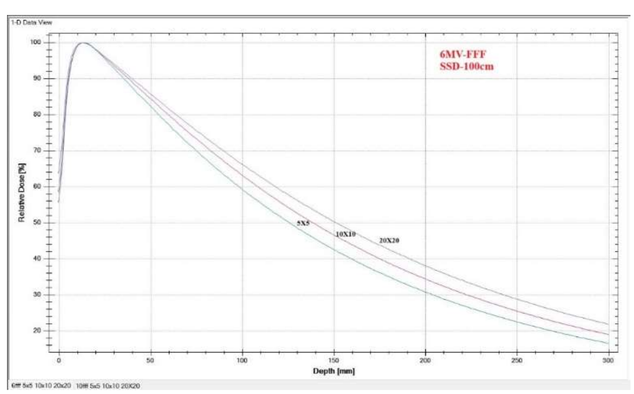


Fig 4(b): 6FFF PDD for 5x5, 10x10, 20x20 field sizes

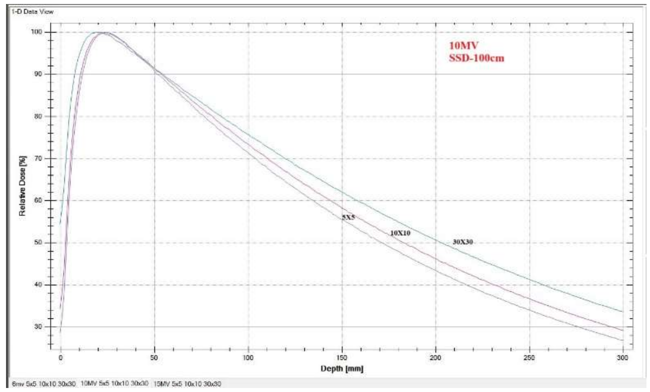


Fig 4(c): 10MV PDD for 5x5, 10x10, 20x20 field sizes

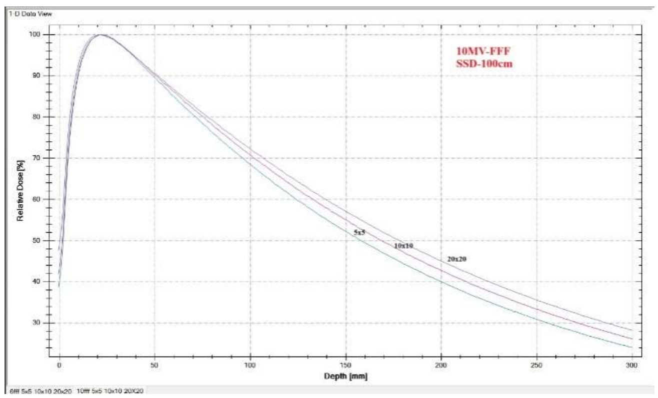


Fig 4(d): 10FFF PDD for 5x5, 10x10, 20x20 field sizes.

Beam profile

FFF profiles have their maximum dose on the central axis and decrease gradually towards the field edge. This non-flattened shape becomes more pronounced with increasing field size and beam energy. Symmetry, flatness, and Penumbra values of FF and FFF photon beams are shown in Table 4. According to AERB specification, FF Beam symmetry, the flatness of the reference field size (10×10cm2), and the max field size at 10cm depth are within the tolerance intervals (flatness < ± 6%, Symmetry<3%).

Table 4:Symmetry, Flatness, for 6MV,10MV, and 15MV energies.

Photon beam energy	Field Size (cm x cm)	Beam flatness for photon beam energy at 10cm depth		Symmetry of the radiation field for Photon Beam energy available at 10cm depth	
		Inplane (%)	Crossplane (%)	Inplane (%)	Crossplane (%)
6 MV	05x05	102.16	102.27	100.22	100.18
	10x10	105.00	104.86	100.45	100.23
	30x30	104.62	104.51	100.46	100.24
10 MV	05x05	103.63	103.06	100.41	100.38
	10x10	104.65	104.31	100.55	100.34
	30x30	103.68	103.67	100.64	100.55
15 MV	05x05	103.44	102.98	100.69	100.40
	10x10	103.90	104.10	100.33	100.57
	30x30	104.46	104.32	100.63	100.64

Flatness values for the FF photon beam were within tolerance, i.e., the maximum values for 6 MV, 10 MV, and 15 MV were observed in the crossline profile, which are 105%, 104.65%, and 103.9%, respectively. In symmetry, the maximum value was observed for the crossline profile. The maximum valuesare 100.24%, 100.55%, and 100.57% for 6 MV, 10 MV, and 15 MV, respectively.Similarly, the beam profile for the FFF beam is also well within the tolerance limit, as stipulated by AERB, and crossline results.

Output factor

Due to challenges posed by the radiation source's obstruction and sharp dose gradients, measuring the output factor for small fields proved to be complex. The photon output factor is shown in Fig. 5 for square field sizes ranging from 1cm to 40 cm. The output factors ranged from 0.65 to 1.18 for 6MV, 0.67 to 1.13 for 6FFF, 0.58 to 1.13 for 10MV, 0.63 to 1.08 for 10FFF and 0.56 to 1.11 for 15MV. The ranges of output factor for FFF beams were higher relative to flattened beams up to the field size 10x10 cm2 but beyond the ranges were smaller.

DLG

The DLG for the HDMLC was less than 1mm for all energies and smaller in FFF beams. Generally, MLC transmission increases with increasing energy. On the same analogy, it has been found that DLG also increases with increasing energy due to increased transmission across a round leaf gap of MLC.

There are many other tests were performed during this commissioning test.

1. Output consistency at lower and higher dose rates
2. Output consistency for low MU settings
3. Neutron leakage other than patient plane
4. Temporal stability of photons in a day
5. Monitor response during gantry rotation
6. Monitor chamber reproducibility
7. Output consistency at different gantry levels

All these tests have met their criteria and passed the tolerance levels. Hence, this commissioning test shows that all the installation acceptance and commissioning tests meet their criteria and function within the tolerance limit specified in the TG protocol and AERB specifications.

DISCUSSIONS

The data presented here are intended to serve as a guide to help potentially identify gross errors in the commissioning of medical linear accelerators. Regardless of the ability to model a photon beam's dosimetric characteristics in the treatment planning system from an institution's measurements, if the measurements were taken inappropriately, then the treatment to the patient leads to inaccurate. The need for an institution to make accurate commissioning measurements is crucial for accurate treatment planning system calculations. Institutions must use extreme caution when selecting the dosimeter and experienced medical physicist to ensure that its measurement processes are adequate and covered in all areas of interest.

All the beam data obtained for photon beams are well within tolerance as per the AERB recommendation to apply for a license. All beam data required as per the Varian Eclipse treatment planning system were configured and verified by point dose calculation and the TG-119 protocol.[15]

For FFF photon beam commissioning, not much literature is available to date. To compare the beam data, we have taken AERB task group recommendations by Sahani et al. as a reference.[13]. The measured values for the degree of unflatness are in good agreement with the referred report values. Penumbra values measured are equivalent to values obtained by Sahani et al. and A. Pichandi et al. {13,16]. The Task Group recommended that periodic QA tests be carried out on a daily/monthly basis and proper records should be maintained to verify the constancy in the performance of the LINAC in comparison to baseline data of the given parameter generated at the time of acceptance testing/clinical commissioning. Hence it is highly recommended to take baseline data with proper care and to ensure the consistency of the performance.

CONCLUSION

Photon beam reference dosimetric characteristics of TrueBeam SVC Linear Accelerator were successfully obtained in this study to be utilized by the Eclipse TPS. Moreover, after comparing the results from the Varian model, good compliance was achieved according to vendor-specific recommendations. All the tests were performed according to AERB recommendations. In this paper, we have described a few of them elaborately. The commissioning data are found to be well within the tolerance limit as per AERB recommendation and equivalent tothe reference literature. From installation to commissioning, overall machine performance was good and stable.

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