DOI: 10.7860/JCDR/2025/81038.21299

Original Article

Oncology Section

Beam Data Validation during Transition from Flattened to Unflattened Beams in IMRT and VMAT Delivery: An Experimental Study

PRADEEP GOSWAMI[1], PUNAM KUMARI[2], BRIJESH GOSWAMI[3], RAKESH KUMAR JAIN[4], SURESH YADAV[5], S CHOUDHARY[6], ASIYA HILAL[7], KISHORE SINGH[8]

ABSTRACT

Introduction: The commissioning process for Intensity-Modulated Radiotherapy (IMRT) and RapidArc is very rigorous and tedious. It involves manifold beam data measurement, Quality Assurance (QA) and acceptance testing of different parts of Linear Accelerator (Linac).

Aim: To find out how the commissioning parameter of TG-119 will change when it is shifted from a flattened beam (6X) to Flattening Filter Free (6X_FFF) for RapidArc and IMRT plans.

Materials and Methods: In this experimental study conducted at the Department of Radiation Oncology, Subharti Medical College, Meerut, Uttar Pradesh, India, between December 2021 to November 2022 the authors evaluated the effect of dose rate, gantry speed, leaf speed and intentional error by Picket Fence (PF) tests using Electronic Portal Imaging Device (EPID) and Gafchromic™ EBT3 films during commissioning of TrueBeam Linac (Varian Medical System, Palo Alto, CA). For comparison, RA and IMRT plans are made for all tests as per American Association of Physicists in Medicine Task Group-119 (AAPM TG-119). Confidence Limit (CL) was set to have 95 percent of the measured data within tolerance limit.

Results: For IMRT (static and arc mode) recommendations and methodology were evaluated effectively to check commissioning parameter precision. Average absolute deviation ($Diff_{Abs}$) for variable Dose Rate and Gantry Speed (DR_GS) has been within 1.5% for both 6X and 6X_FFF energies. Their ($Diff_{Abs}$) for variable Leaf Speed and Dose Rate (LS_DR) was also within 1.5%. Result for field-by-field measurements for IMRT and RapidArc for 6X and 6X_FFF energies shows that overall mean for 6X energy is 99.83 and 99.88, respectively, for IMRT and RapidArc cases, with CL values of 0.50 and 0.32. The 6X_FFF energy result is 99.81 and 99.87 for IMRT and RapidArc cases, with CL values of 0.55 and 0.34.In comparison to RapidArc, IMRT plans have more Monitor Units (MUs). RapidArc plans require less time to deliver the same or better results than IMRT plans.

Conclusion: Accurate delivery of RapidArc and IMRT plans for different beam modalities (6X and 6X_FFF), accepted CL values can be utilised as a baseline to evaluate the quality of QA procedure, accuracy and wholeness of Treatment Planning System (TPS).

Keywords: Confidence limit, Flattening filter-free, Intensity-modulated radiotherapy, RapidArc, Task group-119, Volumetric-modulated arc therapy

INTRODUCTION

The IMRT is a sophisticated but highly conformal approach for treating cancer patients worldwide [1-3]. The IMRT technique provides a very sharp dose gradient. Utilising this IMRT feature allows the authors to provide very high conformal dose to target area while minimising impact on function of surrounding Organs at Risk (OAR). Yu CX introduced Intensity-Modulated Arc Therapy (IMAT) or Volumetric-Modulated Arc Therapy (VMAT) with better conformity than other types of conventional treatment in 1995 [4]. Currently, utilisation of VMAT/RapidArc has grown globally. RapidArc has shown equivalent or better results for the many cancer site cases compared to IMRT and other available treatment techniques [5,6]. Unlike IMRT, RapidArc utilises continuous gantry rotation at variable dose rates with dynamic Multi-Leaf Collimator (MLC) for dose delivery motion [7-9]. It is discussed in detail in the commissioning and QA of VMAT [10,11].

TrueBeam Linear accelerators (Linac) (Varian Medical System, Palo Alto, CA) have both photon modes, such as FF and FFF [12,13]. FF beam creates a more homogeneous dose spatial arrangement throughout the treatment field, making it easier to calculate with precision. Its delivery rate is less than the FFF beam due to its uniform dose distribution and more peripheral dose between fields. FFF beams can be generated by removing FF from beam's path and developing conical and non uniform dose distribution. FFF beam provides less peripheral dose with higher dose rate between fields. The nature of FFF beam is beneficial in delivering a high dose in less time [14]. Its inhomogeneous dose distribution, like more center dose (to target) and less peripheral dose (to OAR), makes it a most suitable beam for Stereotactic Radiosurgery (SRS), Stereotactic Radiotherapy (SRT) and Stereotactic Body Radiation Therapy (SBRT) [15]. In the true beam machine, we have 6, 10 and 15 MV in FF mode with extra freedom of FFF mode in 6 MV and 10 MV energies. Maximum dose rate in FF mode of energies 600 MU/minute and in FFF mode it depends on the type of energies, like 1400 MU/minute in 6 MV and 2400 MU/minute in 10 MV [10].

There is a deficiency in commissioning a literature review focusing on planning and delivery accuracy of RapidArc and IMRT in both FF and FFF modes [16]. Consequently, it is crucial to assess planning and verification accuracy more thoroughly and establish their baseline value during commissioning. According to 2008 study by radiological physics centre, 28% of 250 head and neck phantom irradiations used for IMRT verification did not satisfy set standards. This comprised 4 mm Distance to Agreement (DTA) in high dose gradient area and seven percent dosage variation in low

dose gradient area [17]. Improper commissioning and inadequate acceptance and agreement between delivery and planning processes were leading causes of this. Then, in 2009, American Association of Physicists in Medicine (AAPM) published Task Group-119 (TG-119), IMRT commissioning guideline, evaluating precision of IMRT delivery and planning systems [18].

The commissioning process for IMRT and RapidArc is very rigorous and tedious. It involves manifold beam data measurement, QA and acceptance testing of different parts of Linac. TPS, QA is essential to whole system because it involves dose calculation and dose delivery checks before treating any patient. Some tests before delivery of IMRT/RapidArc are point dose, portal dose, fluence check and MLC accuracy with reproducibility, which need to be performed regularly [19].

MATERIALS AND METHODS

The present experimental study was conducted at the Department of Radiation Oncology, Subharti Medical College, Meerut, Uttar Pradesh, India, between December 2021 to November 2022, during installation of Linac (TrueBeam, Varian Medical System, Palo Alto, CA). An Installation, beam data gathering, commissioning and licensing for Linac is a continuous and very long process.

Study Procedure

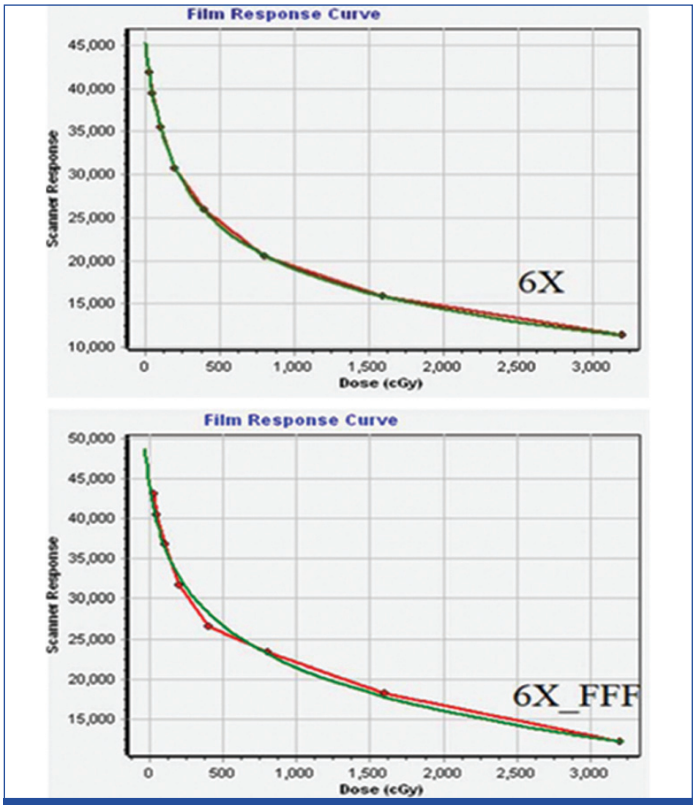
The authors evaluated the effect of dose rate, gantry speed, leaf speed and intentional error in MLC by PF tests using EPID and Gafchromic™ EBT3 films. Apart from the above the authors also evaluated Dosimetric Leaf Gap (DLG), leaf transmission and couch modelling for TPS. For comparison, RA and IMRT plans are made for all tests as per American Association of Physicists in Medicine Task Group-119 (AAPM TG-119) on the phantom datasets, along with sample structure set planning, downloaded from the AAPM website (www.aapm.org). CL was set to have 95 percent of the measured data within tolerance limit.

(A) Multi-Leaf Collimator (MLC) performance check: Multiple tests are needed to analyse effect of dose rate, MLC speed gantry speed and range on MLC performance [20]. A PF test has been conducted to assess system's error detection capability [13]. A series of PF tests, both static and dynamic, were performed. The varian medical system provided QA files on its "My Varian" portal, which can be downloaded free of cost.

(B) Measurement of Dosimetric Leaf Gap (DLG) and leaf transmission: DLG and leaf transmission significantly impact dosimetric accuracy of IMRT and RapidArc plans. A baseline value was measured according to manufacture's guidelines. An SNC 125 chamber (Sun Nuclear Corporation, Florida, USA) measured leaf transmission for both leaf banks. DLG was also calculated for various sliding MLC gap widths, but for the same set-up and according to the guidelines.

(C) Couch Modelling for Treatment Planning System (TPS): The authors first need to model a couch into the TPS (v16.1, Eclipse, Varian, Palo Alto, CA, USA) for treatment planning. According to different parts of the couch, i.e., thin, medium and thick portions, there is indexing on the couch like F8 to F1, F1 to H2 and H2 to H4, respectively, for different sites, pelvis, thorax and head-neck. Using a chamber of volume 0.6 cc (SNC600c) placed in middle of solid water phantom, thin and thick couch transmission has been measured. Solid water phantom was exposed to Posteroanterior (PA) fields in various locations to get chamber readings and compute couch transmission factors.

(D) Calibration curve and film dosimetry: The authors used Varian Medical System's EPID aS1200 for gamma analysis. The aS1200 detector features large measurement area (40 cm×40 cm) with small pixel size (0.0336 cm) [21]. Gafchromic™ film does not depend on beam angle, dose rate, or energy, with excellent spatial resolution. This quality of Gafchromic™ film makes it most suited for treatment plans with various commissioning QA [22,23]. In film dosimetry, we convert optical density to its respective dose with the help of a calibration curve. Cut an 8"×10" sheet of EBT3 film in 1.25"×8" strips. Film orientation should be maintained throughout this procedure to avoid irregularities in the results. Eight to 10 equal strips are sufficient to make a good calibration curve. Calibration is valid for doses to the highest dose used during this procedure. So, a different dose point can be selected per the institution's protocol. The authors have chosen dose pattern 25 cGy, 50 cGy, 100 cGy, 200 cGy 400 cGy, 800 cGy 1600 cGy and 3200 cGy for making their calibration curve [Table/Fig-1]. After exposing the films, we should wait around 24 hours for better results. To scan a film, the authors utilised Epson software and Epson expression 1200XL flatbed scanner (Nagano, Seiko Epson Corp, Japan). Before scanning any dose film, at least 16 successive blank scans should be taken. Position the film at center of scanner bed for a more uniform response. Films were scanned using transmission mode to enhance scan stability, utilising a scanner fix setting of 75 dots per inch and 48 bit colour resolution. Tagged Image File Format (TIFF) was utilised to export images for analysis. The authors used Gafchromic™ EBT3 films in the ArcCHECK phantom (Sun Nuclear Corporation, Florida, USA) for film dosimetry.



[Table/Fig-1]: Calibration curve for 6X and 6X_FFF.

(E) IMRT and RapidArc dosimetry as per TG-119: The institution has recently commissioned a TrueBeam system equipped with HD 120 MLC, featuring all five photon and electron energy levels. Commissioning of TrueBeam Linac was done with the help 3D SCANNERTM RFA (Sun Nuclear Corporation, Florida, USA) with its software SNC Dosimetry (version 3.7.1.21). The authors employed Varian Medical System's EPID aS1200 for gamma analysis. AS1200 detector features large measurement area (40 cm×40 cm) with small pixel size (0.0336 cm). We also used ArcCHECK, a helical detector grid with 1386 diode detectors with multi plug TM that accepts ion chambers, stereotactic detectors and film for the measurement. We also used a solid water phantom (density of 1.04 g/cm^3) of dimension LxWxH (30×30×15 cm^3) for point dose measurement. Our dedicated CT-simulator, Discovery RT Gen 3 (GE Healthcare, Chicago, USA) scanned all the required items. TG-119 has four test structures set for evaluation, i.e., C-shape target, head-neck, prostate and multi-target. On AAPM website, CT datasets with their defined structure set are freely accessible. By TG-119 recommendations on TrueBeam

system, this study attempts to evaluate overall beam commissioning accuracy and calculate CLs for IMRT and RapidArc utilising 6 MV photon energies in FF and FFF modes. Then, it can be incorporated with TPS (v16.1, Palo Alto, Varian, Eclipse, CA, USA) to make further plans, as well as an Analytical Anisotropic Algorithm (AAA) and evaluation. Before making a comparison plan, we have adopted the same criteria as the TG-119 guideline [24]. Preliminary tests P1 have AP-PA open field of 10×10 cm^2 with 2Gy dose prescription at the isocenter. Test P2 involves various AP-PA open fields with differing sizes, establishing stair-step dosing pattern that varies from 40 cGy-200 cGy. For the tests P1 and P2, we used a Sun Nuclear ionisation SNC125c chamber of Volume 0.125 cc for measurement.

The energy used for planning is 6X and 6X-FFF. No predefined weighting factor selected for the field; it is set automatically by Eclipse TPS. The authors used an equi spaced field for all test plans, like seven fields for prostate and multi-target, nine for head-neck and C-shape target [25,26]. The authors used two full coplanar arcs, like clockwise (181°-179°) and counterclockwise (179°-181°), with complementary angles for collimator, i.e., 45° and 315°. Before planning, we set the same isocenter position and optimisation parameter for all IMRT and their corresponding RapidArc plan. We used a 2.5 mm grid size for dose calculation without normalising to compare DVH for RapidArc and IMRT plans. The present study aimed to provide RapidArc and IMRT plans for TG-119 structural set. Dose objective that is provided in TG-119 used as standard guideline for creating plans with similar complexity and modulation. The number of beams and their arrangement per TG-119 recommendation, while RapidArc with two full arcs is the easiest way to achieve dose goal criteria as per TG-119 is shown in [Table/Fig-2]. Many plan parameters are available for different target coverage comparisons, like D_{99}, D_{95}, D_{90}, D_5, D_{50}, D_{10}, D_{max}, for different OARs comparisons. The authors also examined several Monitor Units (MUs) to evaluate low doses to normal organs and determine treatment duration. Homogeneity Index (HI) and Conformity Index (CI) act as parameters for evaluating plans' quality against one another [25,27]. They are defined as:

Parameters	Number of beam/ arcs	Beam arrangement	Collimator angle	Prescribe dose	Dose per fraction (Gy)
IMRT					
Multitarget	7	50° from anterior	0	50	2
Prostate	7	50° from anterior	0	80	2
Head and neck	9	40° from anterior	0	50	2
C-shape target (easy constraint)	9	40° from anterior	0	50	2
C-shape target (hard constraint)	9	40° from anterior	0	50	2
RapidArc					
Multitarget	2	179°-181° CCW 181°-179° CW	45° 315°	50	2
Prostate	2	179°-181° CCW 181°-179° CW	45° 315°	80	2
Head and neck	2	179°-181° CCW 181°-179° CW	45° 315°	50	2
C-shape target (easy constraint)	2	179°-181° CCW 181°-179° CW	45° 315°	50	2
C-shape target (hard constraint)	2	179°-181° CCW 181°-179° CW	45° 315°	50	2

[Table/Fig-2]: Beam parameter for IMRT and RapidArc.

Conformity Index (CI):

$CI=(TV^2_{PIV})/TV\times PIV$

Where,

TV refer as target volume;

PIV refer as prescribed isodose volume;

TVPIV define as the target volume encompassed by the defined isodose volume.

Homogeneity Index (HI):

$HI=(D_{2\%}-D_{98\%})/D_{50\%}$

Where,

$D_{2\%}$ defined as dose revived by 2% of the PTV volume;

$D_{98\%}$ defined as dose revived by 98% of the PTV volume;

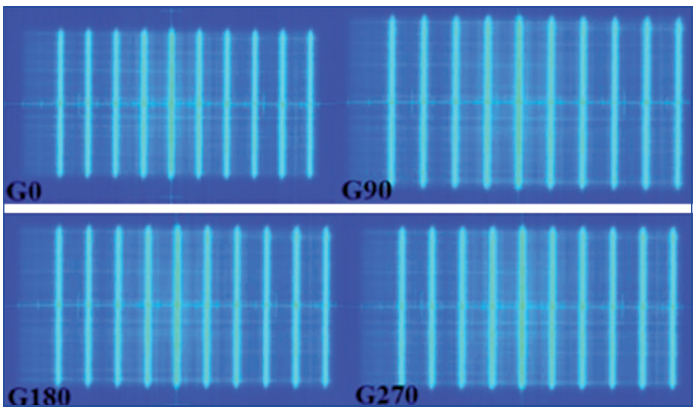
$D_{50\%}$ defined as dose received by 50% of the PTV.

STATISTICAL ANALYSIS

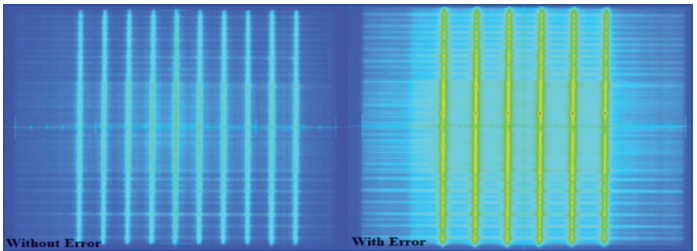
With aid of measured and planned dose, dose difference ratio may be computed. This is defined as prescription dose/(divided dose-plan dose). TG-119 identified agreement between set of measurements and anticipated values using CL approach. Formula for CL for point dosages is {|mean|+1.96 σ}, where σ and mean are the standard deviation and average value, respectively, for many measurements. CL for gamma analysis is {(100-mean)+1.96 σ}, where σ is standard deviation and mean is the average % of points that meet predetermined criteria. 95% of data should be within range of confidence.

RESULTS

(A) MLC performance check: Using EPID, effect of gantry angle and rotation on leaf position and precision was evaluated. PF images were compared between 6X-FFF and 6X modes. The PF images at static and dynamic modes is shown in [Table/Fig-3-6]. Intentional 0.5 mm positional errors were easily discerned with the help of EPID. Dose deviation calculations using seven different DR_GS combinations for 6X and 6X-FFF are listed in [Table/Fig-7]. Four LS_DR combinations for 6X-FFF and 6X are displayed in [Table/Fig-8]. Region of interest described in one of the strips, delivered with distinct LS_DR and DR_GS, corresponds to each place in tables. DR_GS and LS_DR test images with EPID for 6X and 6X-FFF are displayed in [Table/Fig-9,10]. The DMLC dosimetry results for 6X_FFF and 6X energies is shown in [Table/Fig-11]. Output variation is within the tolerance <±3% at 4 cardinal gantry angles.

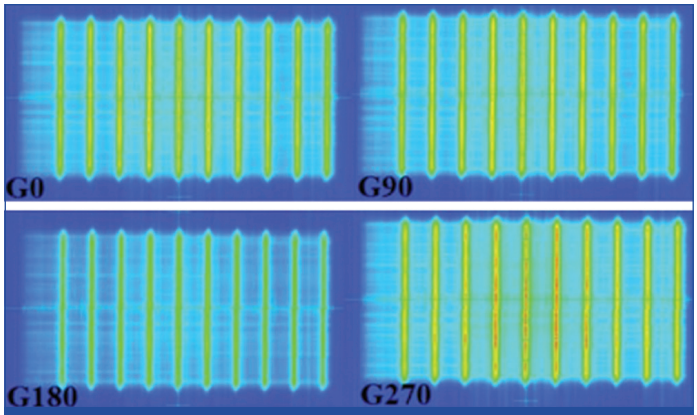


[Table/Fig-3]: Picket fence images for 6X at static mode.

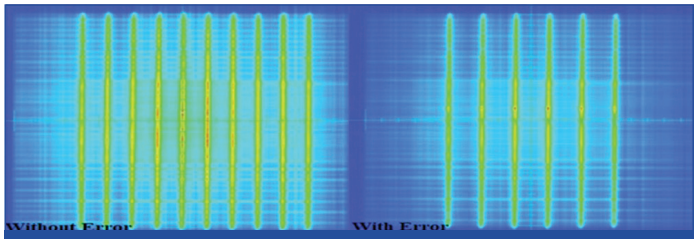


[Table/Fig-4]: Picket fence in RapidArc mode without and with error (6X).

(B) Measurement of Dosimetric Leaf Gap (DLG) and leaf transmission: MLC and DLG transmission values were acquired



[Table/Fig-5]: Picket fence images for 6X_FFF at static node.



[Table/Fig-6]: Picket fence in RapidArc mode with and without error (6X_FFF).

as recommended by the vendor. The DLG and MLC transmission results for 6X and 6X-FFF energies is shown in [Table/Fig-12].

(C) Couch modelling for TPS: The calculated and measured transmission values for the couch's thin and thick indexing parts for the 6X and 6X-FFF energies is listed in [Table/Fig-13].

(D) Gamma analysis:

(D-1) Film dosimetry: Film measurement is done with the help of the Sun Nuclear ArcCHECK phantom by placing the film in the assigned slot. Percentage of locations in high-dose and low-dose zones that meet suggested 3 percent/3 mm gamma requirements for both RapidArc plans and IMRT for 6X and 6X-FFF energies is displayed in [Table/Fig-14,15], respectively. Percentage of points passing during gamma analysis according to set criteria (3%/3 mm), averaged over all tests was 96.32 (IMRT) and 98.92 (RapidArc) for the high-dose plans for 6X, 96.90 (IMRT) and 98.66 (RapidArc) for the high-dose plans for 6X-FFF. The CLs using 3%/3 mm gamma criteria were 7.7 for IMRT and 2.5 for RapidArc in the high-dose planes for 6X, 6.7 for IMRT and 2.8 for RapidArc in the high-dose planes for 6X_FFF.

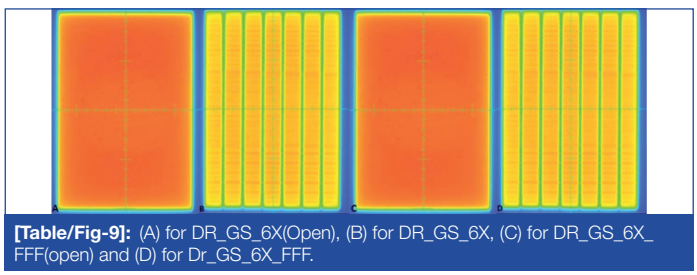
(D-2) Field by field gamma measurement: Portal dosimetry is the easiest and convenient way to do any field-by-field measurement and gamma analysis for any modality like IMRT and RapidArc. The field-by-field measurements for IMRT for 6X and 6X_FFF is shown in [Table/Fig-16] and the same result for RapidArc for 6X_FFF and 6X energies is shown in [Table/Fig-17]. Result shows that overall mean for 6X energy is 99.83 and 99.88, respectively, for IMRT and RapidArc cases, with CL values of 0.50 and 0.32. The 6X_FFF energy result is 99.81 and 99.87 for IMRT and RapidArc cases, with CL values of 0.55 and 0.34.

Band no.	-6		-4		-2		0		2		4		6		Threshold
	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	
R_{DR-GS}	0.6005	0.6012	0.6135	0.6135	0.6147	0.6141	0.6149	0.6146	0.6127	0.6126	0.6102	0.6107	0.5931	0.5935	
R_{Open}	4.117	4.119	4.231	4.233	4.225	4.226	4.216	4.216	4.215	4.216	4.215	4.216	4.063	4.064	
R_{Corr}	14.59	14.60	14.50	14.49	14.55	14.53	14.58	14.58	14.54	14.53	14.48	14.48	14.60	14.60	
Diff(x)	0.27	0.35	-0.32	-0.35	0.01	-0.10	0.26	0.22	-0.08	-0.09	-0.48	-0.42	0.35	0.40	<±3%
Average of absolute deviations ($Diff_{Abs}$)	6X													0.25	<1.5%
	6X_FFF													0.28	

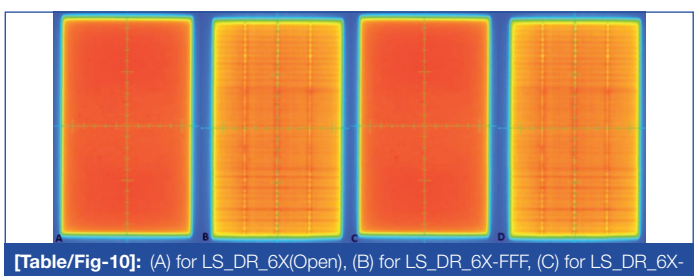
[Table/Fig-7]: DR_GS test for RapidArc delivery corresponding to their respective energies.

Band no.	-4.5		-1.5		1.5		4.5		Threshold
	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	
R_{LS}	0.1666	0.1666	0.1716	0.1713	0.1710	0.1709	0.1663	0.1663	
R_{Open}	1.244	1.245	1.257	1.257	1.253	1.254	1.233	1.235	
R_{Corr}	13.39	13.38	13.65	13.63	13.65	13.63	13.49	13.47	<±3%
Diff(x)	-1.12	-1.08	0.79	0.74	0.76	0.75	-0.42	-0.41	
Average of absolute deviations ($Diff_{Abs}$)	**6X**							**0.77**	<1.5%
	6X_FFF							**0.75**	

[Table/Fig-8]: DR_GS test for RapidArc delivery corresponding to their respective energies.



[Table/Fig-9]: (A) for DR_GS_6X(Open), (B) for DR_GS_6X, (C) for DR_GS_6X_FFF(open) and (D) for Dr_GS_6X_FFF.



[Table/Fig-10]: (A) for LS_DR_6X(Open), (B) for LS_DR_6X-FFF, (C) for LS_DR_6X-FFF(Open) and (D) for LS_DR_6X-FFF.

Gantry angle	Output result		Variation (%)		Tolerance
	6X	6X_FFF	6X	6X_FFF	
0° (Ref)	0.0534	0.04985	0%	0%	<±3%
90°	0.0531	0.04958	-0.5618%	-0.5416%	<±3%
180°	0.0535	0.04999	-0.1873%	-0.2808%	<±3%
270°	0.0532	0.04976	0.3745%	0.1805%	<±3%

[Table/Fig-11]: DMLC dosimetry results corresponding to their respective energies.

Energy	6x	6X_FFF
DLG (mm)	0.96	0.83
Transmission (%)	1.55%	1.32%

[Table/Fig-12]: DLG and transmission values corresponding to their respective energies.

Energy	Thicker area			Thinner area		
	Calculated	Measured	% Diff	Calculated	Measured	% Diff
6X	0.9769	0.9685	-0.84%	0.9830	0.9747	-0.83%
6X_FFF	0.9795	0.9730	-0.65%	0.9847	0.9805	-0.42%

[Table/Fig-13]: Couch transmission corresponding to their respective energies.

Test	IMRT		RapidArc	
	6X	6X_FFF	6X	6X_FFF
Prostate	95.8	98.7	99.2	99.5
Head and neck	96.4	94.5	97.7	98.7
C-shape target (hard constraint)	97.5	95.8	99.3	97.5
C-shape target (easy constraint)	98.7	98.8	98.9	98.5
Multitarget	93.2	96.7	99.5	99.1
Overall mean	96.32	96.90	98.92	98.66
Overall SD	2.1	1.9	0.7	0.7
Confidence limit	7.7	6.7	2.5	2.8

[Table/Fig-14]: Gamma evaluation (3%, 3 mm) in high dose PTV plane for IMRT and RapidArc with ArcCHECK Phantomcorresponding to their respective energies.

Test	IMRT		RapidArc	
	6X	6X_FFF	6X	6X_FFF
Prostate	98.6	97.9	98.9	95.1
Head and neck	98.8	99.2	98.7	96.5
C-shape target (hard constraint)	99.1	98.8	98.5	95.1
C-shape target (easy constraint)	98.9	95.1	96.1	99.9
Overall mean	98.9	97.8	98.1	96.7
Overall SD	0.2	1.8	1.3	2.3
Confidence limit	1.6	5.9	4.5	7.8

[Table/Fig-15]: Gamma Evaluation (3%, 3mm) in the low dose avoidance structure plane for IMRT and RapidArc with ArcCHECK Phantom corresponding to their respective energies.

(E) IMRT and RapidArc Dosimetry as per TG-119

(E-1) Preliminary tests: These preliminary tests were designed to check accuracy of TPS and its dosimetry before implementing IMRT and RapidArc in any system. First, output dose calibration for 6X and 6X_FFF energy was done according to TRS 398 before any experiments were performed. The variation between the measured and reference doses was 0.025%, meaning the plan and estimated values were very close. Their calibration result was utilised in IMRT and RapidArc plans. Preliminary test for 6X and 6X_FFF was performed and measured as recommended in TG-119. Dose point measurement for P1 and P2 preliminary tests utilising ion chamber SNC125 is displayed in [Table/Fig-18,19], together with difference between measured and planned doses. Dose variation result for tests P1 and P2 was less than 2%, which shows that non IMRT and RapidArc system was commissioned with decent accuracy.

For both RapidArc plans and IMRT, ion chamber measurement findings in high and low-dose locations are displayed in [Table/Fig-20,21], respectively. CLs and dose difference ratios are computed according to TG-119. 0.014 in 6X_IMRT, 0.019 in 6X_RapidArc, 0.017 in 6X_FFF_IMRT and 0.0102 in 6X_FFF_RapidArc are average dose difference ratios for high-dose, low-gradient targets. These values translate into average 95% CLs of 0.028, 0.044, 0.030 and 0.034, respectively. Average CL for all test cases was within 0.045 and institution took part in TG-119. Average dose difference ratios for low dose points in avoidance structures are 0.015 in 6X_IMRT, 0.013 in 6X_RapidArc, 0.012 in 6X_FFF_IMRT and 0.006 in 6X_FFF_RapidArc. These ratios translate into average 95% CLs of 0.030, 0.045, 0.029 and 0.035, respectively. For CLs, average of all tests and institutions in low-dose area from TG-119 was 0.047.

(E-2) RapidArc and IMRT plan comparison: RapidArc and IMRT dose results for 5 clinical tests are tabulated in [Table/Fig-22]. With exception of C-shaped hard clinical test, [Table/Fig-22] demonstrates that clinical tests can meet dose target criteria established by TG-119.

Field	Multitarget		Prostate		Head-neck		C-shape target (easy constraint)		C-shape target (hard constraint)	
	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF
1	99.8	99.9	100	99.9	100	100	99.9	100	99.8	99.6
2	99.5	99.7	99.8	100	99.6	99.8	100	100	100	99.9
3	99.9	100	99.5	99.8	99.8	100	100	99.8	99.9	100
4	100	99.9	99.9	100	99.9	99.6	99.7	99.5	99.5	99.7
5	99.6	100	100	99.9	99.8	99.5	99.5	99.7	99.7	99.4
6	100	99.8	99.8	99.6	99.7	100	100	99.8	99.8	100
7	99.7	99.5	99.6	99.4	100	99.8	99.9	99.6	100	99.8
8					99.8	99.7	100	99.9	99.7	99.8
9					100	99.8	99.8	100	100	100
Mean	99.79	99.83	99.80	99.80	99.84	99.80	99.87	99.81	99.82	99.80
Overall mean			6X					99.83		
			6X_FFF					99.81		
Overall sigma			6X					0.167		
			6X_FFF					0.185		
CL			6X					0.50		
			6X_FFF					0.55		

[Table/Fig-16]: Field by field measurement for IMRT corresponding to their respective energies.

Field	Multitarget		Prostate		Head-neck		C-shape target (easy constraint)		C-shape target (hard constraint)	
	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF
1	100	99.8	99.9	100	99.8	100	100	99.8	99.7	100
2	99.8	99.9	100	99.8	99.9	99.7	99.8	99.9	99.9	99.8
Mean	99.9	99.85	99.95	99.9	99.85	99.85	99.9	99.85	99.8	99.9
Overall mean			6X					99.88		
			6X_FFF					99.87		

Overall sigma	6X	0.103
	6X_FFF	0.106
CL	6X	0.32
	6X_FFF	0.34

[Table/Fig-17]: Field by field measurement for RapidArc corresponding to their respective energies.

Test		Plan dose (cGy)	Measure dose (cGY)	Dose variation	% of variation
P1	6X	200	200.8	0.0040	0.4
	6X_FFF	200	201.3	0.0065	0.65

[Table/Fig-18]: The point dose measurements for preliminary test P1 corresponding to their respective energies.

Test	Location	Plan dose (cGy)	Measured dose (cGy)	Dose variation	% of variation
P2 (6X)	1st band left	40	40.45	0.0113	1.13
	2nd band left	80	80.57	0.0071	0.71
	Isocenter	120	121.25	0.0104	1.04
	1st band right	160	161.35	0.0084	0.84
	2nd band right	200	201.77	0.0089	0.89
	Mean dose variation			0.00922	0.90
P2 (6X_FFF)	1st band left	40	40.54	0.0135	1.35
	2nd band left	80	80.65	0.0081	0.81
	Isocenter	120	121.40	0.012	1.2
	1st band right	160	161.42	0.0089	0.89
	2nd band right	200	201.87	0.0094	0.9
	Mean dose variation			0.0104	1.04

[Table/Fig-19]: The point dose measurements for preliminary test P2 corresponding to their respective energies.

Test	Location	IMRT		RapidArc	
		6X	6X_FFF	6X	6X_FFF
Prostate	Isocenter	0.014	0.020	0.010	-0.007
Head and neck	Isocenter	0.003	0.023	0.005	0.005
C-shape target (hard constraint)	2.5 cm anterior to isocenter	0.020	0.006	0.034	0.025
C-shape target (easy constraint)	2.5 cm anterior to isocenter	0.012	0.016	0.031	0.015
Multitarget	Isocenter	0.020	0.021	0.013	0.013
Overall mean		0.014	0.017	0.019	0.0102
Overall SD		0.0070	0.0067	0.0130	0.0120
Confidence limit		0.028	0.030	0.044	0.034

[Table/Fig-20]: High dose point in PTV for both IMRT and RapidArc corresponding to their respective energies.

Established a target for core D10 <10 Gy, established by TG-119 for C-shape hard, which is nearly impossible to achieve at required PTV coverage. It tests any planning system and how much we can push it to achieve the desired value of D10 by maintaining an optimal coverage of PTV. The RapidArc and IMRT plan parameters; their respective values are tabulated. Both modalities and energies include CI, HI, dosage per fraction, total MU, number of beams and MU ratio of RapidArc and IMRT is compared in [Table/Fig-23]. All the plans have good CI values with better comparative results as defined in [Table/Fig-23], 6X and 6X_FFF. As CI, all the plans for 6X and 6X_FFF also have well-defined values of HI and their results are well tabulated in [Table/Fig-23] for comparison. The MUs of all the plans for 6X and 6X_FFF is described in [Table/Fig-23]. It defines a ratio of IMRT and RapidArc for their respective energies. From their MU values, it is well described that as plan complexity increases, the number of MUs also increases. In comparison to RapidArc, IMRT plans have more MUs. This is due to a greater degree of freedom in RapidArc plan, so fewer MUs are required to achieve

Test	Location	IMRT		RapidArc	
		6X	6X_FFF	6X	6X_FFF
Prostate	2.5 cm posterior to isocenter	0.023	0.023	0.045	0.023
Head and neck	4 cm posterior of isocenter	0.002	0.015	0.010	0.019
C-shape target (Hard constraint)	Isocenter	0.021	0.001	0.005	-0.019
C-shape target (Easy constraint)	Isocenter	0.009	0.002	0.002	0.007
Multitarget	4 cm superior to isocenter	0.015	0.016	0.013	0.005
Multitarget	4 cm inferior to isocenter	0.018	0.015	0.005	0.003
Overall mean		0.015	0.012	0.013	0.006
Overall SD		0.008	0.009	0.016	0.015
Confidence limit		0.030	0.029	0.045	0.035

[Table/Fig-21]: Low dose point in the avoidance structure for both IMRT and RapidArc corresponding to their respective energies.

the same result as IMRT. In some cases, the ratios between IMRT and RapidArc are almost double. RapidArc plans require less time to deliver the same or better results than IMRT plans.

(F) Statistical calculation: CL and dose difference ratio measurement and calculation done as per TG-119 methodology only. CL is given as {(100-mean)+1.96σ} for gamma analysis and {|mean|+1.96σ} for point doses. 95 percent of data should fall inside CL and CL was computed using gamma passing conditions of 3%/3 mm.

DISCUSSION

The authors utilised TG-119 test cases for TPS commissioning to compare 6X and 6X_FFF energies for RapidArc and IMRT plans. It included information on optimising MLC settings and displayed a straightforward commissioning quality evaluation. 6X_FFF and 6X beams provide the same CLs value without showing much difference [26,28]. Due to DLG optimisation and transmission employing RapidArc measurement data, RapidArc CLs show somewhat better values than their respective IMRT plans. Each energy and technique's CLs are lower than baseline values listed in TG-119. This practice involves checking accuracy of new technology, which gives us confidence to use any new technology in clinical settings. The HDMLC performance evaluation was performed per the recommendations and standard guidelines, including PF test performed in rotational and stationary modes. For several combinations of DR_GS and LS_DR, radiation pattern about associated open field has been investigated. For 6X and 6X_FFF energies, we conducted a comprehensive analysis of changes in DLG and leaf transmission. It is crucial to assess DLG and leaf transmission settings appropriately because dose delivery is sensitive to both. Many uncertainties from various sources related to film dosimetry, like film uniformity, background and type of scanner, can affect the accuracy of film dosimetry. All the films were scanned after 24 Hr only to minimise the effect of time on our measurement results. For RapidArc and IMRT commissioning, all measurements were divided based on respective energies. A separate calibration curve was drawn with different film sets and energy types. After that, only the respective plans were exposed under the series for IMRT and RapidArc. RapidArc and IMRT plans have been created and equated regarding QA and planning for 6X and 6X_FFF energies by TG-119 recommendations. The IMRT and RapidArc planning and QA findings showed some parallels, but not all of them.

			IMRT plans (cGy)		RapidArc plans (cGy)		IMRT/TG_119		RA/TG_119	
	Plan parameter	Planning goal (cGy)	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF
Multitarget	Central D_{99}	>5000	5039	5060	5044	5028	1.008	1.012	1.009	1.006
	Central D_{10}	<5300	5280	5298	5286	5286	0.996	0.999	0.997	0.997
	Superior D_{99}	>2500	2568	2584	2549	2550	1.027	1.034	1.020	1.02
	Superior D_{10}	<3500	3248	3265	2942	2942	0.928	0.933	0.841	0.841
	Interior D_{99}	>1250	1258	1270	1299	1294	1.006	1.016	1.039	1.035
	Interior D_{10}	<2500	1981	1998	1718	1696	0.792	0.799	0.687	0.678
Prostate	PTV prostate D_{95}	>7560	7673	7705	7763	7748	1.01	1.02	1.03	1.02
	PTV prostate D_{5}	<8300	8539	8487	8156	8166	1.03	1.02	0.98	0.98
	Rectum D_{30}	<7000	5012	5060	4713	4917	0.72	0.72	0.67	0.70
	Rectum D_{10}	<7500	6985	7047	7331	7319	0.93	0.94	0.98	0.98
	Bladder D_{30}	<7000	3108	3127	3252	3395	0.44	0.45	0.46	0.49
	Bladder D_{10}	<7500	5089	5109	5182	5189	0.68	0.68	0.69	0.69
Head and neck	PTV D_{90}	5000	5133	5155	5084	5073	1.03	1.03	1.02	1.01
	PTV D_{99}	>4650	4759	4809	4674	4684	1.02	1.03	1.01	1.01
	PTV D_{20}	<5500	5322	5320	5352	5378	0.97	0.97	0.97	0.98
	Cord max	<4000	3652	3721	3907	3923	0.91	0.93	0.98	0.98
	Rt_Prt D_{50}	<2000	1478	1499	1567	1496	0.74	0.75	0.78	0.75
	Lt_Prt D_{50}	<2000	1503	1471	1613	1559	0.75	0.74	0.81	0.78
C-shape target (easy constraint)	PTV D_{95}	5000	5041	5039	5026	5022	1.01	1.01	1.01	1.00
	PTV D_{10}	<5500	5367	5375	5235	5233	0.98	0.98	0.95	0.95
	Core D_{10}	<2500	2380	2417	2141	2102	0.95	0.97	0.86	0.84
C-shape target (hard constraint)	PTV D_{95}	5000	5037	5077	5053	5042	1.01	1.02	1.01	1.01
	PTV D_{10}	<5500	5389	5438	5250	5253	0.98	0.99	0.95	0.96
	Core D_{10}	<1000	2232	2307	2012	2012	2.23	2.31	2.01	2.01

[Table/Fig-22]: RapidArc and IMRT planning results in the respect of TG-119 reference data corresponding to their respective energies.

	Multitarget				Prostate			
	IMRT		RA		IMRT		RA	
Parameters	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF
CI	0.95	0.94	0.96	0.95	0.96	0.95	0.97	0.96
HI	0.11	0.12	0.09	0.10	0.13	0.15	0.10	0.12
No of beams	7	7	2	2	7	7	2	2
Dose per fraction (cGy)	200	200	200	200	200	200	200	200
MU	639.1	832.2	546.1	619.2	823.4	1064.9	712.4	694.9
MU ratio	1.17	1.34	1	1	1.16	1.5	1	1

	Head and neck				C-shape target (easy constraint)				C-shape target (hard constraint)			
	IMRT		RA		IMRT		RA		IMRT		RA	
Parameters	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF	6X	6X_FFF
CI	0.95	0.94	0.97	0.96	0.91	0.89	0.93	0.92	0.86	0.85	0.88	0.87
HI	0.20	0.22	0.15	0.17	0.25	0.26	0.23	0.25	0.28	0.26	0.26	0.25
No. of beams	9	9	2	2	9	9	2	2	9	9	2	2
Dose per fraction (cGy)	200	200	200	200	200	200	200	200	200	200	200	200
MU	1843.5	2058.5	962.6	1089.3	1493.4	1943.1	779.2	854.5	1554.5	2028.4	789.6	826.9
MU ratio	1.91	1.89	1	1	1.91	2.27	1	1	1.97	2.45	1	1

[Table/Fig-23]: Plan evaluation parameter corresponding to their respective energies.

Clinical implication: Implementing FFF beams for IMRT and RapidArc offers potential clinical advantages, including reduced treatment time, lower scatter dose and enhanced patient comfort. However, these benefits must be weighed against the need for careful commissioning and re-validation of TPS beam models, especially for high-precision techniques.

Limitation(s)

The planning rules applied as similar as possible between techniques and evaluation tools were unified, but a lot of care should be taken for minimising arbitrary elements. It is impossible to completely control all potential sources of bias and their effect on the planning result comparison. Additionally, the reliance on 3%/3 mm gamma analysis may overlook subtle yet clinically relevant discrepancies, particularly in high-dose gradient regions. Finally, the lack of clinical outcome data limits the ability to correlate dosimetric advantages with patient benefits such as improved local control or reduced toxicity. It is phantom based study, so the results cannot be applied to the actual patient. This should be further investigated systematically on large number of groups.

CONCLUSION(S)

Understanding a system's limitations is better before using it in a clinical application. There is always a balance between minimum OAR dosages and maximum target dose. Accurate delivery of RapidArc and IMRT plans for different beam modalities (6X and 6X_FFF), accepted CL values can be utilised as baseline to evaluate quality of QA procedure, accuracy and wholeness of TPS. For the welfare of patient, other anatomical test plan can be created for validation and improvement in commissioning process.

REFERENCES

[1] Webb S. The physical basis of IMRT and inverse planning. Br J Radiol. 2003;76(910):678-89. Doi: 10.1259/bjr/65676879. PMID: 14512327.

[2] Goswami B, Jain RK, Yadav S, Kumar S, Oomen S, Manocha S, et al. Comparison of treatment planning parameters of different radiotherapy techniques for craniospinal irradiation. Iran J Med Phys 2021;18:164-70. Doi: 10.22038/ijmp.2020.45574.1712.

[3] Otto K. Volumetric modulated arc therapy: IMRT in a single gantry arc. Med Phys. 2008;35(1):310-17. Doi: 10.1118/1.2818738. PMID: 18293586.

[4] Yu CX. Intensity-modulated arc therapy with dynamic multileaf collimation: An alternative to tomotherapy. Phys Med Biol. 1995;40(9):1435-49. Doi: 10.1088/0031-9155/40/9/004. PMID: 8532757.

[5] Verbakel WF, Cuijpers JP, Hoffmans D, Bieker M, Slotman BJ, Senan S. Volumetric intensity-modulated arc therapy vs. conventional IMRT in head-and-neck cancer: A comparative planning and dosimetric study. Int J Radiat Oncol Biol Phys. 2009;74(1):252-59. Doi: 10.1016/j.ijrobp.2008.12.033. PMID: 19362244.

[6] Ong CL, Verbakel WF, Dahele M, Cuijpers JP, Slotman BJ, Senan S. Fast arc delivery for stereotactic body radiotherapy of vertebral and lung tumors. Int J Radiat Oncol Biol Phys. 2012;83(1):e137-43. Doi: 10.1016/j.ijrobp.2011.12.014. Epub 2012 Feb 24. PMID: 22365628.

[7] Matuszak MM, Yan D, Grills I, Martinez A. Clinical applications of volumetric modulated arc therapy. Int J Radiat Oncol Biol Phys. 2010;77(2):608-16. Doi: 10.1016/j.ijrobp.2009.08.032. Epub 2010 Jan 25. PMID: 20100639.

[8] Wu QJ, Yoo S, Kirkpatrick JP, Thongphiew D, Yin FF. Volumetric arc intensity-modulated therapy for spine body radiotherapy: Comparison with static intensity-modulated treatment. Int J Radiat Oncol Biol Phys. 2009;75(5):1596-604. Doi: 10.1016/j.ijrobp.2009.05.005. Epub 2009 Sep 3. PMID: 19733447.

[9] Chang Z, Wu Q, Adamson J, Ren L, Bowsher J, Yan H, et al. Commissioning and dosimetric characteristics of TrueBeam system: Composite data of three TrueBeam machines. Med Phys. 2012;39(11):6981-7018. Doi: 10.1118/1.4762682. PMID: 23127092.

[10] Glide-Hurst C, Bellon M, Foster R, Altunbas C, Speiser M, Altman M, et al. Commissioning of the Varian TrueBeam linear accelerator: A multi-institutional study. Med Phys. 2013;40(3):031719. Doi: 10.1118/1.4790563. PMID: 23464314.

[11] Beyer GP. Commissioning measurements for photon beam data on three TrueBeam linear accelerators, and comparison with Trilogy and Clinac 2100 linear accelerators. J Appl Clin Med Phys. 2013;14(1):4077. Doi: 10.1120/jacmp.v14i1.4077. PMID: 23318395.

[12] Ling CC, Zhang P, Archambault Y, Bocanek J, Tang G, Losasso T. Commissioning and quality assurance of RapidArc radiotherapy delivery system. Int J Radiat Oncol Biol Phys. 2008;72(2):575-81. Doi: 10.1016/j.ijrobp.2008.05.060. PMID: 18793960.

[13] Kielar KN, Mok E, Hsu A, Wang L, Luxton G. Verification of dosimetric accuracy on the TrueBeam STx: Rounded leaf effect of the high definition MLC. Med Phys. 2012;39(10):6360-71. Doi: 10.1118/1.4752444. PMID: 23039672.

[14] Cashmore J. The characterization of unflattened photon beams from a 6 MV linear accelerator. Phys Med Biol. 2008;53(7):1933-46. Doi: 10.1088/0031-9155/53/7/009. Epub 2008 Mar 11. PMID: 18364548.

[15] Fu W, Dai J, Hu Y, Han D, Song Y. Delivery time comparison for intensity-modulated radiation therapy with/without flattening filter: A planning study. Phys Med Biol. 2004;49(8):1535-47. Doi: 10.1088/0031-9155/49/8/011. PMID: 15152690.

[16] Hrbacek J, Lang S, Klöck S. Commissioning of photon beams of a flattening filter-free linear accelerator and the accuracy of beam modeling using an anisotropic analytical algorithm. Int J Radiat Oncol Biol Phys. 2011;80(4):1228-37. Doi: 10.1016/j.ijrobp.2010.09.050. Epub2010 Dec 2. PMID: 21129855.

[17] Ibbott GS, Followill DS, Molineu HA, Lowenstein JR, Alvarez PE, Roll JE. Challenges in credentialing institutions and participants in advanced technology multi-institutional clinical trials. Int J Radiat Oncol Biol Phys. 2008;71(1 Suppl):S71-S75. Doi: 10.1016/j.ijrobp.2007.08.083. PMID: 18406942.

[18] Ezzell GA, Burmeister JW, Dogan N, LoSasso TJ, Mechalakos JG, Mihailidis D, et al. IMRT commissioning: Multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119. Med Phys. 2009;36(11):5359-73. Doi: 10.1118/1.3238104. PMID: 19994544.

[19] Xing L, Curran B, Hill R, Holmes T, Ma L, Forster KM, et al. Dosimetric verification of a commercial inverse treatment planning system. Phys Med Biol. 1999;44(2):463-78. Doi: 10.1088/0031-9155/44/2/013. PMID: 10070795.

[20] Pönisch F, Titt U, Vassiliev ON, Kry SF, Mohan R. Properties of unflattened photon beams shaped by a multileaf collimator. Med Phys. 2006;33(6):1738-46. Doi: 10.1118/1.2201149. PMID: 16872081.

[21] Miri N, Baltes C, Keller P, Greer P. SU-E-T-265: Development of dose-to-water conversion models for pre-treatment verification with the new AS1200 imager. Med Phys. 2015;42(6):3393-94. Available from: https://doi.org/10.1118/1.4924627.

[22] Casanova Borca V, Pasquino M, Russo G, Grosso P, Cante D, Sciacero P, et al. Dosimetric characterization and use of GAFCHROMIC EBT3 film for IMRT dose verification. J Appl Clin Med Phys. 2013;14(2):4111. Doi: 10.1120/jacmp.v14i2.4111. PMID: 23470940.

[23] Martisíková M, Ackermann B, Jäkel O. Analysis of uncertainties in Gafchromic EBT film dosimetry of photon beams. Phys Med Biol. 2008;53(24):7013-27. Doi: 10.1088/0031-9155/53/24/001. Epub 2008 Nov 18. PMID: 19015581.

[24] Nainggolan A, Pawiro SA. Dosimetric evaluation of Volumetric Modulated Arc Therapy (VMAT) and Intensity Modulated Radiotherapy (IMRT) using AAPM TG 119 protocol. J Biomed Phys Eng. 2019;9(4):395-408. Doi: 10.31661/jbpe.v0i0.839. PMID: 31531292.

[25] Ahmad M, Liu W, Lund M, Moran M, Richards P, Wu D, et al. Clinical evaluation of inverse planning models and IMRT delivery systems in the framework of AAPM TG-119 protocol. Med Phys. 2011;38(6):3600. Available from: https://doi.org/10.1118/1.3612438.

[26] Yan Y, Yan Y, Yadav P, Bassetti M, Du K, Saenz D, et al. Dosimetric and biologic differences in flattened and flattening-filter-free beam treatment plans. arXiv preprint arXiv:1506.05152. 2015 Jun 16.

[27] Pan L, Zhang N, Wang EM, Wang BJ, Dai JZ, Cai PW. Gamma knife radiosurgery as a primary treatment for prolactinomas. J Neurosurg. 2000;93 Suppl 3:10-13. Doi: 10.3171/jns.2000.93.supplement. PMID: 11143223.

[28] Yang B, Yu L, Wang Z, Li W, Zhang J, Hu K, et al. Validation of dosimetric commissioning accuracy of IMRT and rapidarc for halcyon linear accelerator using AAPM TG-119 protocol. Int J Radiat Oncol Biol Phys. 2020;108(3):Supplement e323 - e324. Doi: 10.1016/j.ijrobp.2020.07.773.

PARTICULARS OF CONTRIBUTORS:

1. Research Scholar, Department of Physics, Shobhit Institute of Engineering and Technology, Meerut, Uttar Pradesh, India.
2. Assistant Professor and Senior Medical Physicist, Department of Radiation Oncology, Subharti Medical College, Meerut, Uttar Pradesh, India.
3. Assistant Professor and Head Medical Physicist, Department of Radiation Oncology, Subharti Medical College, Meerut, Uttar Pradesh, India.
4. Professor, Department of Physics, Shobhit Institute of Engineering and Technology, Meerut, Uttar Pradesh, India.
5. Professor, Department of Radiation Oncology, Gandhi Medical College, Bhopal, Madhya Pradesh, India.
6. Professor, Department of Engg. Physics, Lakshmi Narain College of Technology, Bhopal, Madhya Pradesh, India.
7. Associate Professor, Department of Radiation Oncology, Subharti Medical College, Meerut, Uttar Pradesh, India.
8. Professor and Head, Department of Radiation Oncology, Subharti Medical College, Meerut, Uttar Pradesh, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Brijesh Goswami,
Assistant Professor and Head Medical Physicist, Department of Radiation Oncology, Subharti Medical College, Meerut-250005, Uttar Pradesh, India.
E-mail: drbrijeshgoswami@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Jun 05, 2025
- Manual Googling: Jun 16, 2025
- iThenticate Software: Jun 18, 2025 (8%)

ETYMOLOGY: Author Origin

EMENDATIONS: 6

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? No
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **May 31, 2025**
Date of Peer Review: **Jun 12, 2025**
Date of Acceptance: **Jun 20, 2025**
Date of Publishing: **Aug 01, 2025**