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Acceptance test for fan beam CT linac treatment planning system using AAPM TG 119 test cases

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► ***Original article***

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ABSTRACT

***Background*:** To assess accurately the URT treatment planning system from the United Imaging Healthcare, the American Academy of Pain Medicine (AAPM) TG 119 test plans for Intensity-Modulated Radiation Therapy (IMRT) and Volumetric-Modulated Arc Therapy (VMAT) were used. ***Materials and Methods*:** Based on the URT-Linac 506C, the plans were sent to the phantom. The overall accuracy was tested and examined using five geometry tests supplied in TG 119 for various treatment modes of IMRT and VMAT, with three types of beams using the Flattening Filter modality, estimated using the URT-TPS Monte Carlo algorithm. Moreover, a Farmer-type ion chamber was used to measure the point values, and a film was used to measure the fluence. ***Results*:** The disparities between the measured point doses and the anticipated doses for the FF photon beams for static MLC, dynamic MLC, and VMAT were within 2.16%, 1.89%, and 1.89%, respectively. The TG 119 report confidence limits were all met, and SMLC, DMLC, and VMAT had gamma passing rates greater than 99.80%, 99.60%, and 99.70%, respectively. ***Conclusion*:** The URT treatment planning system and the URT-Linac 506C have correctly commissioned IMRT and VMAT processes, according to this analysis, which was completed following the recommendations given by TG 119.

INTRODUCTION

The Intensity-Modulated Radiation Therapy (IMRT) can make highly conformal distributions to the target while preserving Organs at Risk (OARs) [1]. It has been utilized extensively in clinics [2-4] with the Multileaf Collimator and a variety of delivery techniques, including tomotherapy [5], Static Multileaf Collimator (SMLC) [6], and Dynamic Multileaf Collimator (DMLC) [7]. Later in 1995 [8], the gantry can continuously rotate with the Volumetric-Modulated Arc Therapy (VMAT) during treatment, which was developed to optimize the dose delivery. Therefore, more freedom and shorter treatment times are among the main advantages of VMAT with one or two full arcs as opposed to the prior system [9-11]. However, the planning and delivery of IMRT and VMAT treatments should be evaluated for accuracy and precision as they are not always as accurate as practitioners believe. For such reasons, rules and protocols should be established. Due to the lack of a common benchmark, few medical institutions failed to fulfill the targeted accuracy of the TPS commissioning planning and the medical linac delivery system requirements [12].

As a result, with a testing process consisting of two preliminary tests and four mock models, the overall precision of the planning and dosage administration can be evaluated; thus, the TG 119 published multi-institution IMRT test results [13] (*i.e.*, multitarget case, head and neck case, prostate case, and C-shape case). Moreover, a local IMRT system could be assessed using this approach and compared to a reference baseline suggested in the TG119 guidelines. Additionally, a statistical test, known as the Confidence Limit (CL), can be used to quantify the test results to evaluate the dosimetry commissioning accuracy. In more detail, the CL is used to show an estimate's dependability [14]. Additionally, a previous study has confirmed that the TG119 report is reliable on VMAT plans that are on par with IMRT plans in terms of quality [15].

On another hand, the URT-linac 506c medical linear accelerator (developed by the United Imaging HealthCare co., LTD. Shanghai China) is a cutting-edge accelerator that combines the diagnostic helical CT with a high dose rate intensity modulated accelerator to perform a precise radiotherapy coupled with a high-resolution CT image.

To summarize, the study aims to test the dosimetry commissioning of the URT-Linac 506C using baseline plans for SMLC, DMLC, and VMAT for Flattening Filter (FF) beams based on the AAPM (American Academy of Pain Medicine) TG 119. At present, although few scholars have studied this accelerator, we have comprehensively evaluated the

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Static IMRT, Dynamic IMRT, and VMAT plans. Finally, the CL parameters are introduced to evaluate the VMAT plans and the machine's performance.

MATERIALS AND METHODS

MLC position accuracy and repeatability

The system's ability to identify errors was tested, and the impacts of the gantry range and speed, leaf speed, and dosage rate on MLC alignment were assessed. All parts incorporated in TG119 test plans were provided by URT-linac 506c medical linear accelerator. Moreover, the tests were created to mimic the work that was initially proposed by Wen *et al.* [16]. With the help of the Electronic Portal Imaging Device (EPID), several MLC tests were performed and measured. Therefore, four cardinal gantry angles were used for the static MLC testing to assess the gantry angle dependence.

AAPM TG 119

We closely complied with the procedures and materials used in the TG119 [11] to contrast the regional findings with those found in that study. To assess the precision of planning and dosimetry systems, the AAPM TG119 contains the P1 and P2 primary tests (figure 1). Asymmetric jaws, which can produce five bands every 3 cm wide, were utilized in the second primary test P2 with dosages ranging between 40 and 200 cGy.

The 30*30*15cm^3 phantom of water equivalent slabs for nearby IMRT/VMAT certification (Gammex Solid Water) was used to transfer the phantom, which had a contoured structural set, from the AAPM website. Therefore, five treatment plans were created using the URT-TPS on the URT-Linac 506C with 120 MLC.

Moreover, seven fields were chosen for the IMRT and VMAT designs for the prostate and multi-target cases, respectively, at 50° angles from the baseline. For the head-and-neck and C-shaped tests, two complementary full arcs for VMAT and nine fields at 40° angles from the baseline for IMRT were also identified. Finally, the collimator angle was kept constant for IMRT plans at 0°, while it was maintained at 30° for all VMAT designs.

The measurement analysis was done using TG 119 metrics such as the dose targets, Homogeneity Indexes (HI), and Conformity Indexes (CI), and the analysis was based on discrepancies between intended and measured results, where $PTV_{100\%}$ means the volume of PTV that covered by 100% of the prescription dose, $V_{100\%}$ indicates the total volume contained in 100% of the prescribed dose, and VPTV refers to the PTV volume [17]. Thus, this may lead to equation (1):

$$CI = \frac{PTV_{100\%}}{VPTV} \cdot \frac{PTV_{100\%}}{V_{100\%}} \quad (1)$$

Moreover, the HI analysis (refer to equation 2) involves the ratio of the dose that covers a 2% volume (D2%), a 98% volume (D98%), and a 50% volume (D50%) of PTV. The distribution of the absorbed dose is nearly homogenous when the HI is zero [18]. Therefore, the relation of HI can be presented as follows:

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

Point dose measurement

The designs were converted to the solid water phantom state in accordance with the AAPM TG 119 methodology, and the dose point was calculated using the 0.125 cc ionization chamber (PTW TM31010). While measuring the dose point, the location of the ionization chamber must be taken into account because changes in the sub-millimeter level could significantly change the results.

Also, a comparison is made between the point dosage determined by the TPS and the point dose recorded by the ionization chamber. Equation (3) states that the findings of the measurement error should fall within a range of 4.5% in the target region and 4.7% in the OARs, respectively. Thus, equation 3 is represented as follows:

$$discrepancy = \frac{D_{measured} - D_{calculated}}{D_{prescribed}} \times 100\% \quad (3)$$

where $D_{measured}$, $D_{prescribed}$, and $D_{calculated}$ represent the measured, prescribed, and calculated, doses, respectively.

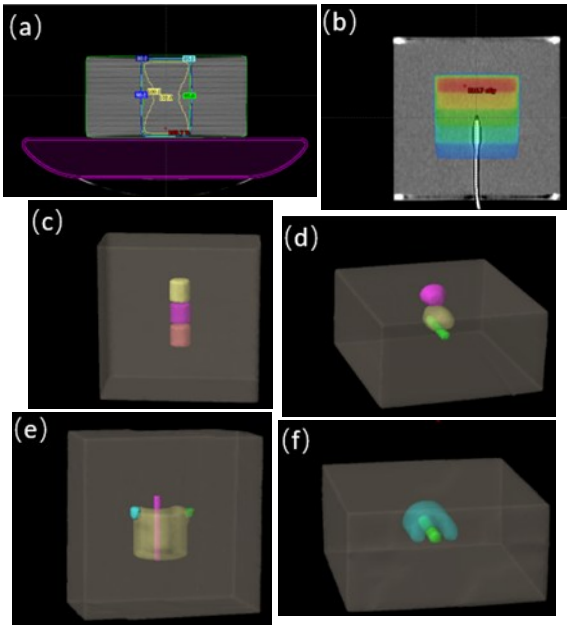

Figure 1. Test structures P1 **(a)**, P2 **(b)**, prostate **(c)**, multi-target **(d)**, H and N **(e)**, and C-shaped **(f)**.

Fluence measurement

The *gamma* evaluation was performed using GAFCHROMIC TM EBT3-1417 Films, an EPSON Expression 11000XL Scanner, and an IBA OmniPro

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IMRT 1.7 software (IBA Dosimetry Germany), as required in the AAPM TG 119 report. For each photon energy, the calibration films were irradiated with the seven 5×5 cm^2 square MU range between 0 MU and 1000 MU with a variable step (0, 50, 100, 200, 400, 800, 1000). The calibration curve was then created using the cubic polynomial least squares fitting of the measured optical density values for every color channel and the estimated dosage values. It took around 24 hours from irradiation to scanning in order to perform the post-irradiation coloration.

Moreover, in this study, the films were scanned by Epson Scan software and a document flatbed scanner, *e.g.*, the Epson Expression 10000XL (Seiko Epson Corp, Nagano, Japan). The transmission mode, while defining 75 dots per inch and a 48-bit RGB mode, was used to scan films to improve scanning stability. Moreover, all the films were facing the same way while they were scanned with the EpsonTM Expression 10000XL scanner. The scanned films were assessed by OminiPro IMRT software and in the study, the gamma criterion of 3% dosage differential and 3 mm distance was used.

Statistical analysis

Statistical analyses were conducted using logistic regression based on SPSS Statistics software, version 23.0 (IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL). Moreover, OriginPro 8.0 software (OriginLab Corporation, Northampton, MA, USA) was used for data drawing.

RESULTS

MLC Position Accuracy

At the treatment panel, the location accuracy should be lower than 1 mm. Table 1 shows the results of MLC position accuracy at different angles. The field size were 5* Ymax, so the test field in x direction were -10cm,-5cm,0cm,5cm,10cm respectively. In this study, the test results were less than 0.37 mm.

Table 1. Position accuracy experiment condition.

Angle		Move direction	field size cm×cm	field center x/cm	results
Gantry	Collimator				
0°	0°	+/- direction	$5\times Y_{max}$	-10cm, -5cm, 0cm, 5cm, 10cm	Less than 0.37 mm
90°	0°	+/- direction	$5\times Y_{max}$		
180°	90°	+/- direction	$5\times Y_{max}$		
270°	0°	+/- direction	$5\times Y_{max}$		

MLC position repeatability

The results must fall within the usual linac distance, and the MLC field's repeated positioning precision must not exceed 0.5 mm. Table 2 shows the results of MLC position repeatability at different angles, The field size were 5* Ymax, so the test field in x direction were -10cm, -5cm, 0cm,5cm, 10cm respectively. The maximum velocity was used to test in positive and negative directions.In this study, the test results were less than 0.25 mm. Moreover, Tables 3-5 present some statistical results for the key set planning outcomes for each of the five planners. In this study, each planner made its own choices to determine the parameters, although all plans adhered to the major principles laid out in TG 119, such as the beam angles, the isocenter point, the dose per fraction, etc.

Table 2. Position repeatability experiment conditions.

Angle		field size cm×cm	Field center x/cm	velocity	direction	results
Gantry	Collimator					
0°	0°	$5\times Y_{max}$	-10cm, -5cm, 0cm, 5cm, 10cm	Max	positive/ egative direction	less than 0.25 mm.
90°	0°	$5\times Y_{max}$		Max	positive/ egative direction	
180°	90°	$5\times Y_{max}$		Max	positive/ egative direction	
270°	0°	$5\times Y_{max}$		Max	positive/ egative direction	

Treatment plan statistics

The estimated doses for the 6 MV photon beam for preliminary test P1 were 199.8 Gy, whereas the measured doses at the isocenter point were 201.0 Gy with a variation of 0.67%. Having a 0.80% difference for the 6MV energy beam, the calculated dose for the isocenter position of P2 was 137.2 Gy while the observed dose was 138.3 Gy.

To sum up 99.13% of the data points have a gamma value smaller than one for P1 and 99.09% for P2, according to the criterion of DD 3% and DTA 3 mm.

Planning results

Table 3 provides the outcomes of all treatment planning for the following indications: Multi-target case, Prostate case, Head-and-neck case, C-shape Easy case, and C-shape Hard case. Like the mean value (1630 cGy) from the other nine institutes, the D10 of the C hard core dose was below the threshold (1000 cGy) specified by the TG 119. Following the TG119 regimen in our clinic, all other parameters have been reached in the meantime.

Point dosimetry measurement results for different test cases

Table 4 lists the outcomes of point measurements at high and low doses (within the target). Point dosimetry deviation results in high and low dose regions of SMLC, DMLC and VMAT of FF were showed in figure 2. For the SMLC plan, Every plan succeeded in achieving its objectives. High and low dose regions of the SMLC's measured point doses were recorded and found within 2.16% corresponding to the CL of 0.021. Moreover, all cases under the DMLC plan met the AAPM TG 119 planned objectives. All doses of the FF and plans' measured point doses were within 1.89% of one another, yielding to a CL of 0.026. Therefore, all cases under the VMAT plan met the

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planned objectives. Finally, all results of the DMLC plans' measured point doses were within 1.89% of one another or a CL of 0.023.

Table 3. Treatment plan statistics with results for SMLC, DMLC, and VMAT plans of FF mode.

Case	Location	Parameter	Goal (cGy)	SMLC (cGy)	DMLC (cGy)	VMAT (cGy)
Multi Target case	Center	D99	>5000	5002.49	5021.67	5003.98
		D10	<5300	5216.15	5257.36	5274.22
	Superior	D99	>2500	2647.81	2580.56	2614.56
		D10	<3500	3378.64	3441.27	3453.14
	Inferior	D99	>1250	1464.52	1534.71	1295.25
		D10	<2500	2269.23	2362.48	2194.77
Prostate case	PTV	D95	>7560	7661.34	7637.14	7911.38
		D5	<8300	8124.82	8231.33	8222.11
	Rectum	D30	<7000	6351.52	6158.71	6683.05
		D10	<7500	7418.83	7349.25	7349.29
	Bladder	D30	<7000	5019.56	4084.47	3840.22
		D10	<7500	6967.55	5892.56	5765.92
Head-and -neck case	PTV	D90	>5000	5025.82	5017.94	5092.82
		D99	>4650	4779.99	4735.00	4796.43
		D20	<5500	5458.16	5482.39	5434.59
	Cord	Max	<4000	3897.95	3966.22	3965.13
	Left Parotid	D50	<2000	1631.97	1599.82	1651.25
	Right Parotid	D50	<2000	1670.81	1547.74	1617.81
C-shaped case (easy)	PTV	D95	>5000	5021.97	5002.63	5012.72
		D10	<5500	5454.85	5377.08	5440.35
	Core	D10	<2500	2293.44	2080.08	2351.41
C-shaped case (hard)	PTV	D95	>5000	5025.05	5007.53	5004.44
		D10	<5500	5479.51	5481.29	5483.28
	Core	D10	<1000	1398.47	1641.75	1611.80

Table 4. Point dosimetry results in high and low dose regions of SMLC, DMLC and VMAT of FF mode.

Case	Location	SMLC	DMLC	VMAT
Multitarget	Isocenter	0.15%	-0.55%	0.38%
Multitarget	4 cm superior to isocenter	-0.52%	-0.69%	-0.43%
Multitarget	4 cm inferior to isocenter	-0.67%	0.02%	0.13%
Prostate	Isocenter	0.69%	0.71%	0.19%
Prostate	2.5 cm posterior to isocenter	0.81%	1.07%	1.42%
Head neck	Isocenter	-0.81%	-0.07%	-0.15%
Head neck	4 cm posterior to isocenter	-0.51%	1.37%	1.54%
C-shaped case(easy)	Isocenter	2.16%	1.89%	1.22%
C-shaped case(easy)	2.5 cm anterior	1.03%	0.94%	1.89%
C-shaped case(hard)	Isocenter	1.09%	0.93%	1.05%
C-shaped case(hard)	2.5 cm anterior	-0.58%	-0.63%	0.41%
Mean		0.26%	0.45%	0.70%
Standard deviation		0.010	0.009	0.008
Confidence limit = |Mean|± 1.96*σ		0.021	0.026	0.023

Gamma analysis

Results Results of gamma analysis were showed in table 5. The planar dose of PTV in three cases for IMRT was measured with I'mRT MatriXX. When deliver doses using a 6MV beam, the maximum gamma passing rate was 100% and the minimum was 99.60% in Head neck. The mean percentage of passing gamma for were 99.94%, 99.92% and 99.94% for SMLC, DMLC and VMAT, with a standard deviation of 0.10%,0.20% and 0.10% respectively.

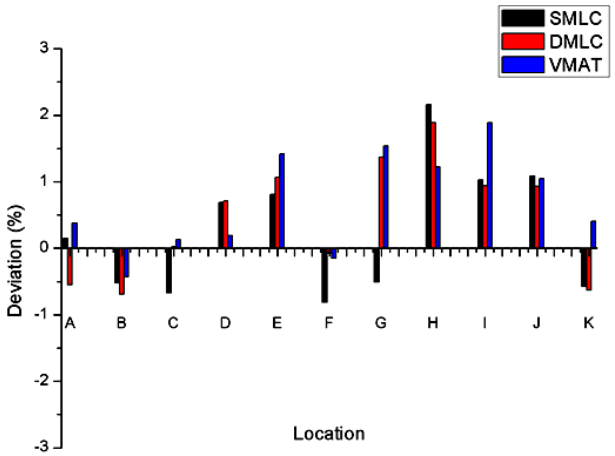

Figure 2. Point dosimetry results in high and low dose regions. where A, B, and C represent the Multitarget location of the isocenter, 4 cm superior to the isocenter and 4 cm inferior to the isocenter, respectively; where D and E represent the Prostate location of the isocenter and 2.5 cm posterior to the isocenter, respectively; where F and G represent the Head neck location of the isocenter and 4 cm posterior to the isocenter, respectively; where H and I were the C-shaped case (easy) location of the isocenter and 2.5 cm anterior, respectively; where J and K were the C-shaped case(hard) location of the isocenter and 2.5 cm anterior, respectively.

Table 5. Gamma Analysis (3%/3mm) Results of SMLC, DMLC and VMAT of FF mode.

Case	Location	SMLC	DMLC	VMAT
Multitarget	Isocenter	100%	100%	99.70%
Prostate	Isocenter	100%	100%	100%
Head neck	Isocenter	99.90%	99.60%	100%
C-shaped case(easy)	Isocenter	100%	100%	100%
C-shaped case(hard)	Isocenter	99.80%	100%	100%
Mean		99.94%	99.92%	99.94%
Standard deviation		0.001	0.002	0.001
CL= | 100-mean | + 1.96σ		0.062	0.084	0.063

DISCUSSION

According to the planning outcomes of the various TG 119 cases displayed in table 1, URT-Linac 506C has achieved the dose objectives. Moreover, our findings were consistent with those of Kadam *et al.* [17], and both studies evaluated the single energy (IMRT, 6 MV). All TG 119 requirements are met, if not exceeded. The D10 value of C- Hard core dose in SMLC, DMLC, and VMAT were 1398.47 cGy, 1641.75 cGy, and 1611.80 cGy; however, these were still below the TG 119 objectives (1000 cGy), just as the other nine institutes reported by AAPM TG 119. At the same time, we shared the same results as Zhang *et al.* and Jiang *et al.* [19, 20]. Following the TG119 regimen applied in our clinic, all other parameters have been reached in the meantime.

Before starting the clinical therapy, it was essential to assess the VMAT and IMRT systems' accuracy [21, 22]. Therefore, a useful tool for assessing the commission of planning and delivery, *i.e.*, the TG 119 test suite, was applied. For IMRT and VMAT systems with various energy beams, the CL was

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established as a standard for commission and quality assurance, and the outcomes enable us to feel confident in the treatment's accuracy. It is clear that, referring to the above measurements and results analysis, the CLs obtained by this CT-linac surpass the standard set by the TG 119. Moreover, the AAMP TG 119 test case was also used for dosimetry validation through Acuros® XB algorithm for RapidArc™ treatment technique [23].

Moreover, in this study, all dose regions of the SMLC's measured point doses were obtained within 2.16% and 1.89% for the DMLC and VMAT, respectively. For instance, Jiang *et al.* [20] results of all dose values of SMLC, DMLC and VMAT were within 3.92%, 3.26% and 4.11% (for URT-Linac 506C), respectively. Moreover, Laugeman *et al.* [24] reported that all dose regions of IMRT and VMAT values were within 6.4% and 4.2%, respectively for halcyon 2.0 plans. The average CLs for this accelerator varied from 0.026 to 0.21, which was lower than the TG119's suggested CLs for the low dosage zone (SMLC and VMAT for FF). Following the TG119 regimen obtained in our clinic, all other parameters have been reached in the meantime. Moreover, for the FF mode, the average gamma value with the 3%/3 mm passing condition were higher than 99.92% and the CLs were below 6.200, the values in Zhang study gamma values were higher than 98.17 ang CLs were below 1.98 [19], while the recommended CLs value in TG 119 was 12.4. Furthermore, the obtained results were similar to Jiang *et al.* [20] and Kadam and Sharma's data [22], where all researchers only tested the IMRT technology with 6 MV. Finally, Kadam *et al.* [26] and Gordon *et al.* [27] have also reported results similar to the found ones in the proposed experience.

In addition, to a certain extent, planning is influenced by the planners' experience. As part of the commissioning procedure, The TG 119 report was suggested as a helpful instrument to assess the effectiveness of the IMRT system. The CLs values of TG 119 are predicted to benefit physicists in assessing if the system may be employed in clinical practice, even though its findings cannot identify the causes of the problem [20].

In this article, we examine the first home accelerator, the CT-Linac. This article can make a thorough evaluation of the level of its results and it can also offer some recommendations for improving performance. The optimization outcomes for ten hospitals using commercial TPS were presented in the TG 119 report. Referring to the AAPM TG119 report, there are three goals (PTV D95, PTV D10, and C-hard D10) that cannot meet TG 119 result. It follows that the real setting of the AAPM test condition is more demanding and difficult to achieve. Therefore, the planning outcomes for each plan matched those of TG 119. Thus, the Static IMRT, Dynamic IMRT, and VMAT recorded point dosage deviations from anticipated doses were all within 4.11%. Finally, all three systems measured the film dosimetry gamma passage rates that were greater than 99.92%. Even yet, the planning system's preclinical testing in this study fulfilled the TG119 test case and had high validation accuracy. Further validation findings from clinical cases must be gathered before it can be determined whether the accelerator has good long-term stability.

This innovation of CT-linac, its commissioning process, as well as the early experiences with the clinical operation, were summarized by Yu *et al.* [28]. The original clinical model type is now being studied, along with long-term repeatability and stability.

CONCLUSIONS

It is clear from this analysis, which was carried out following the recommendations proposed by TG 119, that the URT TPS and the URT-Linac 506C have accurately ordered the SMLC, DMLC, and VMAT procedures. In more detail, the obtained results show treatment planning dose results, point dose measurements and gamma passing rate are fully compliant with TG119 requirements.

In the future, we will continue to study the long-term stability of this machine.

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***Authors' contributions*:** WT and WQ contributed to the conception and design of the study and drafted the manuscript; LM and GP participated in data collection and literature research; all authors read and approved the final manuscript.

***Ethics approval and consent to participate*:** Not applicable.

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***Competing interests*:** The authors declare that they have no competing interests.

REFERENCES

1. Boyer AL, Butler EB, Dipetrillo TA (2001) Intensity modulated radiation therapy collaborative working group. Intensity-modulated radiotherapy: current status and issues of interest. *Int J Radiat Oncol Biol Phys, **51**(4): 880-914*.
2. Michael JZ, Zvi F, Laura H, *et al.* (2000) Clinical experience with intensity modulated radiation therapy (IMRT) in prostate cancer. *Radiotherapy and Oncology, **55**(3): 241-249*.
3. Lorenzo L, Fabrizio B, Gabriele S, *et al.* (2010) Accelerated partial breast irradiation with IMRT: new technical approach and interim

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analysis of acute toxicity in a phase III randomized clinical trial. *Int J Radiat Oncol Biol Phys,* ***77****(2): 509-515*.
4. Nishi T, Nishimura Y, Shibata T, *et al.* (2013) Volume and dosimetric changes and initial clinical experience of a two-step adaptive intensity modulated radiation therapy (IMRT) scheme for head and neck cancer. *Radiotherapy and Oncology,* ***106****(1): 85-89*.
5. Mackie TR, Holmes T, Swerdloff S, *et al.* (1993) Tomotherapy: a new concept for the delivery of dynamic conformal radiotherapy. *Medical Physics,* ***20****(6): 1709-1719*.
6. Vulpen MV, Field C, Raaijmakers CP, *et al.* (2005) Comparing step-and-shoot IMRT with dynamic helical tomotherapy IMRT plans for head-and-neck cancer. *Int J Radiat Oncol Biol Phys,* ***62****(5): 1535-1539*.
7. Sharma SD, Upreti RR, Laskar S, *et al.* (2008) Estimation of risk of radiation-induced carcinogenesis in adolescents with nasopharyngeal cancer treated using sliding window IMRT. *Radiother Oncol,* ***86****(2): 177-81*.
8. Otto K (2008) Volumetric modulated arc therapy: IMRT in a single gantry arc. *Medical Physics,* ***35****(1): 310-317*.
9. Wolff D, Stieler F, Welzel G, *et al.* (2009) Volumetric modulated arc therapy (VMAT) vs. serial tomotherapy, step-and-shoot IMRT and 3D-conformal RT for treatment of prostate cancer. *Radiother Oncol,* ***93****(2): 226-33*.
10. Van Benthuysen L, Hales L, Podgorsak MB (2011) Volumetric modulated arc therapy vs. IMRT for the treatment of distal esophageal cancer. *Medical Dosimetry,* ***36****(4): 404-409*.
11. Sharma S, Subramani V, Kumar P, *et al.* (2017) EP-1498: IMRT and VMAT commissioning for Versa HD linear accelerator using AAPM TG-119. *Radiotherapy and Oncology,* ***123****: S803-S804*.
12. Nelms BE, Chan MF, Jarry G, *et al.* (2013) Evaluating IMRT and VMAT dose accuracy: practical examples of failure to detect systematic errors when applying a commonly used metric and action levels. *Med Phys,* ***40****(11): 111722*.
13. Ezzell GA, Burmeister JW, Dogan N, *et al.* (2009) IMRT commissioning: multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119. *Med Phys,* ***36****(11): 5359-73*.
14. Knill C and Snyder M (2011) An analysis of confidence limit calculations used in AAPM Task Group No. 119[J]. *Med Phys,* ***38****(4): 1779-1784*.
15. Mynampati DK, Yaparpalvi R, Hong L, *et al.* (2012) Application of AAPM TG 119 to volumetric arc therapy (VMAT). *J Appl Clin Med Phys,* ***13****(5): 3382*.
16. Wen N, Zhao B, Kim J, *et al.* (2014) Imrt and rapidarc commissioning of a truebeam linear accelerator using tg-119 protocol cases. *Journal of Applied Clinical Medical Physics,* ***15****(5): 74-88*.
17. Murshed H, Liu HH, Liao Z, *et al.* (2004) Dose and volume reduction for normal lung using intensity-modulated radiotherapy for advanced-stage non-small-cell lung cancer. *Int J Radiat Oncol Biol Phys,* ***58****(4): 1258-67*.
18. Wieland P, Dobler B, Mai S, *et al.* (2004) IMRT for postoperative treatment of gastric cancer: covering large target volumes in the upper abdomen: a comparison of a step-and-shoot and an arc therapy approach [J]. *Int J Radiat Oncol Biol Phys,* ***59****(4): 1236-1244*.
19. Zhang J, Jiang D, Liu H, *et al.* (2020) Analyzation of the local confidence limits for IMRT and VMAT based on AAPM TG119 report. *Med Dosim,* ***45****: 66-72*.
20. Jiang DZ, Wang DJ, Shen JL, *et al.* (2021) Analyzing the performance of the URT treatment planning system and URT-Linac 506C for flattening filter (FF) and flattening filter free (FFF) photon beams of Monte Carlo algorithm by use of AAPM TG119 test cases. *Int J Radiat Res,* ***19****(3): 695-702*.
21. LoSasso T, Chui CS, Ling CC (2001) Comprehensive quality assurance for the delivery of intensity modulated radiotherapy with a multileaf collimator used in the dynamic mode. *Med Phys,* ***28****(11): 2209-19*.
22. Kaviarasu K, Nambi RN, Hamid M, *et al.* (2017) Verification of dosimetric commissioning accuracy of intensity modulated radiation therapy and volumetric modulated arc therapy delivery using task group-119 guidelines. *J Med Phys,* ***42****(4): 258-265*.
23. Kumar L, Bhushan M, Kishore V, *et al.* (2021) Dosimetric validation of Acuros® XB algorithm for RapidArc™ treatment technique: A post software upgrade analysis. *J Cancer Res Ther,* ***17****(6): 1491-1498*.
24. Laugeman E, Heermann A, Hilliard J, *et al.* (2020) Comprehensive validation of halcyon 2.0 plans and the implementation of patient specific QA with multiple detector platforms. *J Appl Clin Med Phys,* ***21****(7): 39-48*.
25. Kadam AS and Sharma S (2016) Estimation of local confidence limit for 6 MV photon beam IMRT system using AAPM TG 119 test protocol. *International Journal of Cancer Therapy and Oncology,* ***4****(1): 4110*.
26. Kaviarasu K, Nambi Raj NA, Hamid M, *et al.* (2017) Verification of dosimetric commissioning accuracy of intensity modulated radiation therapy and volumetric modulated arc therapy delivery using task group-119 guidelines. *J Med Phys,* ***42****(4): 258-265*.
27. Gordon JD, Krafft SP, Jang S, *et al.* (2011) Confidence limit variation for a single IMRT system following the TG 119 protocol. Med Phys **38**: 1641–8.
28. Yu L, Zhao J, Zhang Z, *et al.* (2021) Commissioning of and preliminary experience with a new fully integrated computed tomography linac. *Journal of Applied Clinical Medical Physics,* ***22****(7): 208–223*.

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