Journal Homepage: - www.journalijar.com
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)
ISSN NO. 2320-5407
Article DOI: 10.21474/IJAR01/3819
DOI URL: http://dx.doi.org/10.21474/IJAR01/3819

RESEARCH ARTICLE

IMRT AND VMAT COMMISSIONING FOR VERSA HD LINEAR ACCELERATOR USING AAPM TG-119.

[*]Seema Sharma MSc Dip, RP Subhash Chander, MD Velliyan Subramani, PhD Pratik Kumar, PhD Suman Bhaskar, MD Sushmita Pathy, MD Sanjay Thulkar, MD N.Gopishankar, PhD Megha Sairem, MSc, Dip. RP Ashish Binjola MSc Dip, RP Dhayanethi N, MSc Pradeep Kumar S., MSc Priyanka Agarwal, MSc Dip. RP.
All India Institute of Medical Sciences, New Delhi, India.

Manuscript Info

Manuscript History

Received: 01 February 2017
Final Accepted: 01 March 2017
Published: April 2017

Key words:-
TG-119, IMRT, VMAT, Versa-HD. Patient specific quality assurance.

Abstract

Aim: Purpose of study is to evaluate the end to end commissioning accuracy of intensity modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) for Versa HD linear accelerator using AAPM TG-119 protocol. **Materials & methods:** IMRT and VMAT plans were created for TG119 test cases. All the plans were generated using Monaco 5.1 treatment planning system (TPS) for Elekta Versa HD linear accelerator. Prescription and planning goals were as kept as per TG119. For point dose measurement CC01 (0.01cc) ion chamber was used and measurements were carried out as per TG119 specified points in high and low dose gradient regions. Planar dose measurement I'matriXX along with multicube-lite phantom was used. Planned and measured dose planes were compared using gamma index criteria. **Results:** All planning goals have been achieved as per TG119 report. At high dose point measurement mean dose differences averaged over different techniques planned with different energies for all test cases was 0.002±0.020, and corresponding confidence limit was 0.041. At low dose point measurement mean dose averaged over different techniques planned with different energies for all test cases was -0.004±0.021, and corresponding confidence limit was 0.045. For planar dose measurement gamma passing rate averaged over all test cases was 99.40%±0.40 for 3%/3mm criteria and 97.82%±0.13 for 2%/2mm criteria respectively. Present work overall confidence limit for composite planar dose measurement was 1.38(i.e., 98.62% passing) for 3%/3mm and 2.45(i.e., 97.55% passing) for 2%/2mm criteria. **Conclusion:** Planning and delivery of IMRT/VMAT has been validated using published TG119 report results.

Introduction:-

Intensity modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) allows for highly conformal dose distribution with sharp dose gradient for complex target volumes with concave surfaces. These steep dose gradients and concavity are accomplished by the complex motion of Multi-leaf collimator (MLC) leaves equipped on a medical linear accelerator (LINAC) [1]. IMRT delivery technique using linear accelerator can be divided into two main categories: (1) standard IMRT and (2) rotational IMRT [2, 3]. Improvement in patient

Corresponding Author:- Seema Sharma.
Address:- Department of Radiotherapy, All India Institute of Medical Sciences, New Delhi, India.

planning and delivery techniques (i.e. IMRT/ VMAT) does not come without a risk. The clinical outcome of IMRT depends on the ability of planning and delivery system to accurately deliver planned dose to the target. IMRT planning causes high dose gradient in the proximity of critical organ to tumor which leads to stringent requirements on radiation beam modeling quality assurance [4, 5].

The Radiological Physics Center (RPC) published the results of 250 irradiation of head and neck phantom and reported that 28% irradiation results failed in high and low gradient region. Above 28% failure rate shows that inadequate commissioning of IMRT planning and delivery system therefore a system is required to check that how much quality assurance is good enough [6,7 & 8]. Having this concern in mind the American association of physicists in medicine (AAPM) has designed a guideline of TG-119 (Task Group) regarding IMRT commissioning and quality assurance (QA) [9]. The goal of TG-119 was to determine that what is practically possible to achieve in clinic to do so TG-119 defined the test suits to compare the results of multi institutions to establish the tolerance limits. TG-119 has proposed the concept of confidence limits (CL) any individual institute can perform these test suit and can compare its results with TG-119 confidence limits to get the confidence that all the system involved tin IMRT delivery are commissioned perfectly. TG-119 is an end to and verification method and if any discrepancy is found means there is some problem in commissioning process.

Recently commissioned the Versa HD digital linear accelerator (linac) at our institution is capable of delivering flattening filter (FF) photon beam, flattening filter free (FFF) photon beam and electron beam [10,11 & 12]. The versa HD linac has 80 pair of multileaf collimator (MLC) called as Agility MLC (Elekta, Stockholm, Sweden) having leaf width of 5mm at isocenter. Monaco 5.1 treatment planning system (TPS) was commissioned with the Versa HD machine for all the photon and electron energies for monte calro dose calculation algorithm. Beam data collection for commissioning of Versa HD along with Monaco TPS was performed based on vendor provided commissioning guide (manual) of Monaco. All the care has been taken during data collection i.e. selection of proper detector, proper step size and measurement mode (step by step or continuous) as recommended by American association of physicists in medicine (AAPM) task group (TG)-106 guidelines [13]. All the commissioning measurements have been performed at SSD 90 as per the International Electrotechnical Commission (IEC) protocol (Elekta follows IEC protocol). Measurements were carried out using IBA Blue phantom-2 using Omni-pro accept 7.1 software.

Present study is to evaluate the commissioning of IMRT & VMAT using TG-119 mock cases for final end to end validation of whole treatment work flow and to establish the institutional confidence limits (CLs) as the base line for patient specific pre-treatment quality assurance (QA).

Materials and methods:-

Delivery accuracy of the linear accelerator has been checked for conventional anterior posterior (two filed plan) and four field plan by point dose measurement and results were found within 2%. For validation of IMRT/VMAT the phantom with contoured structure set was downloaded from AAPM website provided with the TG-119 report and above structure sets were used as the patient for all plans created in the study. TG-119 mock cases represents clinically relevant structures and shapes i.e. multitarget, prostate, head and neck and C-shape target. The three dimensional view of TG-119 test suites is shown in figure.1. All the treatment plans were calculated for dose to medium in Monaco TPS using Monte Carlo dose calculation algorithm. Treatment plans were generated for 6MV, 6MV-FFF (FFF stands for flattening filter free), 10MV-FFF energy beams having maximum dose rate of 600MU/min, 1400MU/min and 2400MU/min respectively. For IMRT plans 7-9 equispaced fields were used as directed in TG-119 report on the other hand for VMAT plan single arc was used. In case of IMRT all the plans were planned in two ways with step and shoot (SMLC) technique and sliding window (DMLC) or dynamic MLC technique. For all the plans prescription and dose volume constraints were kept as per TG-119 guidelines.

Ion chamber dosimetry: For point dose measurement CC01 (**IBA,** Scanditronix Wellhofer, Germany) ion chamber along with Dose-1 (**IBA,** Scanditronix Wellhofer, Germany) electrometer was used. IBA RW3 slab phantom (40x40x15cm^3) was scanned having CC01 (0.01cc) chamber adapter plate at levels as specified by TG-119. All TG-119 test plans were converted to a QA plan in TPS for point dose measurement in RW3 phantom at gantry angle zero. Figure.2 (a) is showing the phantom setup on machine for point dose measurement. Point doses were averaged over the sensitive volume of the chamber. Then these point doses were compared with TPS calculated point doses. In present study dose differences are calculated as per formula given below, same formula was used in TG119.

$$\text{Dose difference } = \frac{\text{Measured dose} - \text{Plan dose}}{\text{Prescription dose}}$$

Measurement points Measurements were carried out as per TG-119 specified points and planes in high and low dose gradient regions for different test suite as follows (refer figure.3), (i) Multi target test suite point dose measurement was done at isocenter (middle of central target) and center of other two superior and inferior targets. (ii) prostate case point dose measurement was at mid-PTV (isocenter) and 2.5cm posterior from isocenter (midrectum) (iii) head and neck point dose measurement was at isocenter (mid-PTV) and 4.0cm posrerior from isocenter (midspinal cord) (iv) C-shape point dose measurement was performed at central core (isocenter) and 2.5cm anterior to isocenter (mid-PTV).

I'matriXX composite dosimetry: I'matriXX (**IBA,** Scanditronix Wellhofer, Germany) two dimensional detector array was scanned along with IBA multicube lite phantom. Detector plane was kept at 11.0cm depth. For all the plans verification plans were generated and optimised fluence was transferred to the previously scanned I'matriXX phantom. For measurement of composite dose planes, the I'matriXX was kept 11.0cm depth having SSD of 89.0cm. All the measurements were performed by keeping the phantom on couch for gantry angle zero. Measured and TPS planned fluence were compared using gamma index [14] criteria of 3%/3mm and 2%/2mm (dose difference / distance to agreement). Figure.2 (b) is showing the phantom setup on machine for planar dose measurement.

Statistical evaluation: statistical evaluation was performed in terms of confidence limit (CL) as specified by TG-119 report. The confidence limit for point and plannar dose measurement is defined as, CL (point) = mean ± 1.96σ and CL (planar) = [100 - mean] ± 1.96σ, where σ stands for standard deviation of measured data. This formula is based on the statistics of normal distribution, expecting that 95% the measurement will fall within the confidence limit.

Results:-

The summarized planning results of all the cases are shown in table-1.

Prostate case:-

As per TG119 goal prostate PTV D95 should be covered by at least 7560cGy which has been achieved in all the plans. The overall PTV D95 of present study is 7561±4cGy. Kim et.al. (2013) has reported PTV D95 7620.4±52.9cGy for IMRT linac group similarly Mynampati et. al. (2012) and Nithya et al. (2015) were also achieved the goal as per TG119 [15, 16]. PTV D5 should be less than 8300cGy present study overall results showed the value of 7963±65cGy.

For rectum D30 and D10 should be less than 7000cGy and 7500cGy respectively as per TG119 present study showed the overall result for D30 and D10 of rectum, 5917±102cGy and 7294±21cGy.

For bladder D30 and D10 should be less than 7000cGy and 7500cGy respectively, our overall results were 4520±86cGy and 6247±85cGy which is very below the tolerance defined by the TG119.

Multi target case:-

As per TG119 dose volume constraints central target, superior target and inferior target D99 should get at least 5000cGy, 2500cGy and 1250cGy respectively. Present study has achieved the above goals and overall results were 5000±0cGy, 2663±73cGy and 1345±24cGy for D99 of central superior and inferior target. Other similar studies [17, 15] i.e. Kim et al. (2013), Mynampati et al. (2012) were also achieved the TG119 specified goal as shown in the table1.

For central superior and inferior target D10 should be less than 5300cGy, 3500cGy and 2500cGy respectively. Present study achieved the above goals and results were 5286±86cGy, 3461±90cGy and 2402±40cGy.

Head and Neck case:-

For head and neck case PTV D90 should be 5000cGy, PTV D99 should be covered by at least 4650cGy and PTV D20 should not be more than 5500cGy. Preset study resulted in 5000±0cGy, 4616±29cGy and 5313±59cGy for PTV D90, PTV D99, and PTV D20 respectively which is within the TG119 specified goals.

Cord should not receive more than 4000cGy whereas in present study overall dose to cord was 3710±141, which was well achieved.

Parotids D50 should be less than 2000cGy, present study achieved the 2063±58cGy for right parotid and 2155±73cGy for left parotid, which is marginally high compare to goal specified by TG119. Whereas other similar studies [17, 15 & 16] Kim et al. Mynampati et al. and Nithya el al. could able to achieve parotid D50 below 1944cGy as shown in table-1.

C-Shape easy:-

As per TG119 specified goals for c-shape easy case PTV D95 should get 5000cGy and PTV D10 should not be more than 5500cGy. Doses achieved in present study for PTV D95 and PTV D10 was 5000cGy and 5337±91cGy respectively.

Dose to Core D10 should not be more than 2500cGy. Present study dose received by core D10 was 2302±119cGy.

C-Shape hard:-

Dose volume constraints for PTV D95 and PTV D10 were same as C-shape easy. Present study results were 5000±0cGy and 5684±95cGy. PTV D10 was observed higher compare to TG119 goal. Other parallel studies also reported higher values for PTV D10 such as Kim et al 5639.4±162.7cGy [17].

For C-shape hard core should not be more than 1000cGy, present study resulted in 1691±183cGy which is marginally high.

Point dose measurement:-

High dose point measurement (inside the target) results are summarized in table-2. At high dose point measurement the mean dose differences averaged over different techniques planned with different energies for all test cases was 0.002±0.020, and corresponding confidence limit (mean + 1.96σ) was 0.041. In high dose region only for two plans dose variations were observed more than 3.0% between planned and measured dose. In few more plans we were getting large differences but as mentioned in report of TG119, that shifting the chamber position by one or two millimetre will correct the results, by doing that our results improved. Similarly, Wen et. al. (2014) has conducted a study for commissioning a true beam machine using TG119 has reported the confidence limit 0.030±0.007 and 0.029±0.011 for IMRT and rapid arc plans respectively planned with different energies [18]. Present study showed the confidence limit of 0.041 in high dose region which is within the 0.045 which was the average confidence limit for overall test cases and institutions participated in TG119.

At low dose point measurement (inside OAR) the mean dose averaged over different techniques planned with different energies for all test cases was -0.004±0.021, and corresponding confidence limit (mean + 1.96σ) was 0.045. For low dose point measurement results are summarized in table-3. Wen et al. (2014) has observed the dose difference ratio of 0.001 ± 0.014 for IMRT plan and 0.008± 0.011 for rapid arc plan and their corresponding confidence limits were 0.029 and 0.027 respectively in low dose point measurement [18]. Kim et al. (2013) has reported the average difference between measured and planned doses, averaged over all test cases was -1.0% ±1.9% for LINAC group [17]. Present study showed the confidence limit of 0.045 in low dose region which is within the 0.047 which was the average confidence limit for overall test cases and institutions participated in TG119.

Composite planar dose measurement:-

Results of composite planar dose measurement are summarized in table-4 & table-5.

All the results were analysed by using gamma index criteria. The gamma passing rate averaged over all test cases was 99.40%±0.40 for 3%/3mm criteria and 97.82%±0.13 for 2%/2mm criteria respectively. Present work the overall confidence limit for composite planar dose measurement was 1.38(i.e., 98.62% passing) for 3%/3mm and 2.45(i.e., 97.55% passing) for 2%/2mm criteria.

Kim et al.(2013) reported the overall gamma pass rate for composite film measurement was 94.6%±4.0% for linac group and their associated confidence limit was 86.8 [17]. Whereas Wen et al. (2014) study has observed the percentage gamma pass rate of Averaged over all tests was 98.0% ± 2.2% (IMRT) and 98.7% ± 1.8% (Rapidarc) for high dose plane measurement, 98.5%±1.8%(IMRT) and 99.0%±1.6(Rapidarc) for low dose plane measurement [18]. Figure.4 is showing the composite planar dose measurement results. TPS computed, I'matriXX measured and corresponding gamma analysis (3%/3mm) for representative TG-119 test suites (a) prostate (b) multi target (c) head & neck and (d) C-shape

Discussion:-

Gordon et. al. (2011) evaluated the robustness of TG119 and concluded that TG119 results are planner dependent because each planner has their own method to optimise the plan therefore to overcome the variation due to different planners, many planners from the institute has to participate in establishing the institutional confidence limits [19]. Many other authors i.e. Saminathan et. al. (2011), Thomas et al. (2014) and Kadam et al. (2016) also followed the TG119 to establish the local confidence limits [20, 21 & 22]. In an another study conducted by McVicker et al. (2016) to evaluate the sensitivity of TG119 in finding the error involved in any stage of commissioning , author has created one more beam model by introducing some intentional errors in the original beam model and concluded that TG119 commissioning criteria is effective in detecting errors [23].

Present study used the concept of confidence limits as described in TG119 and overall confidence limits were within the TG119 specified limits for point and composite planar dose measurement. Some authors have evaluated the concept of confidence limits as used in TG119 i.e. Knill et. al. (2011) [24] has done a study using the gamma pass rate results of 111 head and neck patients to analyse the concept of confidence limits used in TG119 protocol. Knill et al. has fitted the results in TG119 normal distribution, truncated normal distribution and weibull probability distribution and author concluded that weibull probability distribution fits the gamma index pass rate results more accurately compared to normal distribution used in TG119. In an another study by Kim et al. (2016) [25] to establish the tolerance level for patient specific quality assurance using the concept of confidence limit, the study found that confidence limit is not a suitable metric to establish the tolerance level for patient specific quality assurance. Present study showed the almost similar quality assurance results for IMRT and VMAT delivery techniques for point and planar dose measurement, some random fluctuations in the results were observed but that was not because of the technique (IMRT/VMAT) of delivery. Because of some variations in point/planar dose measurement the corresponding confidence limits for that particular energy or technique is changing rapidly because of the large standard deviation (small sample size), those point dose measurement results can be adjusted by re-aligning the phantom by one or two millimetre and repeating the measurement. TG119 is an end to end quality assurance process to make sure that all the systems are configured with each other properly, in case of any major error during data collection or beam modelling results will not come similar as published in TG119. One has to measure TG119 test cases many times so that they can have large number of sample size to avoid the random errors in measurement.

Table-1: Planning results of SMLC, DMLC & VMAT plans, corresponding to energies 6MV, 6MV FFF, 10MV FFF.

Test Suite	Parameters	Goal (cGy)	TG-119 results mean±SD (cGy)	Kim et.al.(2013) (cGy)	Mynampati et. al.(2012) (cGy)		Nithya et. al. (2015) (cGy)			Present study results mean±SD (cGy)		
				IMRT Linac	IMRT	VMAT	SMLC	DMLC	VMAT	IMRT	VMAT	Overall
Prostate	PTV D95	7560	7566±21	7620.4±52.9	7567	7564	7571	7564	7586	7562±5	7560±1	7561±4
	PTV D5	<8300	8143±156	8267.4±188.1	8146	8230	8261	8157	8159	7935±17	8017±97	7963±65
	Rectum D30	<7000	6536±297	6630.6±392.4	5455	5612	5777	5489	5427	5893±46	5965±176	5917±102
	Rectum D10	<7500	7303±150	7324.6±208.7	7140	7212	7401	7397	7403	7293±26	7296±4	7294±21
	Bladder D30	<7000	4394±878	5452.7±738.7	3785	3130	5136	5107	4677	4488±67	4583±96	4520±86
	Bladder D10	<7500	6269±815	7414.8±144.8	5944	5247	7025	6954	6953	6204±15	6333±108	6247±85
Multi Target	Central target D99	>5000	4955±162	4975.6±54.0	5007	5000	4904	4958	4905	5000±0	5000±0	5000±0
	Central target	<5300	5455±173	5417.2±117.1	5358	5352	5450	5404	5445	5244±47	5370±91	5286±86

	D10											
	Superior target D99	>2500	2516±85	2676.2±204.2	2621	2687	2509	2471	2493	2656±90	2679±20	2663±73
	Superior target D10	<3500	3412±304	3521.3±352.0	3243	3133	3146	3262	3282	3422±69	3539±81	3461±90
	Inferior target D99	>1250	1407±185	1430.2±353.2	1364	1367	1400	1514	1413	1335±19	1364±22	1345±24
	Inferior target D10	<2500	2418±272	2593.5±607.2	1960	1904	2133	2106	2482	2387±40	2432±22	2402±40
Head & Neck	PTV D90	5000	5028±58	5052.9±84.6	5057	5000	5058	5007	5015	5000±0	5000±0	5000±0
	PTV D99	>4650	4704±52	4784.1±94.8	4670	4840	4658	4656	4698	4623±33	4602±16	4616±29
	PTV D20	<5500	5299±93	5289.6±147.2	5216	5200	5369	5312	5349	5729±28	5381±38	5313±59
	Cord Max.	<4000	3741±250	3915.0±257.5	3834	3790	3901	3928	3812	3650±94	3832±154	3710±141
	Rt. Parotid D50	<2000	1798±184	1916.7±160.2	1915	1925	1927	1780	1905	2042±43	2107±69	2063±58
	Lt. Parotid D50	<2000	1798±184	1887.3±135.3	1865	1798	1944	1770	1933	2128±56	2207±84	2155±73
C-Shape easier	PTV D95	5000	5010±17	4985.6±64.8	-	-	5005	5009	5001	5000±0	5000±0	5000±0
	PTV D10	<5500	5440±52	5463.3±188.6	-	-	5436	5488	5472	5282±16	5449±69	5337±91
	Core D10	<2500	2200±314	2446.3±145.1	-	-	-	-	-	2225±21	2455±47	2302±119
	Core D5	<2500	-	-	-	-	2159.0	2498	2474	-	-	-
C-Shape harder	PTV D95	5000	5011±16.5	4937.0±116.6	5000	5004	-	-	-	5000±0	5000±0	5000±0
	PTV D10	<5500	5702±220	5639.4±162.7	5482	5493	-	-	-	5701±114	5651±39	5684±95
	Core D10	<1000	1630±307	1552.9±211.9	-	-	-	-	-	1573±53	1926±41	1691±183
	Core D5	<1000	-	-	1585.0	1677	-	-	-	-	-	-

Table-2:- Results of high dose point (inside PTV) measurement with ion chamber [(measured dose) – (plan dose)]/ prescription dose, for SMLC, DMLC & VMAT plans corresponding to 6MV, 6MV FFF, 10MV FFF.

Test case	Location	SMLC			DMLC			VMAT			Overall		
		6MV	6FFF	10FFF	6MV	6FFF	10FFF	6MV	6FFF	10FFF	Mean	STD	CL
Prostate	isocenter	0.013	-0.022	0.019	0.02	0.042	0.016	-0.026	-0.014	0.028	0.008	0.024	0.055
Multi Target	isocenter	0.025	-0.017	-0.022	0.019	0.031	0.011	-0.021	-0.024	0.018	0.002	0.023	0.047
Head & Neck	isocenter	0.001	0.024	-0.017	0.031	0.022	0.019	-0.009	0.014	-0.017	0.008	0.018	0.044
C-easier	2.5cm anterior to isocenter	-0.013	0.019	0.014	-0.011	0.023	0.017	-0.019	0.013	-0.021	0.002	0.018	0.037
C-harder	2.5cm anterior to isocenter	-0.028	-0.016	0.019	-0.025	0.013	-0.018	-0.013	-0.021	0.014	-0.008	0.018	0.044
Mean(energy/technique)		0.000	-0.002	0.003	0.007	0.026	0.009	-0.018	-0.006	0.004	-	-	-
STD (energy/technique)		0.021	0.022	0.020	0.024	0.011	0.015	0.007	0.019	0.022	-	-	-
CL (energy/technique)		0.041	0.046	0.042	0.053	0.048	0.039	0.031	0.043	0.048	-	-	-
Overall Combined											**0.002**	**0.020**	**0.041**
Overall CL = (mean) + 1.96σ													

Table-3:- Results of low dose point (inside OAR) measurement with ion chamber [(measured dose) – (plan dose)]/ prescription dose, for SMLC, DMLC & VMAT plans corresponding to 6MV, 6MV FFF, 10MV FFF.

Test case	Location	SMLC			DMLC			VMAT			Overall		
		6MV	6FFF	10FFF	6MV	6FFF	10FFF	6MV	6FFF	10FFF	Mean	STD	CL
Prostate	2.5cm posterior to isocenter	0.015	-0.032	-0.027	0.015	0.037	-0.011	-0.018	-0.032	-0.019	-0.008	0.025	0.056
Multi Target	4.0cm inferior to isocenter	-0.014	0.012	-0.021	0.015	0.017	0.014	-0.024	-0.019	0.022	0.000	0.019	0.038
	4.0cm superior to isocenter	-0.012	-0.027	0.019	0.012	-0.023	-0.015	0.013	0.029	0.027	0.003	0.022	0.045
Head & Neck	4.0cm posterior to isocenter	-0.016	-0.013	-0.031	-0.004	0.028	-0.025	-0.014	0.042	-0.013	-0.005	0.024	0.053
C-easier	isocenter	0.013	-0.02	-0.030	-0.01	0.031	-0.014	-0.01	-0.02	-0.014	-0.00	0.019	0.047

			1		3			3	4		9		
C-harder	isocenter	0.001	-0.007	0.017	-0.014	0.024	0.016	-0.014	-0.026	-0.028	-0.003	0.019	0.041
Mean(energy/technique)		-0.002	-0.015	-0.012	0.002	0.019	-0.006	-0.012	-0.005	-0.004	-	-	-
STD(energy/technique)		0.014	0.016	0.024	0.014	0.022	0.017	0.013	0.032	0.023	-	-	-
CL(energy/technique)		0.029	0.046	0.058	0.029	0.061	0.039	0.037	0.068	0.049	-	-	-
Overall Combined											**-0.004**	**0.021**	**0.045**
Overall CL = (mean) + 1.96σ													

Table-4:- Results of Composite I'matriXX measurement Gamma (3%/3mm) analysis percentage of pixel passing for SMLC, DMLC & VMAT plans, corresponding to 6MV, 6MV FFF, 10MV FFF.

test cases	SMLC			DMLC			VMAT			Overall		
	6MV	6FFF	10FFF	6MV	6FFF	10FFF	6MV	6FFF	10FFF	Mean	STD	CL
Prostate	99.50	99.10	99.10	100.00	99.30	99.80	99.30	99.20	99.30	99.40	0.31	1.21
Multi Target	98.90	100.00	99.70	100.00	100.00	100.00	100.00	98.60	100.00	99.69	0.55	1.38
Head & Neck	99.20	99.80	100.00	100.00	99.50	99.50	100.00	100.00	96.50	99.39	1.12	2.81
C-easier	99.30	99.10	99.50	99.70	99.10	99.30	99.30	99.60	99.10	99.33	0.22	1.10
C-harder	99.10	99.10	99.30	99.50	99.10	99.10	99.20	99.10	99.10	99.18	0.14	1.10
mean	99.20	99.42	99.52	99.84	99.40	99.54	99.56	99.30	98.80			
STD	0.22	0.44	0.35	0.23	0.37	0.36	0.40	0.53	1.34			
CL	1.24	1.45	1.16	0.61	1.33	1.17	1.23	1.74	3.82			
Overall Combined										99.40	0.40	1.38
Overall CL = (100-mean) + 1.96σ										1.38(i.e., 98.62% passing)		

Table-5:- Results of Composite I'matriXX measurement Gamma (2%/2mm) analysis percentage of pixel passing for SMLC, DMLC & VMAT plans, corresponding to 6MV, 6MV FFF, 10MV FFF.

test cases	SMLC			DMLC			VMAT			Overall		
	6MV	6FFF	10FFF	6MV	6FFF	10FFF	6MV	6FFF	10FFF	Mean	STD	CL
Prostate	98.50	96.80	98.40	99.30	97.30	97.80	96.90	97.10	96.90	97.67	0.89	4.07
Multi Target	98.10	98.10	98.10	97.90	96.90	97.70	97.90	98.50	99.50	98.08	0.69	3.27
Head & Neck	97.90	98.30	97.50	98.70	97.80	99.00	97.00	98.00	98.10	98.03	0.60	3.14
C-easier	97.30	97.50	97.00	99.00	97.20	97.00	97.50	97.00	99.20	97.63	0.86	4.04
C-harder	96.80	96.80	98.70	97.20	97.40	98.70	97.20	97.10	99.10	97.67	0.90	4.10
mean	97.72	97.50	97.94	98.42	97.32	98.04	97.30	97.54	98.56			
STD	0.67	0.70	0.69	0.86	0.33	0.81	0.41	0.67	1.07			

CL	3.60	3.88	3.41	3.26	3.32	3.54	3.50	3.78	3.53			
Overall Combined										97.82	0.13	2.45
Overall CL = (100-mean) + 1.96σ										2.45(i.e., 97.55% passing)		

Figure.1:- showing the three dimensional (3D) view of TG-119 test suites (a) prostate (b) multi target (c) head & neck and (d) C-shape

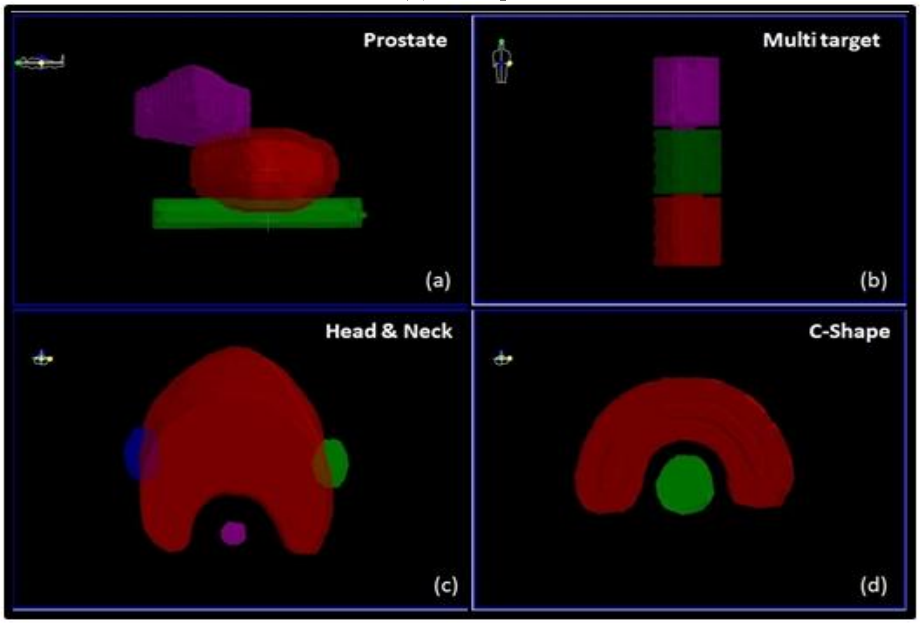


Figure.2:- Showing the measurement setup for points and planar dose measurement.

Figure.3:- showing the measurement points for TG-119 test suites (a) prostate (b) multi target (c) head & neck and (d) C-shape

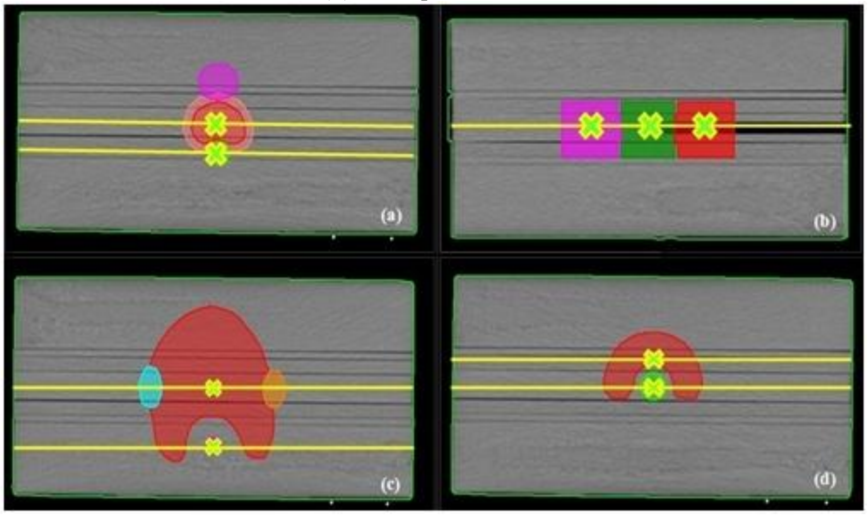
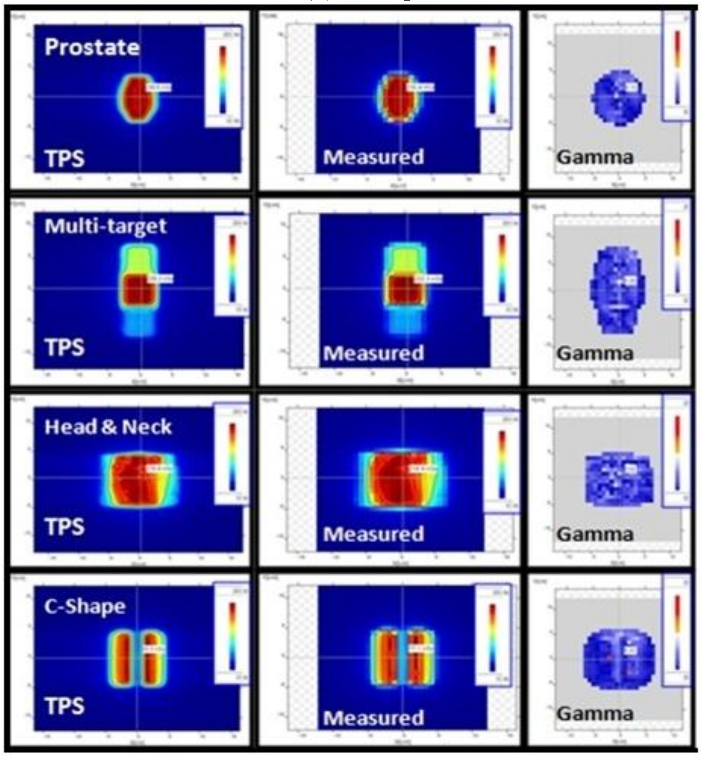


Figure.4:- Showing the composite planar dose measurement results. TPS computed, I'matriXX measured and corresponding gamma analysis (3%/3mm) for representative TG-119 test suites (a) prostate (b) multi target (c) head & neck and (d) C-shape



Conclusion:-

Planning and delivery of IMRT/VMAT has been validated using TG119 report. Local institutional confidence limits were established which can be used as baseline for future patient specific IMRT/VMAT quality assurance.

Reference:-

1. AAPM Medical Physics Monograph No. 29, Intensity-Modulated Radiation Therapy, The State of the Art, Jatinder R. Palta and T. Rockwell Mackie, Editors, Medical Physics Publishing,Madison, WI, USA, 2003.
2. Yu CX, "Intensity-modulated arc therapy with dynamic multileaf collimation: an alternative to tomotherapy." Phys Med Biol. 1995 Sep; 40(9):1435-1449.
3. Otto K, "Volumetric modulated arc therapy: IMRT in a single gantry arc." MedPhys, 2008 Jan; 35(1):310-317.
4. Low DA et al., "Dosimetry tools and techniques for IMRT." Med Phys. 2011 Mar;38(3):1313-1338.[A Report from AAPM TG-120].
5. Markus Alber et al., "Guidelines for the verification of IMRT." 2008. [*ESTRO BOOKLET* NO. *9]*.
6. J. R. Palta et al., "Credentialing of institutions for IMRT in clinical trials," Int. J. Radiat. Oncol., Biol., Phys. 2004 Jul 15;59(4):1257-9.
7. G. S. Ibbott et al., "Challenges in credentialing institutions and participants in advanced technology multi-institutional clinical trials," Int. J. Radiat. Oncol., Biol., Phys. 2008;71(1 Suppl):S71-5.
8. Molineu A et al., "Credentialing results from IMRT irradiations of an anthropomorphic head and neck phantom." Med Phys. 2013 Feb; 40(2):022101.
9. Ezzell GA et al., "IMRT commissioning: multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119." Med Phys. 2009; 36(11):5359–73.
10. Narayanasamy G et al., "Commissioning an Elekta Versa HD linear accelerator." J Appl Clin Med Phys. 2016 Jan 8;17(1):5799.
11. Snyder M et al., "Modeling the Agility MLC in the Monaco treatment planning system." J Appl Clin Med Phys. 2016 May 8;17(3):6044.
12. Saenz DL et al., "Pinnacle3 modeling and end-to-end dosimetric testing of a Versa HD linear accelerator with the Agility head and flattening filter-free modes." J Appl Clin Med Phys. 2016 Jan 8;17(1):5808.
13. Das IJ et al., "Accelerator beam data commissioning equipment and procedures: report of the TG-106 of the Therapy Physics Committee of the AAPM." Med Phys. 2008 Sep;35(9):4186-215.
14. Low DA et al., "A technique for the quantitative evaluation of dose distributions." Med. Phys. 25: 656-661, 1998.
15. Mynampati DK et al., "Application of AAPM TG 119 to volumetric arc therapy (VMAT)" J Appl Clin Med Phys. (2012).
16. Nithya L et al., "Analyzing the performance of the planning system by use of AAPM TG 119 test cases." Radiol Phys Technol. 2016 Jan;9(1):22-9.
17. Kim JI et al., "A multi-institutional study for tolerance and action levels of IMRT dose quality assurance measurements in Korea." J Appl Clin Med Phys. 2013 Mar 4;14(2):3964.
18. Wen N et al., "IMRT and RapidArc commissioning of a TrueBeam linear accelerator using TG-119 protocol cases." J Appl Clin Med Phys. 2014 Sep 8;15(5):4843.
19. Gordon JD et al., "Confidence limit variation for a single IMRT system following the TG119 protocol." Med Phys. 2011 Mar; 38(3):1641-8.
20. Saminathan S et al., "Plan evaluation and dosimetric comparision of IMRT using AAPM TG119 test suites ans recommendations." Australas Phys Eng Sci Med. 2011 Apr;34(1):55-61.
21. Thomas M et al., "Local confidence limits for IMRT and VAMT technique: a study based on TG119 test suite." Australas Phys Eng Sci Med. 2014 Mar;37(1):59-74.
22. Kadam A et al., "Estimation of local confidence limit for 6 MV photon beam IMRT system using AAPM TG 119 test protocol." Int J Cancer Ther Oncol. 2016; 4(1):4110.
23. McVicker D et al., "On the sensitivity of TG-119 and IROC credentialing to TPS commissioning errors." J Appl Clin Med Phys. 2016 Jan 8;17(1):5452.
24. Knill C et al., "An analysis of confidence limit calculations used in AAPM Task Group No. 119." Med Phys. 2011 Apr;38(4):1779-84.
25. Kim JI et al., "Confidence limits for patient-specific IMRT dose QA: a multi-institutional study in Korea." J Appl Clin Med Phys. 2016 Jan 8;17(1):5607.