International Journal of Cancer Therapy and Oncology
www.ijcto.org

Estimation of local confidence limit for 6 MV photon beam IMRT system using AAPM TG 119 test protocol

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Received October 17, 2015; Revised January 02, 2016; Accepted January 16, 2016; Published Online February 03, 2016

Original Article

Abstract

Purpose: The aim of this study was to estimate local confidence limit for 6 MV photon beam based intensity modulated radiation therapy (IMRT) using TG119 test protocol. **Methods:** The American Association of Physicists in Medicine (AAPM) Task Group 119 (TG119) prescribed a protocol to evaluate overall accuracy of IMRT system rather than independent uncertainty in dose calculation, dose delivery and measurement system. Two preliminary and five clinical test cases were created based on dose prescriptions and planning objectives given by TG119 report. Verification plans were created in a planning slab phantom, 2D Matrix dosimetry system (I'MatriXX) with multicube phantom and aS-1000 electronic portal imaging device (EPID). Radiation absorbed doses to high dose points in the planning target volume (PTV) region and low dose points in avoidance structures were measured using CC13 ionization chamber having sensitive volume of 0.13 cm^3. The measured and planned doses were normalized with respect to their prescription doses and intercompared. The gamma analysis was carried out for both I'MatriXX and EPID, adopting the acceptance criteria of 3% DD (dose difference) and 3 mm DTA (distance to agreement) with 10% threshold dose. **Results:** For the point dose measurements with ion chamber, the average dose difference ratio in high dose low gradient PTV region was -0.0133 ± 0.012 corresponding to a confidence limit of 0.037. The average dose difference in low dose region (avoidance structure) was -0.00004 ± 0.010 corresponding to a confidence limit of 0.021. The average percentage of points passing the gamma criteria of 3% DD and 3 mm DTA for composite planar dose distribution measured by I'MatriXX was 99.47 ± 0.43 which corresponds to a confidence limit of 1.38 (i.e. 98.62% passing). Similarly, the average percentage of points passing the gamma criteria of 3% DD and 3 mm DTA for per-field dose distribution measured by EPID was 98.00 ± 2.49 which corresponds to a confidence limit of 6.87. **Conclusion:** Our results were well within action level given by AAPM TG119 report through multi-institutional study providing us adequate confidence in delivering IMRT treatment.

Keywords: Confidence Limit; TG119; IMRT; Dosimetry

1. Introduction

The intensity modulated radiation therapy (IMRT) is a promising treatment technique having advantage of delivering highly conformal dose distribution to target volume and sparing of organs at risk. However, stringent quality assurance programme is required to be instituted in dose calculation, dose delivery and measurement system for effective and safe clinical implementation of this technique. Many medical physicists have already studied dosimetric[1] performance of multileaf collimator (MLC) for different modality of treatments.[2,3] The AAPM report on IMRT commissioning published[4] in 2003 and its further extension by AAPM TG119[5] has helped us not only in quantifying the overall performance of an IMRT system but also provided reasonable confidence limits (CLs) for assessing the adequacy of the dosimetric commissioning. However, a very few papers have demonstrated the usefulness of AAPM TG119 IMRT test protocol in the estimation of

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Cite this article as: *Kadam A, Sharma SD. 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.* ***DOI:*** *10.14319/ijcto.41.10*

ISSN 2330-4049

local confidence limits.[6,7] We implemented TG119 protocol for 6 MV photon beam in our institute in order to get local confidence to check overall accuracy of IMRT system. All the test cases, head-and- neck, prostate, C-shape easy, C-shape hard and multi target were created in a local slab phantom and treatment planning was carried out using Eclipse radiotherapy treatment planning system. The purpose of this study was to find out local confidence limit and compare the results with the action level given by AAPM TG119 through multi-institutional study.

2. Methods and Materials

This study was performed using 6 MV photon beam of our Novalis Tx (Varian Medical Systems, Palo Alto, USA) linear accelerator equipped with high definition MLC (HD120 MLC). Water equivalent plastic phantom (SP34, solid water, IBA dosimetry) having dimension of 30 × 30 × 15 cm³ was used for the implementation of AAPM TG119 prescribed tests. As the phantom is having 15 cm thickness, it is possible to position the ionization chamber at its center for dosimetric measurements. AAPM TG119 test protocol consists of two preliminary tests to evaluate the accuracy of dose calculation module and five clinical test cases concerned with a range of optimization problems requiring simple to complex modulation patterns. In the first preliminary test (Test 1), parallel-opposed 10 × 10 cm² fields were used to deliver 2 Gy to the mid-plane of the phantom. For the second preliminary test (Test 2), 15 cm long parallel opposed anterior-posterior (AP-PA) fields were created by the MLC with a set of five bands each having 3 cm width to deliver 25 monitor unit (MU).

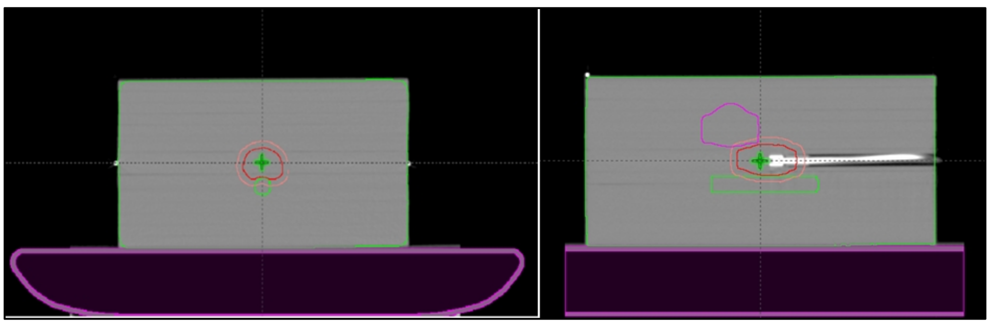

Figure1: AAPM TG119 mock prostate structures.

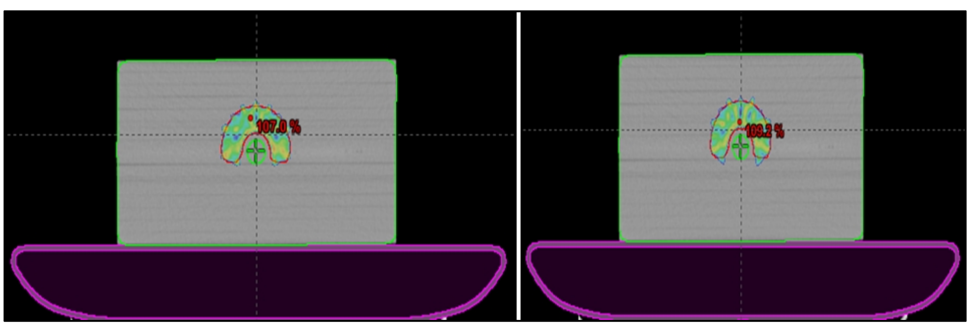

Figure 2: Dose distributions of C-shape easy and C-shape hard treatment plans.

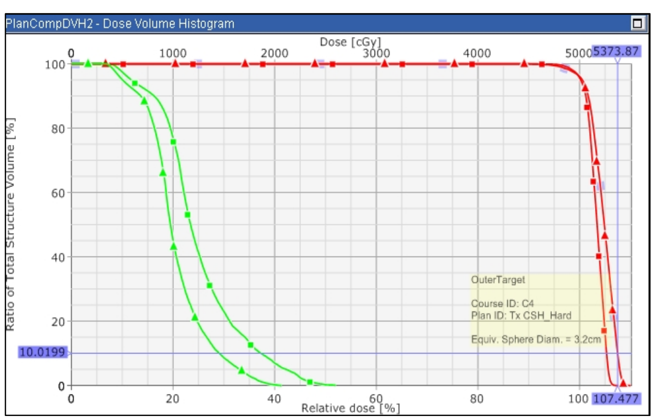

Figure 3: Dose volume histograms (DVH) of C-shape easy and C-shape hard treatment plans generated using Eclipse treatment planning system.

For all clinical test cases (head-and-neck, prostate, C-shape easy, C-shape hard and multi-target) CT and RT structures were downloaded from http://www.aapm.org/pubs/tg119/default.asp.

The target and normal structures were created by registering the center of the CT of the local phantom to that of the downloaded phantom and then transferred these structures to the local phantom (Figure 1) for planning in Eclipse treatment planning system by anisotropic analytical algorithm (Version 10). Figure 2 shows the axial plane dose distributions and Figure 3 shows the dose volume histograms (DVH) of C-shape easy and C-shape hard treatment plans generated by the Eclipse TPS. The prescribed doses for head-and-neck, C-shape easy, C-shape hard and multi-target test cases were 50 Gy (2 Gy × 25 fractions) and for the prostate case it was 75.6 Gy (1.8 Gy × 42 fractions). The treatment plans for head-and-neck and C-shape tests had nine treatment fields at 40° angular intervals of the gantry with respect to its vertical position. However, the treatment plans for prostate and multi-target tests had seven fields at 50° angular intervals of the gantry with respect to its vertical position. These test plans were created as per dose prescriptions and planning objectives specified in AAPM TG119 report. Verification plans were created in a planning slab phantom, 2D Matrix dosimetry system with multicube phantom and aS1000 electronic portal imaging device (EPID). The evaluations of the results were carried out in terms of the confidence limits defined in AAPM TG119 report. Following definitions of the confidence limits (CLs) for the point and planar dose measurements were used.

$$CL_{point} = M \pm 1.96\sigma \quad (1)$$

$$CL_{planar} = (100 - M) \pm 1.96\sigma \quad (2)$$

where, M and σ are the mean value and the standard deviation of the measured data, respectively.

2.1 Point dose measurement

Doses to high dose points in the planning target volume (PTV) region and low dose points in avoidance structures were measured using CC13 ionization chamber (IBA Dosimetry GmbH, Schwarzenbruck, Germany) having sensitive volume of 0.13 cm^3 which is closed to specification given by AAPM TG119 for such measurements. The measured and planned doses were normalized with respect to their prescription doses and intercompared. Necessary care was taken in positioning the ionization chamber during measurement of point dose as sub-millimeter variation may vary the result significantly.

2.2 Fluence measurement

I'MatriXX (IBA dosimetry, Schwrazenbruck, Germany) with multi-cube phantom was used for composite planar dose measurement.[8] I'MatriXX is a two dimensional array of dosimeters consisting of 1020 vented ionization chamber each having sensitive volume of 0.08 cm^3. The ionization chambers are arranged in a 24 × 24 cm^2 area each having diameter 4.5 mm, height 5 mm and 3.6 mm water equivalent thickness on the front side. The distance between each ionization chamber is 0.76 cm. The calibration of I'MatriXX was performed as per manufacture recommended procedure. All the test plans were executed at gantry angle 0^0 and results were analyzed using OmniPro IMRT software (IBA dosimetry, V 1.76). Coronal isocenter plane was used for comparing I'MatriXX measured dose distribution with the treatment planning system (TPS) calculated dose distribution for the entire test plans. Planar dose distribution calculated by TPS was converted into 0.76 cm × 0.76 cm matrix to match the dose distribution resolution with the resolution of I'MatriXX. The TPS calculated and I'MatriXX measured dose matrices were rescaled to 0.1 cm resolution using interpolation software provided by OmniPro IMRT software. The measured and planned dose distribution was compared by gamma analysis[9,10,11] adopting the acceptability criteria of 3% dose difference (DD) and 3 mm distance to agreement (DTA). To avoid the very low dose region, the threshold dose was set in OmniPro IMRT software as 10%.

2.3 Per field dose measurement

In this study, we used portal dosimetry tools for quality assurance of four IMRT test plans. The multi-target plan was excluded from per field dose measurement using EPID. Gamma analysis of planar dose distribution was done by comparing portal dose prediction (PDP) and measured dose by EPID using PDP software. The dose distribution to each of the field was measured by high resolution aSi1000 EPID (Varian portal Vision aS1000). The EPID is made up of array of light sensitive amorphous-Si photodiodes arranged in 40 × 30 cm^2 active area with a matrix of 1024 × 768 pixels which gives resolution of 0.039 × 0.034 mm per pixel pitch. We commissioned aSi1000 EPID as per requirement of PDP algorithm in Eclipse treatment planning system for portal dosimetry. The EPID calibration process details were out of the scope of the present study. EPID images were acquired for the entire IMRT field at an SDD of 105 cm. Several studies have been done on dose response characteristics of the detector and gamma comparison with 2D array detector for IMRT.[12,13] All the test plans were exposed at planned gantry angle and results were analyzed using PDP software. The gamma analysis was done adopting the acceptability criteria of 3% DD, 3 mm DTA and 10% threshold dose which effectively limits the evaluation within collimator jaws and absolute global normalization to the maximum of each dose.

3. Results and Discussion

The ionization chamber measured and calculated point doses for preliminary test 1 at isocenter were 1.99 Gy and 2Gy respectively. Similarly, measured and calculated doses for preliminary test 2 were 46.54 cGy and 47 cGy respectively. The percentage of points passing gamma criteria for I'MatriXX measurements were more than 99% for both of the preliminary tests (Test 1 and Test 2) which indicate about the goodness of dose delivery system for non-IMRT technique.

Figure 4 presents a comparison of I'MatriXX measured and TPS calculated planar dose distribution showing gamma analysis results and line profile agreement for multitarget test plan.

Table 1 to 5 shows treatment plan statistics with results for all the clinical plans whereas Figure 5 shows gamma analysis comparison of PDP calculated and EPID measured planar dose distributions for Head and Neck test plan.

For all clinical test plans, the ionization chamber measurement results in the high and low dose regions have been shown in Table 6. The average dose difference ratio in the high dose low gradient PTV region was -0.0133 ± 0.012 corresponding to the confidence limit of 0.037. This value is below the AAPM TG119 CL of 0.045.

The average dose difference in low dose region (avoidance structure) was -0.00004 ± 0.010 corresponding to the confidence limit of 0.021, which is below the AAPM TG119 CL of 0.047. Thus, our results were below the action levels given by TG119.

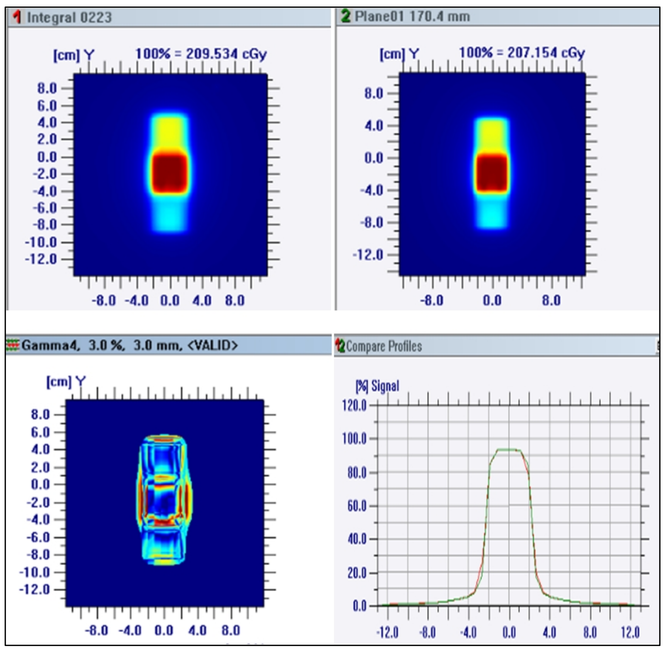

Figure 4: Comparison of MatriXX measured and TPS calculated planar dose distribution showing gamma analysis results (bottom left) and line profile agreement (bottom right) for multitarget plan.

Table 1: Treatment plan statistics with results for prostate plan.

TG Structure prostate	Planning parameters	Plan goal (cGy)	TG119 results mean (cGy)	Present study plan results (cGy)
PTV	D_{95}	>7560	7566	7614
	D_5	<8300	8143	7982
Rectum	D_{30}	<7000	6563	5351
	D_{10}	<7500	7303	7324
Bladder	D_{30}	<7000	4394	2952
	D_{10}	<7500	6269	4847

Table 2: Treatment plan statistics with results for multi-target plan.

TG Structure Multi-target	Planning parameters	Plan goal (cGy)	TG 119 Results mean (cGy)	Present study plan results (cGy)
Central target	D_{99}	>5000	4955	5030
	D_{10}	<5300	5455	5261
Superior target	D_{99}	>2500	2516	2818
	D_{10}	<3500	3412	3379
Inferior target	D_{99}	>1250	1407	1616
	D_{10}	<2500	2418	2063

 ISSN 2330-4049

Table 3: Treatment plan statistics with results for C-shape (easier) plan.

TG structure C-shape(easier)	Planning parameters	Plan goal (cGy)	TG 119 results mean (cGy)	Present study plan results (cGy)
PTV	D_{95}	5000	5010	5009
	D_{10}	<5500	5440	5265
Core	D_{10}	<2500	2200	1864

Table 4: Treatment plan statistics with results for C-shape (harder) plan.

TG structure C-shape (harder)	Planning parameters	Plan goal (cGy)	TG 119 results mean (cGy)	Present study plan results (cGy)
PTV	D_{95}	5000	5011	5025
	D_{10}	<5500	5702	5374
Core	D_{10}	<1000	1630	1452

Table 5: Treatment plan statistics with results for head and neck plan.

TG structure head and neck	Planning parameters	Plan goal (cGy)	TG 119 results mean (cGy)	Present study plan results (cGy)
PTV	D_{90}	5000	5028	5014
	D_{95}	>4650	4704	4687
	D_{20}	<5500	5299	5208
Cord	Maximum	<4000	3741	3707
Rt Parotid	D_{50}	<2000	1798	1856
Lt Parotid	D_{50}	<2000	1798	1869

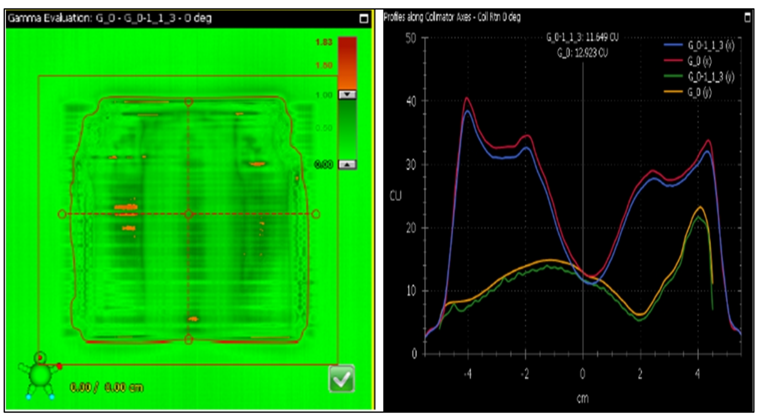

Figure 5: Comparison of PDP calculated and EPID measured planar dose distribution showing gamma analysis results (left) and line profile agreement (right) for head and neck test plan.

Table 6: High dose point in the PTV and low dose point in the avoidance structure measured using ionization chamber and the associated confidence limits.

Test	Prescribed dose/fr (cGy) (**C**)	Location	Measured dose (cGy) (**A**)	Planned dose (cGy) (**B**)	High dose region (A-B)/C	Low dose region (A-B)/C
Multi-target	200	isocenter	203.22	204.6	-0.0069	n/a
		4cm superior	122.64	126.2	n/a	-0.0178
		4cm inferior	0.7138	0.754	n/a	-0.0002
Prostate	180	isocenter	181.0	182.4	-0.0077	n/a
		2.5 cm posterior	104.08	104.5	n/a	-0.0023
Head & neck	200	isocenter	199.16	199.6	-0.0022	n/a
		4cm posterior	0.9495	0.976	n/a	-0.0001
C-shape(easy)	200	isocenter	188.84	187.8	n/a	0.0052
		2.5cm anterior	201.76	208.3	-0.0327	n/a
C-shape(hard)	200	isocenter	181.90	178.9	n/a	0.015
		2.5cm anterior	199.0	202.4	-0.017	n/a
Mean					-0.0133	0.0000
Standard deviation					0.0120	0.0107
Confidence limit = (mean) ± 1.96 σ					0.037	0.021

Table 7: Percentage of gamma passing for composite planar dose measured using I'MatriXX.

Test plans	Plane	% gamma passing (I'MatriXX)
Multi-target	isocenter	99.48
Prostate	isocenter	99.91
Head & neck	isocenter	99.77
C-shape(easy)	isocenter	99.39
C-shape(hard)	isocenter	98.79
Mean		99.47
Standard deviation		0.43
Confidence limit = (100-mean) ±1.96 σ		1.38

Table 8: Percentage of gamma passing for per field measured using EPID.

Field	Prostate	Head & neck	C-shape(easy)	C-shape(hard)
1	100	99.1	94.8	98.7
2	94.5	99.6	98.8	97.5
3	99.7	97.3	98.4	98.8
4	97.8	98.2	100	97.3
5	97	99.3	99.8	98.6
6	99.9	99.4	99.8	99.2
7	87.2	99.7	99.9	96.7
8	n/a	93.9	97.1	97.2
9	n/a	99.8	98.1	99.0
Mean	96.59	98.48	98.52	98.11
Overall mean			98.0	
Standard deviation			2.49	
Confidence limit = (100 - mean) ± 1.96σ			6.87	

We evaluated planar dose distribution at isocenter plane by I'MatriXX array and EPID and the results of percentage gamma passing for these methods are shown in Table 7 and Table 8 respectively. The multitarget test plan was excluded for the estimation of confidence limit using EPID because of poor gamma passing. The reason for poor gamma passing in case of EPID may be due to irradiation of large detector areas with a significant fraction of MU causing production of backscatter electrons from the arm of the detector. However, dosimetric measurements for the multitarget test plans were carried out using I'MatriXX showing gamma passing of 99.48%.

The average percentage of points passing the gamma criteria of 3% DD and 3 mm DTA for composite planar dose distribution measured by I'MatriXX array was 99.47 ± 0.43 which corresponds to the confidence limit of 1.38 (i.e., 98.62% passing). This indicated that the percentage of points passing the gamma criteria should be more than 98.62%, approximately 95% of the time for composite planar dose distribution by I'MatriXX array. Similarly, average percentage of points passing the gamma criteria of 3% DD and 3 mm DTA for per-field dose distribution measured by EPID was 98 ± 2.49. Thus, the corresponding confidence limit was 6.87 (i.e., 93.13% passing). This indicated that the percentage of points passing the gamma criteria should be more than 93.13%, approximately 95% of the time for per field planar dose distribution by EPID. This proved that the results are well within action level given by TG119 report.

4. Conclusion

The estimation of local confidence limit using AAPM TG119 is a very useful study to estimate overall accuracy of IMRT system. Estimated confidence limits for point dose measurements in high dose low gradient PTV region and in low dose region (avoidance structure) were 0.037 (i.e. 3.7%) and 0.021 (i.e. 2.1%) respectively. The recommended action level given by AAPM TG119 Multi-institutional study for point dose measurements in terms of CLs were 5% in a high dose low gradient region and 7% in a low dose low gradient region respectively. The average percentage of points passing the gamma criteria of 3% DD and 3 mm DTA for composite planar dose distribution measured using I'MatriXX array was 99.47 ± 0.43 which corresponds to a confidence limit of 1.38 (i.e., 98.62% passing). Similarly, average percentage of points passing gamma for per-field dose distribution measured using EPID was 98 ± 2.49 which corresponds to a confidence limit of 6.87 (i.e., 93.13% passing). AAPM TG119 has not recommended the action levels for per field dose measurement using EPID and array detectors. It is reasonable to assume that action levels for per field dose measurement using EPID and array detectors should not be worse than the radiographic film measured results reported by TG119. Our results were well within action levels given in TG119 report providing us adequate confidence in delivering IMRT treatment. However, large sample sizes are suggested for better statistical accuracy.

ISSN 2330-4049

Conflict of interest

The authors declare that they have no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

1. Chang Z, Wang Z, Wu QJ, *et al*. Dosimetric Characteristics of NovalisTx System with High Definition Multi-leaf Collimator. Med Phys. 2008;35:4460-3.
2. Jin JY, Yin FF, Ryu S, *et al*. Dosimetric study using different leaf-width MLCs for treatment planning of dynamic conformal arcs and intensity-modulated radiosurgery. Med Phys. 2005;32:405-11.
3. Fiveash JB, Murshed H, Duan J, *et al*. Effect of multileaf collimator leaf width on physical dose distributions in the treatment of CNS and head and neck neoplasms with intensity modulated radiation therapy. Med Phys. 2002; 29:1116-9.
4. Ezzell GA, Galvin JM, Low D, *et al*. Guidance document on delivery, treatment planning, and clinical implementation of IMRT: report of the IMRT Subcommittee of the AAPM Radiation Therapy Committee. Med Phys. 2003;30:2089-115.
5. Ezzell GA, Burmeister JW, Dogan N, *et al*. IMRT commissioning: multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119. Med Phys. 2009;36:5359–73.
6. Chung JB, Kim JS, Ha SW, Ye SJ. Stastical analysis of IMRT dosimetry quality assurance measurements for local delivery guideline. Radiat Oncol. 2011:6:27.
7. Thomas M, Chandroth M. Local confidence limits for IMRT and VMAT techniques: a study based on TG119 test suite. Australas Phys Eng Sci Med. 2014;37:59-74.
8. Saminathan S, Manickam R, Chandraraj V, Supe SS. Dosimetric study of 2D ion chamber array matrix for the modern radiotherapy treatment verification. J Appl Clin Med Phys. 2010;11:3076.
9. Low DA, Harms WB, Mutic S, Purdy JA. A technique for the quantitative evaluation of dose distributions. Med Phys. 1998; 25:656-61.
10. Palta JR, Liu C, Li JG. Quality assurance of intensity-modulated radiation therapy. Int J Radiat Oncol Biol Phys. 2008;71:108-112.
11. Low DA, Moran JM, Dempsey JF, *et al*. Dosimetry tools and techniques for IMRT. Med Phys. 2011;38:1313-38.
12. Sharma DS, Mhatre V, Heigrujam M, *et al*. Portal dosimetry for pretreatment verification of IMRT plan: a comparison with 2D ion chamber array. J Appl Clin Med Phys. 2010;11:3268.
13. Bailey DW, Kumaraswamy L, Balkhtiari M, *et al*. EPID dosimetry for pretreatment quality assurance with two commercial systems. J Appl Clin Med Phys. 2012;13:3736.

ISSN 2330-4049