International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Comparison of Gamma Analysis using Two Different Commercially available 2D Array Detectors for Pre-treatment Verification of Volumetric Modulated Arc Therapy

Nkurunziza Rodgers[1], Avin Kumar[2], Ashwini K[3], Kavya[4], Nisha[5]

[1]Medical Physics Student, Medical Physics Division, Mangalore University, Mangalagangothri-574199, India
Corresponding Author Email: *rodgersnk2[at]gmail.com*

[2]Chief Medical Physicist and Radiation Safety Officer, Department of Radiation Oncology, AJ Hospital and Research Centre, Mangaluru-575004, India
Email: *avinkumarb[at]gmail.com*

[3]Medical Physics intern, department of Radiation Oncology, AJ Hospital and Research Centre, Mangaluru-575004, India
Email: *ashwini269k[at]email.com*

[4]Medical Physics intern, department of Radiation Oncology, AJ Hospital and Research Centre, Mangaluru-575004, India
Email: *kvkavya1999[at]gmail.com*

[5]Medical Physics intern, department of Radiation Oncology, AJ Hospital and Research Centre, Mangaluru-575004, India
Email: *nishakulal247[at]gmail.com*

Abstract: ***Volumetric modulated Arc therapy (VMAT) represents a significant advancement in radiation therapy, offering benefits in treatment efficacy, patient experience, and reduction in side effects. However, due to the complexity of the treatment delivery, precise delivery is required to ensure that the intended dose is accurately administered to the tumor while sparing surrounding healthy tissues. Using two array detectors, the study uses the gamma analysis method to validate patient-specific quality assurance (QA) accuracy and reliability in volumetric modulated arc therapy (VMAT). This study used an Elekta synergy platform electron linear accelerator operated in the range of photon energies,4MV, 6MV, 6MV FFF, and 15MV. The 30 selected esophageal cancer patients were planned in TPS (Monaco V6.1.4) and recalculated on PTWseven29 and MapCHECK3, the 2D dosimetric devices for planar dose distribution. To compare the two dosimetric devices, the gamma analysis method was used with five gamma criteria of dose difference/distance to agreement of 3%/3mm, 3%/2mm, 3%/1mm, 2%/2mm, and 2%/1mm for the threshold values of 0.1%, 5%, and 10% at a tolerance level of 95%. All the gamma criteria used had average gamma pass rates greater than 95%. MapCHECK3 presented higher average gamma pass rates than PTWseven29 at gamma criteria of 3%/1mm and 2%/1m. Therefore, the choice between these two dosimeters should depend on specific clinical needs, such as the complexity of the treatment plan to be verified and the required level of precision.***

Keywords: VMAT, Gamma analysis, dosimetric comparison, 2D array detectors, Patient specific QA

1. Introduction

Intensity-modulated radiation therapy (IMRT) is one of the techniques in which non-uniform fluence is delivered to the patient from different directions to optimize the composite dose distribution. The non-uniform fluence is obtained with the help of a computer-controlled multi-leaf collimator (MLC). Thus, the main goal of IMRT is to deliver radiation more precisely to the tumor while limiting the dose to the surrounding normal tissues. IMRT can be delivered as step-and-shoot, dynamic, or arc-based IMRT [1].

On the other hand, volumetric modulated arc therapy (VMAT), similar to the dynamic IMRT, has been employed effectively as a new treatment delivery method in clinics. In VMAT, the speed of MLC leaves, collimator rotation, gantry rotation, and table rotation are modulated during the treatment planning to deliver the desired dose to the planning target volume (PTV) [1].

Due to the technique's complexity, confirmation of the dose distribution is significant. The plan's quality assurance (QA) is made in the phantom before patient irradiation to verify dose distribution.

The complexity of the VMAT plans and non-uniform dose delivery caused new, effective, and reliable forms of plan verifications to be searched. Many detectors have been used to attain that, including ionization chambers,2D and 3D array detectors, film, and EPID [2]. In recent years, various commercial 2D and 3D ionization chambers or diode detector arrays have become available to verify absolute doses with immediate results. Conventional methods, such as point dose measurements with ionization chambers and film dosimetry, are gradually being replaced by detector arrays. These devices have allowed clinical centers to streamline their QA and increase the number of patients treated with IMRT and VMAT. However, detector arrays are limited by their resolution, giving rise to concerns about their sensitivity to errors [2], [3].

Commercial detector arrays available includes 2D array seven29 (PTW, Freiburg, Germany), mapCHECK3/ArcCHECK (Sun Nuclear Corp, Melbourne), and Matri XX (IBA, Dosimetry, Gmbh, Schwartzberg, Germany). Various studies have previously been performed to assess the sensitivity to the IMRT, or VMAT stimulated errors and dose distribution for MapCHECK3, arc CHECK, and delta4. However, limited studies are available on the Comparison of MapCHECK3 and PTWseven29 for planar dose distribution verification for VMAT plans [3],[4],[5].

In radiation therapy, ensuring the accuracy and reliability of dosimetric tools is vital for patient safety and treatment efficacy. This study findings contribute to better clinical decision making in selecting appropriate dosimetric tools for VMAT.

2. Materials and Methodology

2.1 Detectors arrays.

2D ionization chamber array

The PTW Seven29 2D-array consists of 729 vented, cubic ion chambers creating a field size of 27 X 27 cm^2. Each vented, parallel plate ion chamber is 0.5 × 0.5 × 0.5 cm^3 with a resolution of 1cm from center to center of neighboring chambers. The array weighs 8 kg with a thickness of 2.2 cm, and the effective depth of the chambers is 0.5 cm. The linear dimensions of the 2D array are 2.2 × 30.0 × 42.0 cm^3.

2D diode chamber array

The MapCHECK3 is the 2D-array detector and consists of 1527 diode chambers with a field size of 26 cm X 32cm and detector spacing 0.71cm. The array weighs 5.6kg with an inherent build-up of 1.5gcm^{-2}, an inherent back scatter of 2.3gcm^{-2}, and a linear dimension of 56.0cm X 29.2cm X 3cm.

2.2 Treatment planning and dose distribution measurements

CT scan of the PTWseven29 array detector with 5cm PMMA slabs was used as build-up, and a backup scatter was performed with a 3mm slice thickness. Scanned data was then exported to Monaco TPS through the DICOM network. The procedures were repeated with the MapCHECK3 detector array.

In the TPS, CT data of the phantoms was imported in the Monaco TPS version 6.1.4. The PMMA solid phantom with detector array image was contoured as distinct structures and regions of interest were identified and labelled.

30 patient VMAT plans for Esophageal cancer were generated on the scanned phantoms of the PTWseven29 and MapCHECK3 with 6MV photon beam energy and one arc rotation for the total dose of 5040cGy in 28 fractions.

Quality assurance plans were generated, ensuring all beam and collimator angles were zero. All plans were normalized for 95% of the prescribed dose to cover the PTV and the dose calculation for a single fraction at the isocenter was calculated using the Montecarlo algorithm, and scheduling was done in the MOSAIQ, where the planned data and beam parameters were verified before it was exported to patient-specific QA software and the LINAC machine for delivery.

Measurements were performed using the Elekta Synergy platform linear accelerator. The setup in the CT simulation was used, with the source to the practical point of measurement distance maintained at 100cm.

SSDs of 94.3cm and 93.8cm were used for the PTWseven29 and MapCHECK3 setups, respectively. Then, the detector was connected to the array interface, which is connected to the power supply and the QA software on the computer in the console room.

In the MOSAIQ system, for each VMAT plan, the gantry angle, arc direction, couch, and start angle were adjusted, and then the dose delivered to the phantom. The measured and calculated dose distribution were compared using gamma analysis software for the corresponding array detector. Verisoft software was used to compare the planned dose distribution in TPS and the measured dose distribution by the PTWseven29 detector array. Auto alignment was used to reduce the device's setup uncertainties, and with the help of the slicer, the point of maximum gamma pass rate was determined and used for all the criteria. SNC Patient software compared the planned and measured dose distribution for the MapCHECK3 array detector in absolute and relative modes. The setup uncertainties of the device were reduced with the help of Cal shift in the software that finds the best alignment between the measured and planned dose maps. The Comparison was performed with gamma criteria of 3%/3mm, 3%/2mm, 3%/1mm, 2%/2mm, and 2%/1mm at threshold values of 0.1%, 5%, and 10%. A tolerance level of 95% was used.

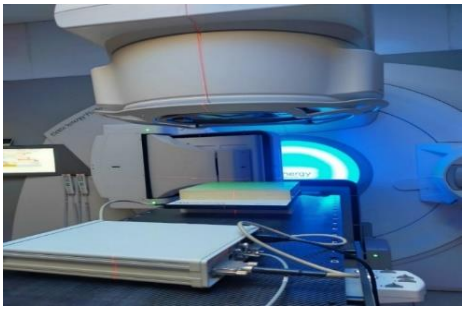

Figure 1: Detector array set up in the Linear accelerator

3. Results and Discussion

The mean values of Gamma pass rates for 30 Esophagus cancer patients obtained from calculated dose distribution in TPS and measured dose distribution by PTWseven29 and MapCHECK3 are presented and discussed. The mean values at different acceptance criteria and for dose thresholds of 0.1%, 5%, and 10% are discussed.

Table 1: The average PTW Verisoft and SNC Gamma pass rates for 30 patients.

Gamma pass rates for SNC Vs PTW (mean values)									
AC	**TH:0.1%**			**TH:5%**			**TH:10%**		
	SNC		**PTW**	**SNC**		**PTW**	**SNC**		**PTW**
	ABSO	**REL**		**ABSO**	**REL**		**ABS**	**REL**	
3%/3mm	100	99.99	100	99.95	99.98	100	99.94	99.97	100
3%/2mm	99.97	99.99	99.94	99.91	99.98	99.96	99.89	99.97	99.95
3%/1mm	99.83	99.9	99.55	99.41	99.67	98.38	99.19	99.54	98.09
2%/2mm	99.9	99.98	99.93	99.63	99.91	99.68	99.5	99.87	99.63
2%/1mm	99.51	99.63	98.75	98.35	98.77	95.51	97.84	98.36	95.21

Table 1 summarizes the mean values of global Gamma pass rates for SNC in both absolute (ABSO) and relative (REL) modes and PTW detector arrays from 30 esophageal cancer patients at different acceptance criteria (AC).

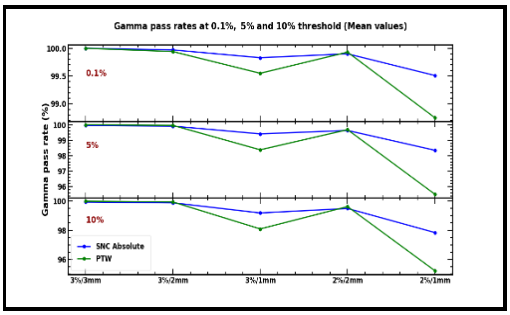

Figure 2: Line graph plots showing mean gamma pass rates of SNC (absolute mode) and PTW

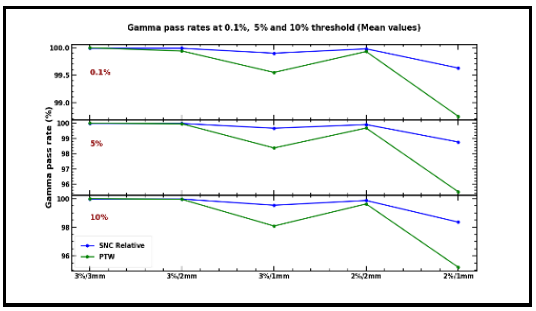

Figure 3: Line graph plots showing mean Gamma pass rates of SNC (Relative mode) and PTW.

Table 1 presented a decreasing tendency in average Gamma pass rates with increased dose thresholds for the two dosimetric equipment. This decreased tendency agrees with findings on gamma analysis by Song et al. [7] and Kim et al. [8]. It was stated that global normalization of dose difference hides errors in low-dose regions and leads to insensitivity in gamma analysis, especially for 3%/3mm, and that applying a low dose threshold in global normalization does not have a critical impact on the judgment of QA.

Figures 2 and 3 indicate higher average gamma pass rates of SNC than PTW at stringent criteria of 3%/1mm and 2%/1mm, irrespective of the threshold value. At the acceptance criterion of 3%/1mm, the average pass rates were 99.83% and 99.55%, 99.41% and 98.38%, 99.19% and 98.09% at thresholds of 0.1%, 5%, and 10% for SNC in absolute and PTW respectively. The average pass rates of SNC and PTW at 2%/1mm were 99.51% and 98.75%, 98.35% and 95.51%, 97.84% and 95.21% at dose thresholds of 0.1%, 5%, and 10%, respectively.

The higher SNC pass rates may be attributed to the higher detector density uniformly distributed across the array, which offers high spatial resolution and sensitivity, thus providing detailed spatial dose measurements under stricter criteria.

For the relaxed acceptance criteria of 3%/3mm, 3%/2mm, and 2%/2mm, there was a lesser difference in average gamma pass rates of SNC and PTW, irrespective of the threshold used.

Jonathan et al. [13], reported average Gamma pass rates of 99.3% and 95.8% at 3%/3mm and 2%/2mm, respectively, for the threshold of 10% using the MapCHECK2 detector array. Kim et al. [8], reported an average gamma pass rate of 97% at 2%/1mm at a threshold of 10% by mapCHECK2. These findings align with our results of 97.84% at 2%/1mm for a threshold of 10%.

Gokcen Ina et al. [10], reported average gamma pass rates of PTWseven29 at 3%/3mm, 3%/2mm, and 2%/2mm of 97.53%, 96.96%, and 95.34% for a threshold of 10%. The results agree with the results obtained in our study for a threshold of 10%. SNC average gamma pass rates in relative mode were slightly higher than gamma pass rates in absolute mode. Relative mode normalizes the dose to the point or region, and this might have caused the slight increase in gamma pass rate values obtained in this mode.

4. Conclusion:

This study thoroughly Compares gamma analysis for pre-treatment verification of VMAT for 30 Esophageal cancer patients using PTWseven29 and MapCHECK3 detector arrays available at AJ Hospital and Research Centre, Mangalore, India. The global Gamma analysis was evaluated for the two detector arrays, and gamma pass rates showed dependence on threshold values. There was a decreasing tendency in Gamma pass rates with increasing threshold values from 0.1% to 5% and 10%. In general, MapCHECK3 showed higher average Gamma pass rates than PTWseven29 at stringent criteria of 3%/1mm and 2%/1mm, irrespective of the threshold value used. If the film is used at these stricter criteria, it could show much better results than detector arrays because of its fine grain structure, which allows it to capture more detailed information and, hence, higher spatial resolution. However, film has some drawbacks, such as film processing time, making 2D array detectors a preferable option.

Therefore, the choice between these two dosimeters should depend on specific clinical needs, such as the complexity of the treatment plan to be verified and the required level of precision.

References

[1] Thayalan, K., *The Physics of Radiation Oncology,* first edition, Jaypee Brothers Medical Publishers, New Delhi ,June 2023,pp.310-321.
[2] Hussein, M., Adams, E. J., Jordan, T. J., Clark, C. H., & Nisbet, A., A critical evaluation of the PTW 2D-ARRAY seven29 and OCTAVIUS II phantom for IMRT and VMAT verification, *Journal of Applied Clinical Medical Physics*, Vol.*14*, No.6, November 2013, pp. 274-292.
[3] Inan, G., & Gul, O. V., Comparison of gamma analysis using different dosimetric systems for pre-treatment verification of intensity-modulated radiation therapy. *Canadian Journal of Physics*, *Vol.99, No.5*, May 2021, pp.390-396.
[4] Harms Sr, W. B., Low, D. A., Wong, J. W., & Purdy, J. A., A software tool for the quantitative evaluation of 3D dose calculation algorithms, *medical physics*, *Vol.25, No.10*, November 1998, pp. 1830-1836.
[5] Low, D. A., Harms, W. B., Mutic, S., & Purdy, J. A., A technique for the quantitative evaluation of dose distributions, *Medical physics*, Vol.*25, No.5*, May 1998, pp.656-661.
[6] Low, D. A., & Dempsey, J. F., Evaluation of the gamma dose distribution (comparison method), *Medical Physics*, *Vol.30, No.9*, August 2003, pp.2455-2464.
[7] Song, J. H., Kim, M. J., Park, S. H., Lee, S. R., Lee, M. Y., Lee, D. S., & Suh, T. S., Gamma analysis dependence on specified low-dose thresholds for VMAT QA. *Journal of Applied Clinical Medical Physics*, Vol.*16*, No.6, July 2015, pp.263-272.
[8] Kim, J. I., Chun, M., Wu, H. G., Chie, E. K., Kim, H. J., Kim, J. H., & Park, J. M., Gamma analysis with a gamma criterion of 2%/1 mm for stereotactic ablative radiotherapy delivered with volumetric modulated arc therapy technique: a single institution experience, *Oncotarget*, *Vol.8, No.44, June 2017*, pp.7607.
[9] Miften, M., Olch, A., Mihailidis, D., Moran, J., Pawlicki, T., Molineu, A., ... & Low, D. A Tolerance limits and methodologies for IMRT measurement-based verification QA, AAPM Task Group No. 218 recommendations. *Medical physics*, Vol.45, No.4, March 2018, pp.53-83.
[10] Inan, G., & Gul, O. V., Comparison of gamma analysis using different dosimetric systems for pre-treatment verification of intensity-modulated radiation therapy, *Canadian Journal of Physics*, Vol.*99, No.5, May* 2021, pp. 390-396.
[11] Altiparmak, D., Coban, Y., Merih, A., Avci, G. G., & Yigitoglu, I., Comparison of dose accuracy between 2D array detectors and Epid for IMRT of nasopharynx cancer, In *AIP Conference Proceedings*, Vol. 1815, No. 1, AIP Publishing, February 2017.
[12] Lee, Y. C., & Kim, Y., A patient-specific QA comparison between 2D and 3D diode arrays for single-lesion SRS and SBRT treatments. *Journal of Radiosurgery and SBRT*, Vol.*7, No.4*, April 2012, pp. 295.
[13] Li, J. G., Yan, G., & Liu, C., Comparison of two commercial detector arrays for IMRT quality assurance, *Journal of Applied Clinical Medical Physics*, Vol.*10, No.2*, April 2009, pp. 62-74.
[14] SOMATOM go. Top – Made to match - Siemens Healthineers (siemens-healthineers.com)
[15] Seven29 Overview (wienkav. at)
[16] Sun Nuclear MapCHECK 3 User Manual (Page 28 of 32) | ManualsLib.
[17] VMAT/IMRT patient verification software with advanced tools for measurement, dose comparison and evaluation, website: VeriSoft | PTW (ptwdosimetry.com).
[18] Overview Of Snc Patient Software - Sun Nuclear MapCHECK 3 User Manual [Page 10] | ManualsLib.
[19] Clements, M., Schupp, N., Tattersall, M., Brown, A., & Larson, R., Monaco treatment planning system tools and optimization processes, *Medical Dosimetry*, Vol.*43, No.2*, Summer 2018, pp.106-117.
[20] Depuydt, T., Van Esch, A., & Huyskens, D. P., A quantitative evaluation of IMRT dose distributions: refinement and clinical assessment of the gamma evaluation. *Radiotherapy and oncology*, Vol.*62, No.3*, March 2002, pp. 309-319

Author Profile

Mr. Avin Kumar, Completed his Masters in Medical Physics from Manipal University. Presently working as Chief Medical Physicist and Radiation Safety Officer at AJ Hospital and Research Centre, Mangaluru, Karnataka, India.

Mr. Nkurunziza Rodgers, Completed his Bachelor of Science with Education (Physics and Mathematics) from Makerere University, Kampala, Uganda and Masters in Medical Physics from Mangalore University, Mangaluru, Karnataka, India

Ms. Ashwini K, Completed her Masters in Medical Physics from Mangalore University. Presently doing Internship in Medical Physics at AJ Hospital and Research Centre, Mangaluru, Karnataka, India.

Ms. Nisha, Completed her Masters in Medical Physics from Mangalore University. Presently doing Internship in Medical Physics at AJ Hospital and Research Centre, Mangaluru, Karnataka, India.

Ms. Kavya, Completed her Masters in Medical Physics from Mangalore University. Presently doing Internship in Medical Physics at AJ Hospital and Research Centre, Mangaluru, Karnataka, India.