A study on the response of 2D ion chamber array detector for VMAT delivery

Abstract

Purpose: This study aims to evaluate the response of 2D ion chamber array detector for VMAT delivery.

Methods: 2D array ionization chamber equipped with 729 ionization chambers uniformly arranged in a 27×27 matrix with an active 27×27cm² was used for the study. An Octagonal shaped phantom (Octavium Phantom) with a central cavity is used to insert the 2D ion chamber array. All measurements were done with a linear accelerator. The plans that are already being verified has been selected for studying the response of 2D array.

Results: This study shows that the response of the 2D array gets reduced as compared to early quality assured plans. Plans were analyzed using the Gamma analysis method. The results show a variation up to 2% comparing earlier plans.

Conclusion: The response of the 2D array gets reduced while compared with earlier quality assured plans.

Keywords: VMAT, 2D array, Octavium phantom, gamma analysis

Introduction

Volumetric intensity modulated single arc technique originally investigated by Otto. The concept of rotational intensity-modulated radiotherapy was first described by Rock Mackie in (1993). It will be commissioned with dosimetric accuracy and also we can favor with other methods of IMRT delivery. VMAT represents a new paradigm in the treatment of patients with external beam radiotherapy. It uses one or more gantry arcs to deliver dose either by coplanar or non-coplanar beams. A shorter treatment time is a significant improvement for both patient compliance issues, due to confining immobilization and respiratory control devices, and patient throughput. The beams are dynamic in orientation and aperture shape and may include small apertures. The scatter conditions are expected to differ in such beams, compared to classical open fields. So the calibration carried out under broad-beam conditions may not be relevant for VMAT.¹

VMAT consists of treating the patient by means of one or more gantry arcs with continuously varying beam aperture, gantry speed and dose-rate. This approach promises to maximize the benefit of intensity-modulated radiotherapy (IMRT). Then the fluence rate and gantry speed are kept constant. The MLC movement variable dose rates and gantry speeds of a Varian can be controlled precisely for accurate rapid arc delivery. VMAT delivery depend not only the beam fluence, but also on the aperture width, leaf, backup diaphragm and X-diaphragm position as well as their synchronization.²,³

This project aims to evaluate the response of 2D seven29 ion chamber array by delivering different VMAT plans. For this study 45 cases that are already being treated with VMAT was selected, which include QA plans that were delivered 2 years back, 1.5 years and one year back. The present gamma values were compared with the previous ones.⁴

Materials and methods

2D array

PTW729 Freiburg Germany is made up of 729 air vented cubic ionization chamber of 5mm×5mm×5mm each with a center to center spacing of 1cm, is used for measuring dose generated in a plane by a radiation beam. Wall material is made up of Graphite. The material is surrounded the vented ionization chamber is Poly Methyl Metha Acrylate (PMMA). It is arranged uniformly in a 27×27 matrix. Central axis of radiation passing through 14×14 chamber. The advantage of using 2D-array diode for QA is for the ability to perform absolute dose comparisons for hundreds of measurement positions using only a single beam delivery, as compared to the many multitudes of delivery repetitions necessary to perform absolute point measurements with a micro ionization chamber.⁵,⁶

Mainly 2D ARRAY is applicable in the case of Quality Assurance of high energy beams. For each application range separate analysis software like Multi Check or Verisoft is required. Software is available to do analytical comparison of measurements versus dose distributions calculated by a treatment planning system. This software is used to convert 2D dose maps from TPS to gray scale virtual films. It will be represented on the screen of the personal computer with the locations of the 729 ion chambers superimposed over the gray scale image. The measuring system consists of 2D ARRAY Seven29...
A study on the response of 2D ion chamber array detector for VMAT delivery

T10024, ARRAY INTERFACE T16026, RS232 Cable T22373/K6730 and Matrix Scan Software S080050.

Octavius phantom

Octavius is an octagonal solid body phantom with an opening to insert the 2D ARRAY Seven29 for verification of dose distributions and absolute dose values of composite IMRT and VMAT plans. It was constructed for actual measurements with the Seven29 ion chamber array. It has a built-in cylindrically symmetric compensation cavity to correct for anisotropic behavior of the 2D ion chamber measurements. The 2D ARRAY Seven29 can be inserted into the Octavius Phantom for irradiation from different angles. The Octavius Phantom is made of polystyrene (water equivalent within 2%). The Octavius Phantom of the following components. The Octavius phantom consists of a Top body T40051.1.007, Plate T40051.1.1004, Engraved lines for aligning with the laser, reclosable fastener, Accessory plate T40051.1.003 with inserted 2D-ARRAY Seven29 Base body “CT” T40051.1.010 for CT scan and Base body “LINAC” T40051.1.011. These two phantoms vary in different base bodies. The CT Phantom is about 2.5Kg heavier. The Patient Specific Quality Assurance with 2 phantoms, as the 2D ARRAY Seven29 shows slightly reduced response if it is irradiated from the back side. In order to compensate this base body of the Octavius Phantom features a cavity. The base body of the OCTAVIUS CT Phantom does not feature a cavity. The Patient Plan will be calculated for the OCTAVIUS CT Phantom and will be delivered to the Octavius LINAC Phantom. In Octavius Linac phantom there is a C-shaped air cavity. Thus the reduced response of the 2D-ARRAY Seven29 irradiated from backside will be compensated. With its cubic detector and geometrically uniform matrix design, the octavius detector 729 provides significantly higher field coverage compared to other detectors.

Gamma analysis

Gamma analysis is a method for comparing two dose distributions. Generally the dose distribution comparison is subdivided into regions of high and low dose gradients. In low gradient regions, the doses are compared directly with an acceptance tolerance placed on the difference between the two dose maps. In high dose gradient regions, a small spatial error, in either of the dose maps or small misalignment results in large dose difference between the dose maps. Dose difference in the high dose gradient regions may therefore be relatively unimportant and the concept of Distance to Agreement (DTA) distribution is used to determine the acceptability of agreement. Dose difference in the high dose gradient regions may therefore be relatively unimportant and the concept of DTA distribution is used to determine the acceptability of agreement. The dose difference and DTA evaluations complement each other when used as determinants of agreement accuracy between the dose maps. The simultaneous use of DTA and a percent dose difference (DD) was proposed by Low et al. These parameters can help evaluate the agreement of the two distributions in terms of misalignment and difference, respectively. So in this study the various gamma index constraints which are a combination of particular DTA value with specific dose difference tolerance value were used. In this study gamma analysis was done for the whole arc. Gamma analysis of measured and TPS calculated fluence were cited in Figure 1.

Verification plan

45 RapidArc verification plans already delivered and analysed were selected for the study. Verification plans were created using Eclipse treatment planning system version 10.0 (Varian Medical Systems, Palo Alto, CA) using AAA algorithm. It was delivered on Octavius phantom with 2D seven29 detector array (PTW, Freiburg, Germany) to study the response of the 2D seven29 detector array over a period of time. With the help of software Verisoft compared the dose distribution of measured and TPS calculated using the gamma-index method proposed by Low et al. The acceptance criteria of 3mm for the distance to agreement (DTA) and dose difference tolerance level of 3% were chosen for analysis. Also the percentage of the evaluated dose points passing the gamma index was kept at a limit of greater than or equal to 95%. Results of this pre-treatment quality assurance plans were compared with the results for the same plan done before stipulated period. Figure 2 shows the Verification Plan created in Eclipse Version 10.

The verification plans created during the following periods were evaluated;

a. Response of 2D array to the plans before 2 Years.

b. Response of 2D array to the plans before 1.5 Years.

c. Response of 2D array to the plans before 1 Year.

Results and discussion

The average gamma pass percentage of present measurement and measurements before 2 years is 95.7 and 97.84; for 1.5 years is 97.02 and 86.28; for 1 year is 96.42 and 98.86 respectively. The result is cited in Table 1. Average response of gamma analysis for a period of 2 years, 1.5 years and 1 year is given in Figure 2.

The plans which passed the gamma analysis (with percentage more than 95) were evaluated. Higher gamma passing criteria where observed for all analyzed plans, when analysis done before 2 years, 1.5 years and 1 year. Response of 2D array for the set of patients treated before 2years, 1.5years and 1 year Vs Present is given respectively in Table 1, 2 & 3. Standard Deviation of gamma pass percentage before 2 years is 1.38 and for present measurement is 0.70. Standard Deviation of gamma pass percentage before 1.5 years is 1.4 and for present measurement is 1.36. Standard Deviation of gamma pass percentage before 1 year is 0.97 and for present measurement is 1.18. Standard Deviation and percentage deviation of gamma pass percentage for present measurement Vs 2 years, 1.5 years and 1 year were given graphically in Figure 4 & Figure 5 respectively.
This study shows that the response of 2D array reduces with period. The reason for reducing the response of the chamber may because of damage to any one of the chamber in the array. Sensitivity is also another factor that affects the response. Sensitivity decreases if the chamber gets damaged. If the radiation affects the circuit region in the 2D array it can damage the array. So, that individualized check of each ionization chamber inside the array is needed.

Table 1 Response of 2D array for the set of patients treated before 2 years Vs present

| Patient No. | before 2 year | Present | % Variation |
|-------------|---------------|---------|-------------|
| 1           | 99.5          | 96.2    | 3.32        |
| 2           | 98.8          | 95.5    | 3.34        |
| 3           | 99.7          | 95.6    | 4.11        |
| 4           | 96.2          | 95.4    | 0.83        |
| 5           | 99            | 96.5    | 2.53        |
| 6           | 99.3          | 95.1    | 4.23        |
| 7           | 97            | 95.7    | 1.34        |
| 8           | 97.9          | 96.2    | 1.74        |
| 9           | 97.4          | 95.8    | 1.64        |
| 10          | 98.5          | 96.5    | 2.03        |
| 11          | 96.7          | 95.1    | 1.65        |
| 12          | 96.4          | 95.8    | 0.62        |
| 13          | 98.8          | 96.5    | 2.33        |
| 14          | 97.3          | 95.8    | 1.54        |
| 15          | 95.1          | 93.8    | 1.37        |

Table 2 Response of 2D array for the set of patients treated before 1.5 years Vs present

| Pt. No: | before 1.5yr | Present | %V |
|---------|--------------|---------|----|
| 1       | 99.3         | 97.5    | 1.81|
| 2       | 100          | 98.9    | 1.1 |
| 3       | 97.1         | 96.2    | 0.93|
| 4       | 96.2         | 95.5    | 0.73|
| 5       | 97.8         | 96.9    | 0.92|
| 6       | 95.7         | 94.3    | 1.46|
| 7       | 99.7         | 96.5    | 3.21|
| 8       | 97.7         | 95.8    | 1.94|
| 9       | 98.5         | 98.1    | 0.41|
| 10      | 98.1         | 97.7    | 0.41|
| 11      | 99.6         | 99      | 0.6 |
| 12      | 97           | 96.5    | 0.52|
| 13      | 99.7         | 97.5    | 2.21|
| 14      | 100          | 98.8    | 1.2 |
| 15      | 97.8         | 96.1    | 1.74|
Table 3 Response of 2D array for the set of patients treated before 1 year Vs present

| Gamma analysis-3mm, 3% | Pt. No: | before 1yr | present | % V |
|------------------------|---------|------------|---------|-----|
| 1                      | 95.6    | 95.2       | 0.42    |
| 2                      | 98.2    | 98.0       | 0.2     |
| 3                      | 95.9    | 94.5       | 1.46    |
| 4                      | 97.1    | 97.1       | 0       |
| 5                      | 96.6    | 96.2       | 0.41    |
| 6                      | 97.3    | 97.0       | 0.31    |
| 7                      | 98.4    | 97.8       | 0.61    |
| 8                      | 96.4    | 95.5       | 0.93    |
| 9                      | 96.6    | 96.5       | 0.1     |
| 10                     | 95.5    | 95.1       | 0.42    |
| 11                     | 97.8    | 97.5       | 0.31    |
| 12                     | 98.0    | 98.0       | 0       |
| 13                     | 97.5    | 97.1       | 0.41    |
| 14                     | 96.2    | 95.8       | 0.42    |
| 15                     | 95.8    | 95.0       | 0.84    |

**Conclusion**

It is found that 2D array shows the reduced response against radiation detection over a period of years. An onsite calibration of the instrument is recommended before the measurements. A dose correction factor is to be applied if the radiation response and efficiency of the array on radiation detection is poor.

**Conflicts of interest**

On behalf of all the contributors I will act and guarantor and will correspond with the journal from this point onward. Also I hereby assure that there is no conflict of interest, regarding this article.

**References**

1. Otto K. Volumetric modulated arc therapy : IMRT in a single gantry arc. *Med Phys*. 2008;35(1):310–317.
2. Shang P, Chong N, Lee H, et al. Feasibility of using a 2D Array Detector to Verify Composite IMRT Delivery for Helical Tomotherapy and Linac. *Int J Rad Onc Biol Phys*. 2008;72(1):S675–S675.
3. Dong L, Antolak J, Salepour M, et al. Patient-specific point dose measurement for IMRT monitor unit verification. *Int J Radiat Oncol Biol Phys*. 2003;56(3):867–877.
4. SE Burch, KJ Clark. The use of radiographic film for linear accelerator stereotactic radiosurgical dosimetry. *Med Phys*. 1999;26(10):2144–2150.
5. Saini AS, Zhu TC. Energy dependence of commercially available diode detectors for in–vivo dosimetry. *Med Phys*. 2007; 34(5):1704–1711.
6. Yu CX. Intensity–Modulated arc therapy with dynamic multileaf collimation: An alternative to tomotherapy. *Phys Med Biol*. 1995;40(9):1435–1449.
7. De Gersem W, Claus F, De Wagter C, et al. Leaf position optimization for step-and–shoot IMRT. *Int J Radiat Oncol Biol Phys*. 2002;52(5):1007–1018.
8. Daniel A Low. Gamma Dose Distribution Evaluation Tool. *Journal of Physics: Conference Series*. 2010;250.
9. Spezi E, Angelini AL, Romani F, et al. Characterization of a 2D ion Chamber ARRAY for the verification of radiotherapy treatments. *Phys Med Biol*. 2005;50(14):3361–3373.
10. VanEsch A, Clermon C, Devillers M, et al. On–line Quality Assurance of rotational radiotherapy treatment delivery by means of a 2D ion chamber array and the OCTAVIUS Phantom. *Med Phys*. 34(10):3825–3837.
11. Jrsinic PA, Nelms BE. A 2–D diode array and analysis software for verification of intensity modulated radiation therapy delivery. *Med Phys*. 2003;30(5):870–879.
12. Bedford JL, Lee YK, Wai P, et al. Evaluation of the Delta(4) phantom for IMRT and VMAT verification. *Med Phys Biol*. 2009;54(9):N167–176.

**Financial disclosure statement**

On behalf of all the contributors I hereby assure that there is no financial aid for this proposed research work.

**Acknowledgements**

None.