

Portal Dosimetry as a patient specific Quality Assurance tool for Volumetric Arc Radiotherapy


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Introduction: Volumetric Arc Radiotherapy (VMAT) is an advanced technique. Calculations of VMAT plans are not so accurate even with State-of-Art dose calculation algorithms due to their complexity. Hence pre-treatment patient specific Quality Assurance (QA) of each VMAT plan is required. In the present study Electronic Portal Imaging Device (EPID) based portal dosimetry system was used for pre-treatment patient specific QA. **Material and Methods:** A total of 50 patients were chosen in this study. Verification plans of each patient were calculated for portal dosimetry then executed on the EPID system to measure the spatial distribution of radiation dose. Calculated and measured dose distribution were compared to evaluate Gamma Index (GI) passing criteria of Dose Difference (DD) of 3% and Distance-to-Agreement (DTA) of 3mm, Area Gamma ($\gamma\% \leq 1$) >95%, Average Gamma (gAve) <0.5% and Maximum Gamma (gMax) <3.5%. **Results:** The mean values of Area Gamma ($\gamma\% \leq 1$) were observed to be varied from 99.14±0.23% to 99.87±0.18%. The Mean Values of Average Gamma (gAve) are found to vary from 0.19±0.05% to 0.15±0.04% and the mean values of Maximum Gamma (gMax) found to be varied from 1.94±0.37% to 1.59±0.41%. All the plans were passed the gamma index criteria with very good agreement. Thus the use of Portal Dosimetry for pre-treatment patient QA is found to be a very useful, quick, precise, efficient and effective pre-treatment patient specific QA tool for VMAT treatment. **Conclusion:** Portal Dosimetry can be utilized for routine use for patient specific quality assurance for Volumetric Arc Radiotherapy treatment.

Keywords: Portal Dosimetry, Gamma Index, VMAT Quality Assurance, Patient-Specific Quality Assurance

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Introduction

Volumetric Arc Radiotherapy (VMAT) is an advanced radiotherapy technique that allows the prescribed radiation dose to precisely conform to the target volume while a minimum dose to the nearby organ at risk. VMAT modulated the photon beam by modulations of Multi-Leaf Collimator (MLC) leaf positions, Gantry rotation speed and dose rate simultaneously during rotations of gantry around the patient (1-2). This rotational therapy delivers prescribed dose in a relatively shorter duration and has better dose conformity, uniformity and normal organ sparing. (3-7)

Calculations of the small or irregular fields which are frequently used for VMAT are not accurate even with the state-of-the-art dose calculation algorithm (8), therefore patient specific Quality Assurance (QA) of every patient treated with VMAT techniques were performed before patient treatment (9-11). The delivery of the radiation beam to the tumour requires quality assurance for every plan before treatment of the patient using a 2D array or portal dosimetry (12). The most widely used form of pre treatment Quality Assurance for IMRT/VMAT generally consists of absolute dose measurement with ionization chamber combined with isodose distribution measurements in a phantom (13-15). Electronic Portal Imaging Device (EPID) offer advantages over other systems as it is attached to the gantry of the accelerator and hence reduced the duration of set up. In the present study EPID based portal dosimetry system was used as a pre treatment patient specific QA for VMAT plans treated at the Department of Radiotherapy, Regional Cancer Centre, Pt. J.N.M. Medical College, Raipur.

Material and Methods

A total of 50 patients were included in this study. The plan of each patient was with 2Arcs. These plans include treatment of carcinoma located at various sites. All selected plans were optimized and calculated using Eclipse Treatment Planning System (TPS) Ver 15.6.3 (Varian Medical Systems Palo Alto CA USA). Progressive Resolution Optimizer (PRO) algorithms were used to generate an optimal plan then the dose was calculated using Anisotropic Analytical Algorithm (AAA) with a 2.5mm grid. This treatment was executed on Clinac DHX Linear Accelerator with millennium 120™ MLC (Multi-Leaf Collimator) and 6MV nominal Photon energy.

All plans were undergone pre-treatment Quality Assurance (QA) with Portal Dosimetry System (Varian Medical Systems Palo Alto CA USA) attached with Linear Accelerators (Clinac DHX). Portal Dosimetry System which consists of a portal vision aSi1000 comprises an 8 mm thickness main plate, a thin copper slice (1 mm) and a 0.5 mm phosphor film. The detector panel has a pixel dimension and spatial resolution of 1024 x 768 and 0.392 mm per pixel respectively. Portal Dosimetry was commissioned and calibrated according to manufacturer protocol before using it for pre-treatment patient specific QA.

The Verification plan of each patient was created for portal dosimetry using Portal Dose Image Prediction (PDIP) algorithms in Eclipse TPS with Source to Image Distance (SID) 100cm. Verification plans were then executed on the EPID system to measure the spatial distribution of radiation dose. Figure-1 shows dose distribution for a VMAT plan (2Arc) of a patient with carcinoma tongue.

Calculated and measured dose distributions were compared to evaluate its accuracy of delivery with pre-defined passing criteria of Gamma Index (GI). Figure-2 shows a graphical representation of predicted and measured dose with their superposition along with the collimator axis for the above-cited VMAT plan. The criteria of gamma evaluation (Dose Difference (DD) of 3% and Distance-To-Agreement (DTA) of 3mm) were set based on clinical experience.

Figure-1: Beam arrangements and dose distributions for VMAT plan of a patient with carcinoma tongue

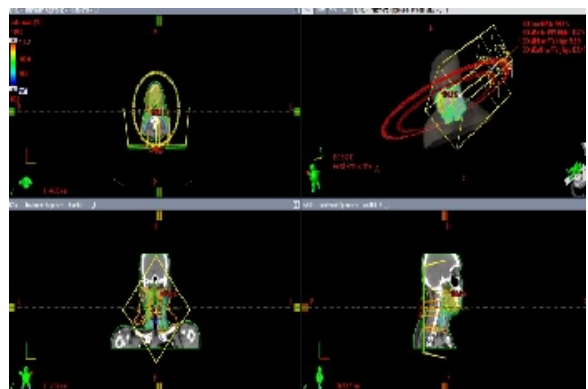
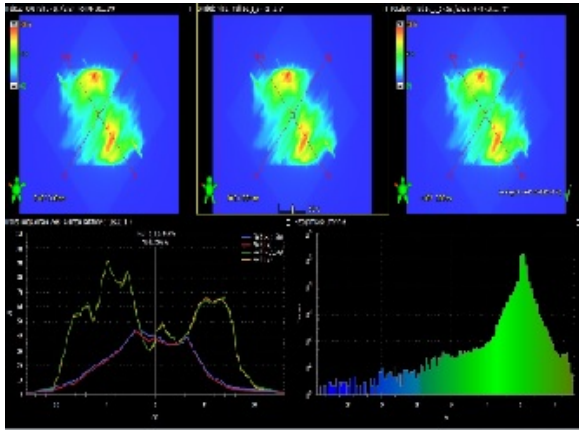


Figure-2 Graphical representation of predicted and measured dose with their superposition along collimator axis for the above-cited VMAT plan using Portal Dosimetry system.



Results

The gamma index (GI) evaluation of the measured dose distributions in the Portal dosimetry/EPID system against the dose distribution predicted by the treatment planning system was performed. For each field of every plan, three gamma scaling parameters estimated are Area Gamma ($g\% \leq 1$), Average Gamma ($gAve$) and Maximum Gamma ($gMax$). Gamma index (Gamma criteria of Dose Difference (DD) 3%, Distance to Agreement (DTA) 3mm) values of 50 patients with various treatment sites are tabulated in Table-1. The mean values of Area Gamma ($g\% \leq 1$) varies from $99.87 \pm 0.18\%$ for Hard Palate to $99.14 \pm 1.20\%$ for the VMAT plan of Brain tumours. The Mean Values of Average Gamma ($gAve$) are found to vary from $0.19 \pm 0.05\%$ to $0.15 \pm 0.04\%$ and the mean values of Maximum Gamma ($gMax$) found to be varied from $1.94 \pm 0.37\%$ for a plan of carcinoma of the cervix to $1.59 \pm 0.41\%$ for Brain tumours.

Discussions

In this study we have analyzed the data of EPID based Portal dosimetry for dose distribution verification as a pre-treatment patient specific quality assurance of VMAT plans to ensure acceptable accuracy of treatment delivery. The tolerance for passing criteria for VMAT plans was based on the per cent of pixel passing, Area Gamma ($g\% \leq 1$) $>95\%$, Average Gamma ($gAve$) $<0.5\%$ and Maximum Gamma ($gMax$) $<3.5\%$ with the passing criteria of Dose Difference (DD) 3%, Distance to Agreement (DTA) 3mm.

In the present study we observed that all gamma parameters are within the tolerance limit which reveals that the comparisons of calculated and measured dose distributions are found within an acceptable level of accuracy for the delivery of a plan to treat the patient. If the gamma parameters go beyond the tolerance limit we need to determine the source of error and eliminate it to achieve maximum possible accuracy of plan and treatment delivery.

No considerable variation has been observed in the values of gamma parameters for various treatment sites covered in this study, which proves the consistency, reproducibility and suitability of portal Dosimetry system for patient specific quality assurance. Results of this study are found comparable to the values of gamma parameters reported by Ibrahim AG, et al (16) and Nainggolan A, et al (17) for dose distribution verifications of VMAT plans for various treatment sites using the Portal Dosimetry system.

Table-1: Data of Gamma parameters of portal dosimetry for VMAT plan with gamma passing criteria DD 3%/DTA 3mm

S.N	Site of treatment	Number of Arcs in each plan	Number of patients	Area Gamma ($g\% \leq 1$)		Average Gamma ($gAve$)		Maximum Gamma ($gMax$)	
				Mean	SD	Mean	SD	Mean	SD
1	Hard palate	2	5	99.87(100.00-99.60)	0.18	0.15(0.20-0.10)	0.04	1.64(2.30-1.13)	0.55
2	Carcinoma Cervix	2	6	99.45(99.90-98.10)	0.69	0.18(0.23-0.14)	0.03	1.94(2.48-1.42)	0.37
3	Tongue	2	13	99.75(100.00-98.70)	0.34	0.19(0.26-0.12)	0.04	1.90(3.42-0.95)	0.65
4	Brain	2	10	99.14(100.00-95.10)	1.20	0.19(0.28-0.14)	0.03	1.59(2.32-0.93)	0.41
5	Buccal Mucosa	2	11	99.73(100.00-98.70)	0.34	0.18(0.29-0.10)	0.04	1.75(2.80-1.02)	0.50
6	Nasopharynx	2	5	99.20(100.00-97.50)	0.98	0.19(0.26-0.15)	0.05	1.82(2.42-1.30)	0.47

Conclusions

Portal dosimetry system for pre-treatment patient-specific QA overcomes the disadvantages of other dose distribution verification system like 2D array detector system which have a low resolution of detectors, and require more time to set up detectors, phantom and connect to the analyzing system.

The results of this study show very good agreement between TPS calculated dose distribution with measured on portal dosimetry system. Thus this study proves that portal dosimetry is a quick, precise, efficient and effective pre-treatment patient specific QA tool for VMAT treatment.

Portal Dosimetry can be utilized for routine use for patient specific quality assurance for Volumetric Arc Radiotherapy treatment.

Author's contribution

Dr V.B. Rathore: Primary investigator of this study, Data Analysis and manuscript preparation.

Mr. V.K Mishra: Helped in data collection, analysis and preparation of the manuscript.

Dr. V Choudhary: Guided to conduct this study and preparation of the manuscript

Mr. G.S. Gautam, Ms. P. Kushawaha, Dr. S.K. Azad, Dr. M. Kerketta, Dr P.K, Chandrakar, Dr R.S. Singh and Dr. R.R. Jain: Preparation of this manuscript.

All authors are critically reviewed and approved the final manuscript.

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