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Rahul Rai
Ph.D. Research Scholar, Department of Physics, FS University, Shikohabad, Uttar Pradesh, India

Krishna Kumar Singh
Assistant Professor, Department of Physics, FS University, Shikohabad, Uttar Pradesh, India

Corresponding Author:
Rahul Rai
Ph.D. Research Scholar, Department of Physics, FS University, Shikohabad, Uttar Pradesh, India

A comparative evaluation of patient-specific quality assurance techniques for head and neck cancer: Portal dosimetry versus ArcCheck

Rahul Rai and Krishna Kumar Singh

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Abstract
The current study employs portal dosimetry and ArcCheck to investigate the consistency of patient-specific quality assurance by implementing different gamma criteria's for evaluating dose fluence in Head and Neck cancer patients. A total of 50 Head and Neck cases were taken retrospectively which were planned with 5 to 7 fields IMRT technique. All treatment plans were generated using Eclipse planning system V.15.6 with no normalization point mode. Gamma Index (GI) & Dose difference variations of portal dosimetry and ArcCheck were compared. Portal dosimetry is done by using DMI of Halcyon V.2.0. From the dosimetry analysis**,** an average value of IMRT plans with gamma evaluation criteria (3%/3mm) using portal dosimetry & ArcCheck were found to be 99.50 ±0.038% & 99.88 ±0.047% with CV of 0.038% and 0.047% respectively. Means of maximum and average absolute dose differences (cGy) for ArcCheck were found to be 0.214±0.09 & 0.023±0.00 respectively. Similarly, for portal dosimetry these values were found to be 0.323±0.19 & 0.216±0.01 respectively. Mean of gamma average for portal dosimetry was found to be 0.2154. Result obtained from our data showed that a lower gamma index values discrepancy between the measured and estimated TPS dosages, which signifies a very high level of accuracy of our IMRT delivery. Since passing criteria using gamma index method is 3%/3mm, which is globally acceptable. Our result shows a very good agreement between dose measured by DMI of Halcyon^{TM}V.2.0 and SNC ArcCheck dosimetry system.

Keywords: Portal dosimetry, ArcCheck, Halcyon, IMRT, DMI

Introduction
When the late 1990s saw the introduction of Intensity Modulated Radiation Therapy (IMRT), it created a lot of buzz [1-4]. It was expected that the novel method would precisely target malignancies [5, 6]. In recent advancements in external beam radiotherapy have introduces various new features which facilitate the requirement of precise delivery of dose to patients. To achieve maximum tumor control and reduction of doses at organ at risk (OAR), it is necessary to carry out the routine measurement to check the quality assurance parameters like, output, flatness, symmetry etc. The Halcyon^{TM} V.2.0 Linear Accelerator was introduced by Varian (Varian Medical System, Palo Alto, CA, USA) (Figure 1) [7]. Halcyon have the machine performance check (MPC) ability to conduct daily measurement to check out variation and uniformity of different parameters [8]. As the usage of volumetric modulated arc treatment (VMAT) and intensity modulated radiation therapy (IMRT) has grown, so too has the need for patient-specific verification. Treatment plans are becoming more complex, which makes it harder to identify potential mistakes because dosage levels and field shapes are no longer intuitive for particular treatment sites and are therefore harder to gauge by experience. There are various methods to measure photon fluence based dose measurement. Digital Megavolt Imager (DMI-aSi1200) is one of the most popular methods used for this, which is introduced in new generation Linear Accelerator Halcyon v.2.0 with inbuilt features [9, 10]. Inside the gantry ring, just above the photon beam stopper, is where DMI is located, 154 cm from the source. With a 1280×1280-pixel matrix and a 43×43 cm^2 field of view (FOV), Imager can record images at a full resolution rate of 25 frames per second. Because deviations can come from a variety of sources, they can impact patient orientation, geometry, detector response variations, and entrance fluence.
This new feature of in-build Digital Megavolt Imager (DMI) reduces some of them errors compare to other method like ArcCheck and 2-Dimentional (2D) array detector.

ArcCheck phantom (Sun Nuclear, Melbourne, FL, USA) is one of the new devices designed for patient-specific quality assurance [11]. This device is specifically made for the delivery of IMRT or VMAT. Absolute point dosage measurement with an ion-chamber is a simpler, more robust, and more dependable form of patient-specific quality assurance (QA). Ion chambers carry the calibration traceable to the primary standard dosimetry laboratory (PSDL) [12, 13].

In the present study an effort has been made to check out the accuracy of patient specific pretreatment quality assurance using DMI and a comparison was also done using ArcCheck on the basis of gamma evaluation method.

Materials and Methods

The gamma criterion for analysis is a 3 mm distance and a 3% dosage differential to agree with a threshold of 10% of the maximal radiation dose was used. A total of Fifty Head and Neck cases were taken in this study retrospectively, and all cases were planned with 5 to 7 fields IMRT technique. All patient plans with no normalization mode were created in TPS Eclipse V. 15.6 software. A verification plan was created for each patient plan using eclipse planning software for portal dose prediction with all fields are in same plane. These plans were delivered to inbuilt DMI on Halcyon v.2.0 in Quality Assurance (QA) mode. After that profile of predicted dose and portal dose were recorded and fluence were analyzed using portal dosimetry software of Eclipse planning system using Gamma evaluation criteria (Figure 2).

For dose fluence measurement using ArcCheck with having software v6.7.1 (Figure 3), all patient verification QA plans were created using computed tomography (CT) image of ArcCheck Phantom in eclipse treatment planning system. Then these verification plans were delivered on physical ArcCheck phantom (Figure 4). This phantom is manufactured by Sun Nuclear Corporation (SNC) made of PMMA (polymethyl methacrylate or Acrylic) material with 1386 diode detector with spacing 1 cm has been used for patient specific QA. The dimensions of its length, external diameter, and interior diameter are 21.0, 26.6, and 15.1 cm, respectively. Every diode's active area is 0.8×0.8 mm². The SNC patient™ v6.7.1 software can be used to measure the absolute or relative semi-3D dosage distribution. The manufacturer recommended dosage calibration using a 10×10 cm² open field with a source axis distance (SAD) of 100 cm and a background adjustment prior to each measurement session.

Before delivering first fraction of radiotherapy treatment to the patient, portal dosimetry is a method use to match dose fluence accuracy with planned dose fluence. Different methods are used for dose verification using ion chambers, diodes, 2D array, thermolumiscence detectors, ArcCheck etc. Dynamic Image guided Radio Therapy (IGRT) on Halcyon v2.0 has the advantages of the point dosage measurements, in vivo measurements, and 3D dose verification are all possible with DMI. When employing the DMI or Electronic Portal Imaging Device (EPID) for dosimetric verification, there are two types of dosimetry: transit (or) projection and non-transit. The non-transit dosimetry is extensively used for the pre-treatment verification without a patient or phantom. The transit dosimetry has the potential of validatory dose delivery by the linear accelerator, positional accuracy of multileaf collimator and the dose calculation of a patient or phantom.

Results

For the ArcCheck and portal dosimetry, delivered results were then compared with predicted dose results from planning system. For portal dosimetry and ArcCheck a criteria of Dose Difference (DD) and Distance to Agreement (DTA) of 3%/3mm with a 10% low dose threshold referenced to the local and improved gamma evaluation respectively [14] as shown in Table 1.

The dosimetry analysis revealed that the average value and standard deviation (SD) (Mean ± SD) of IMRT plans, based on gamma evaluation criteria (3%/3mm) using portal dosimetry and ArcCheck, was determined to be 99.50 ±0.038% and 99.88 ±0.047%, respectively (Figure 5), Coefficient of variation (CV) between local gamma evaluation between portal dosimetry and ArcCheck were found to be 0.038% and 0.047% respectively (Figure 6).The mean maximum and absolute dose differences in cent-Gray (cGy) for ArcCheck were calculated to be 0.214±0.09 and 0.023±0.00, while for portal dosimetry, these values were found to be 0.323±0.19 and 0.216±0.01, respectively as shown in Figure 7. Additionally, the mean of gamma average for portal dosimetry was identified as 0.2154.

Discussion

Quality assurance plays an important role in radiotherapy delivery techniques. Human error, mechanical error, and digital errors are detected by patient-specific quality assurance. ArcCheck Phantom is a stand-alone solution for quality control. The virtual inclinometer algorithm is used to adjust the diode detector's response in relation to the gantry angle [15]. The TPS-calculated dosage and the device measurement for the several patients under study were compared. Every patient's field was less than 20 cm in y-direction, allowing it to fit inside the ArcCheck phantom's active area. Additionally, ArcCheck's electrical circuitry were shielded from unintentional radiation harm. This phantom works well for verifying hybrid plans, where flaws that are invisible at 0° or a different fixed gantry angle will be found [16]. A detector's response must be independent of beam orientation, energy, and dosage rate in order to be used for hybrid plan verification. SNC software made the necessary adjustments to the diode response, including field size, background, and angular corrections.

In this study, both ArcCheck and portal dosimetry were used to verify the treatment plans, and all of them fulfilled the predetermined gamma evaluation criteria, suggesting that there were only slight variations between the two approaches. The DMI has the higher detectors density and closer spacing, as well as its accurate setup during treatment delivery, portal dosimetry showed low variations despite requiring fewer time and material resources.

This study allowed for dose measurements under real treatment parameters by simulating clinical situations by directly delivering IMRT beams to the DMI with gantry rotation. However, the fact that portal dosimetry is unable to provide information regarding the gantry angle is one of its limitations. The ArcCheck system, in contrast, makes use of a cylindrical phantom that has point-size detectors built into it. By measuring dosages perpendicularly from every gantry angle, these detectors make setup easier. Although the ArcCheck method has advantages, its greater detector spacing could result in somewhat larger deviations than portal dosimetry.

Conclusion

The parameters obtained from portal dosimetry using DMI for fluence measurement are within clinically acceptable range.

From comparison with ArcCheck all parameters are comparable and similarity with IMRT fluence of portal dosimetry. The overall outcome indicates that Halcyon's integrated DMI system is regarded as one of the most dependable systems for assessing patient-specific QA prior to treatment. Another advantage of DMI over ArcCheck, it consumes less time for setup i.e. reduces the chances of errors and more accurate results can be obtained. EPIDs can be used to routinely verify IMRT fields with high precision and resolution in order to detect clinically important dosimetric errors before the patient's treatment begins.

Figures

Fig 1: Photograph of varian halcyon linear accelerator

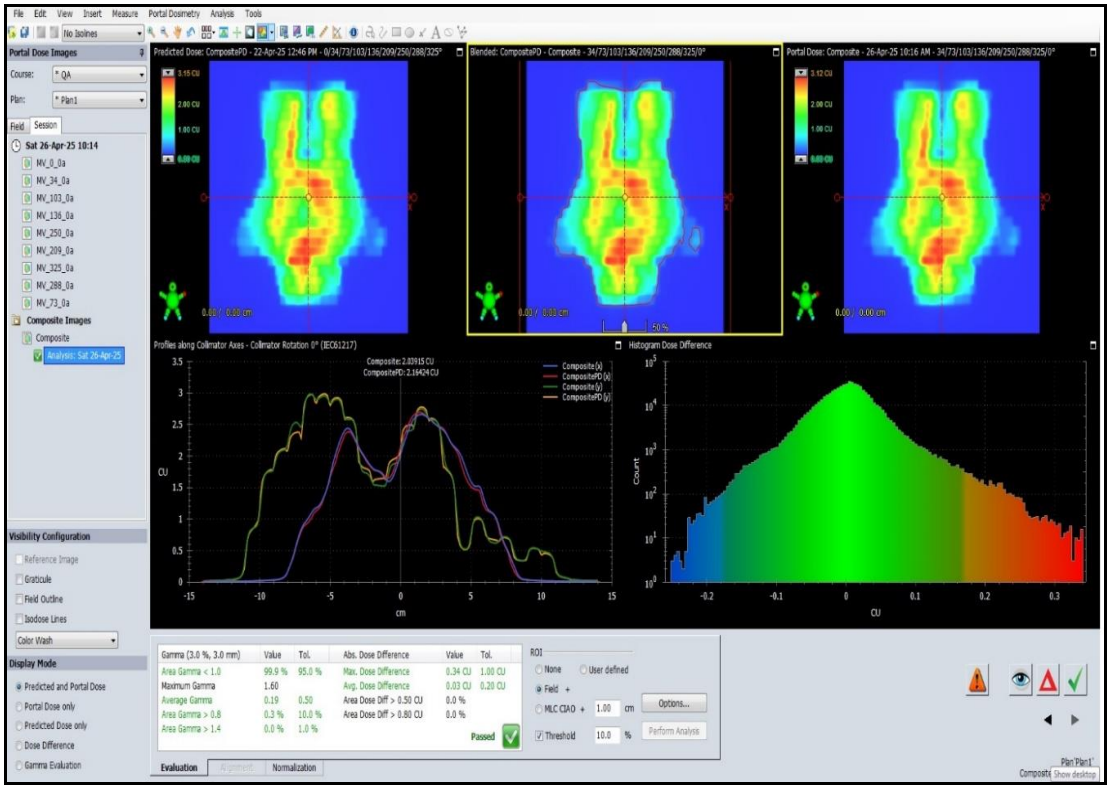

Fig 2: Showing the portal dosimetry software of eclipse treatment planning system doing gamma evaluation for a patient.

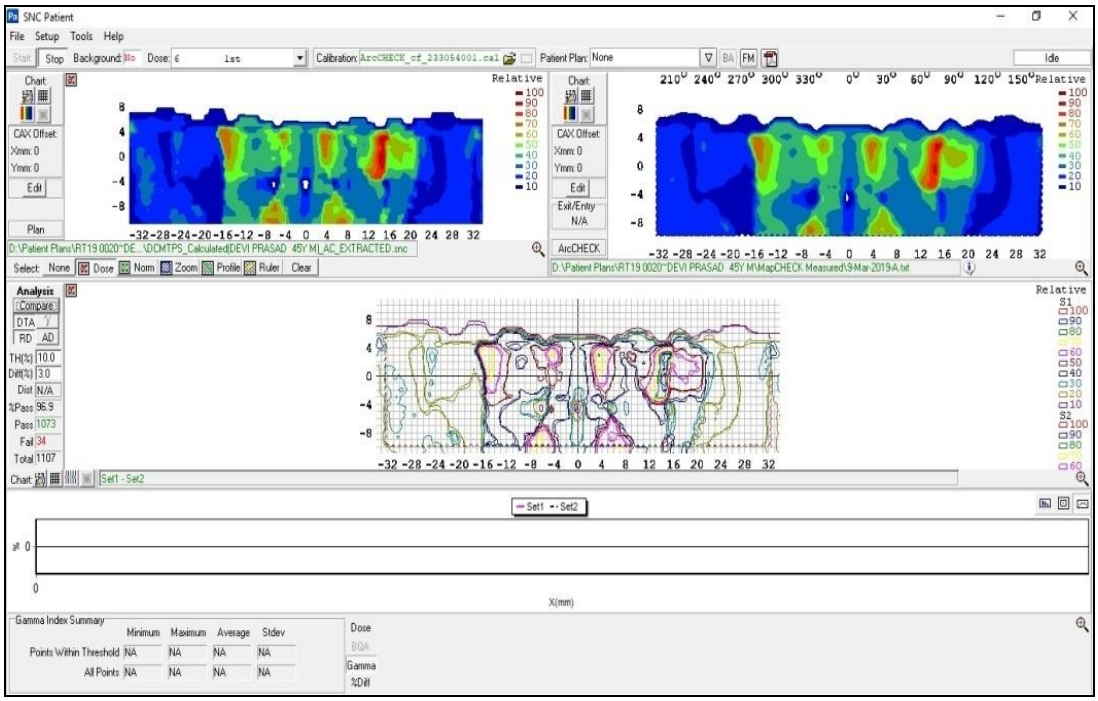

Fig 3: Showing the dose fluence measurement using ArcCheck software v6.7.1.

Fig 4: ArcCheck phantom used for the measurement.

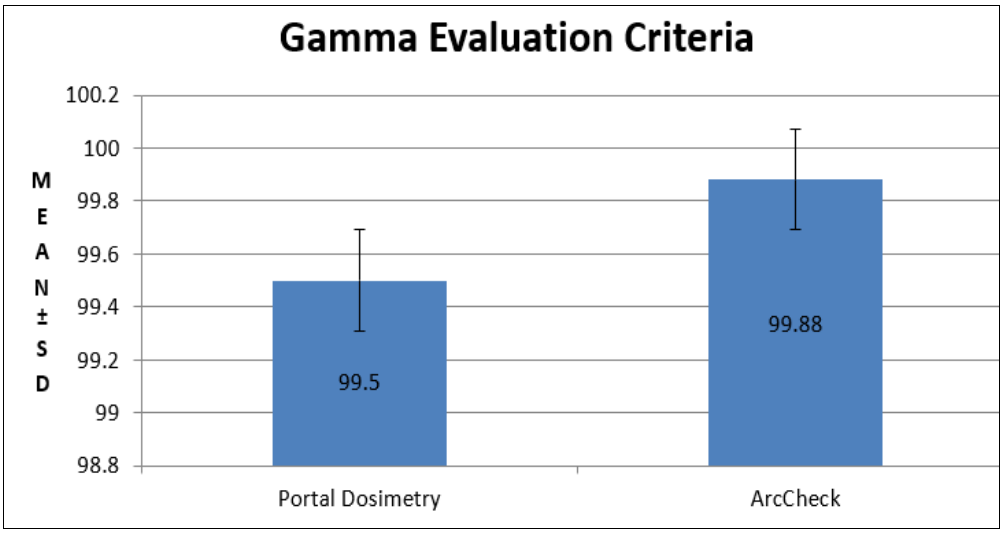

Fig 5: Showing the Mean ± SD for Gamma Evaluation Criteria (%) for DMI and ArcCheck

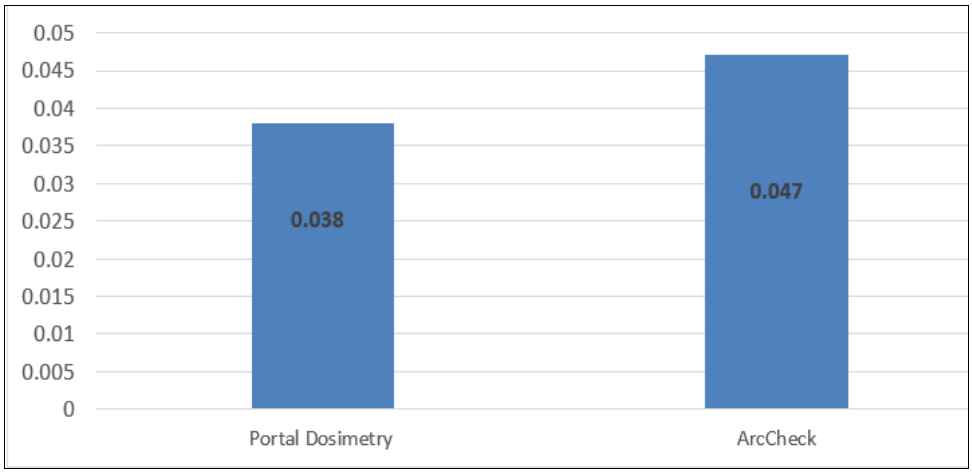

Fig 6: Showing the coefficient of variation (CV) for DMI and ArcCheck.

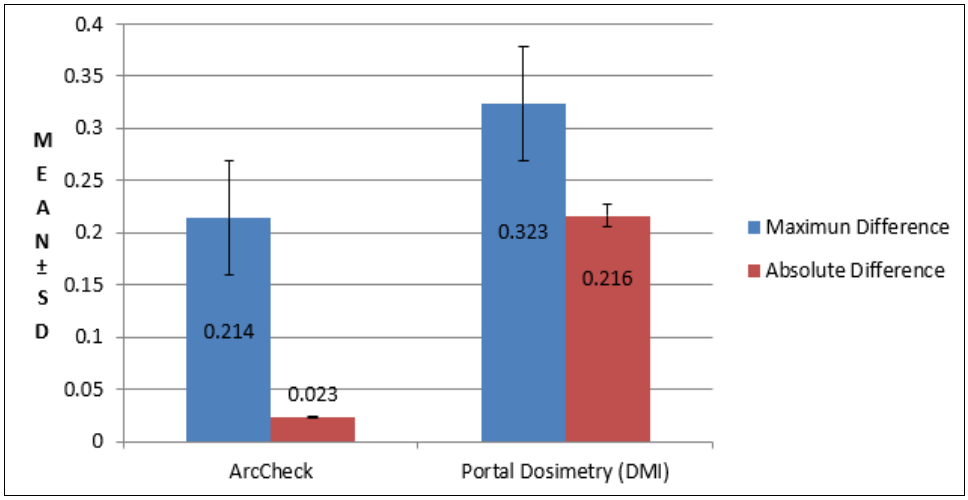

Fig 7: Showing the Mean ± SD for maximum dose difference and Absolute difference (cGy) for DMI and ArcCheck

Table 1: Showing the Results obtained for portal dosimetry and ArcCheck

Parameters	Gamma Criteria (%)	Coefficient of variation (SD/Mean) *100%	Maximum Difference (cGy) (Mean ± SD)	Absolute Difference (cGy) (Mean ± SD)
Portal Dosimetry (PD)	99.50 ±0.038	0.038	0.323±0.19	0.216±0.01
ArcCheck	99.88 ±0.047	0.047	0.214±0.09	0.023±0.00

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Conflict of interest: There is no conflict of interest with the content of this article.

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