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Analyzing the performance of ArcCHECK diode array detector for VMAT plan

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Aim: The aim of this study is to evaluate performance of ArcCHECK diode array detector for the volumetric modulated arc therapy (VMAT) patient specific quality assurance (QA). VMAT patient specific QA results were correlated with ion chamber measurement. Dose response of the ArcCHECK detector was studied.
Background: VMAT delivery technique improves the dose distribution. It is complex in nature and requires proper QA before its clinical implementation. ArcCHECK is a novel three dimensional dosimetry system.
Materials and methods: Twelve retrospective VMAT plans were calculated on ArcCHECK phantom. Point dose and dose map were measured simultaneously with ion chamber (IC-15) and ArcCHECK diode array detector, respectively. These measurements were compared with their respective TPS calculated values.
Results: The ion chamber measurements are in good agreement with TPS calculated doses. Mean difference between them is 0.50% with standard deviation of 0.51%. Concordance correlation coefficient (CCC) obtained for ion chamber measurements is 0.9996. These results demonstrate a strong correlation between the absolute dose predicted by our TPS and the measured dose. The CCC between ArcCHECK doses and TPS predictions on the CAX was found to be 0.9978. In gamma analysis of dose map, the mean passing rate was 98.53% for 3% dose difference and 3 mm distance to agreement.
Conclusions: The VMAT patient specific QA with an ion chamber and ArcCHECK phantom are consistent with the TPS calculated dose. Statistically good agreement was observed between ArcCHECK measured and TPS calculated. Hence, it can be used for routine VMAT QA.

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1. Background

Intensity modulation in radiation beam improves the treatment plan quality in terms of tumor control probability (TCP) and normal tissue complication probability (NTCP). Intensity modulation can be achieved by fixed gantry delivery as well as arc based delivery.[1] Yu[2] proposed intensity modulated arc therapy (VMAT) with dynamic MLC as an alternative to tomotherapy in 1995. Although the concept of VMAT was developed much earlier, it took more time for clinical implementation. This is because of limited scientific work, lack of appropriate and efficient planning algorithm, delivery technique and weak commercial interest. Several researchers developed different techniques to realize single arc VMAT.[3–12] Karl Otto developed progressive resolution optimization (PRO) for single VMAT. The clinical applications and comparisons between existing delivery techniques of VMAT were studied and published in various research works.[13–27] Stringent quality assurance (QA) is required for assessment of any new equipment and technique before its clinical implementation. VMAT delivery is complex in nature, it involved simultaneous changes in gantry speed, multileaf collimator speed and dose rate. VMAT patient specific QA is important to assess the coordination of these parameters and delivery accuracy. One of the novel equipment intended for patient specific QA is ArcCHECK phantom. This equipment is specially designed for VMAT delivery. More reliable, robust and simple method of patient specific QA is absolute point dose measurement using an ion chamber. Ion chambers carry the calibration traceable to the primary standard dosimetry laboratory (PSDL). The aim of this study is to evaluate performance of ArcCHECK diode array detector for the volumetric modulated arc therapy (VMAT) patient specific quality assurance (QA).

2. Materials and methods

2.1. *ArcCHECK*

The ArcCHECK, (Model 1220, Sun Nuclear, Melbourne, FL), is a 3-dimensional beam dosimetry QA system intended for the measurement of radiotherapy dose distributions that are delivered, as defined by a planning system, and compared to the dose distribution, as calculated by the planning system. It is a cylindrical water-equivalent phantom with a three-dimensional array of 1386 diode detectors, arranged in a spiral pattern, with 10 mm sensor spacing. The center of the phantom (15 cm diameter) is designed to accommodate various accessories such as a solid homogeneous core, a dosimetric core with ion chamber(s) or diode arrays, an imaging QA core, a core with heterogeneous materials for dose studies, etc. The ArcCHECK also features two inclinometers to measure the angle of rotation about the cylinder axis and to measure the tilt of the axis. A temperature sensor measures the ambient temperature of the detector area. Dose measurements from each sensor are updated every 50 ms; there is no time limit or dose limit for a measurement (1386 precision diode detectors [size 0.8 × 0.8 mm]) (Fig. 1).

2.2. *Linear accelerator*

The measurements were carried out on a Clinac iX linear accelerator (Varian Medical Systems, Palo Alto, USA), capable of generating 6 MV and 15 MV photon beams. Dose rates available for photon are 100 MU/min to 600 MU/min in steps of 100 MU/min for VMAT delivery the dose rate range 0–600 MU/min (continuous). It is equipped with Millennium 120 MLC with central 40 pairs of 5 mm and peripheral 20 pairs of 10 mm leaf width at the isocentre. By design round tip multileaf collimators are at the tertiary level.

2.3. *Performance tests*

2.3.1. *Linearity and reproducibility of dose*

Linearity of dose measurement of ArcCHECK was evaluated. Monitor units ranging from 1 MU to 500 MU were delivered to ArcCHECK for 10 cm × 10 cm jaw setting. A range of monitor unit (MU) was chosen to cover the clinical VMAT plans. Phantom response to 100 MU was normalized to calculate linearity of dose. Similar measurement was carried out with an ion chamber in water phantom for comparison. Reproducibility of dose delivered is checked for ArcCHECK. It is evaluated in terms of coefficient of variation (COV). Ten repeated dose measurements were observed for 100 MU and 10 cm × 10 cm jaw setting. Similar measurement was carried out with an ion chamber in water phantom for comparison.

2.3.2. *Field size and dose rate dependence*

Response of ArcCHECK for various field sizes was evaluated. Field sizes ranging from 3 cm × 3 cm to 25 cm × 25 cm were exposed to a dose of 100 MU, and respective dose measured by ArcCHECK recorded. All readings of ArcCHECK phantom were normalized to the response of 10 cm × 10 cm field size. Similar measurement was carried out with an ion chamber in water phantom for comparison. The dose response of ArcCHECK was measured with different dose rates ranging from 100 MU/min to 600 MU/min. This measurement shows the Dose rate dependence of ArcCHECK. Similar measurement was carried out with an ion chamber in water phantom for comparison.

2.4. *VMAT Plan QA*

2.4.1. *Treatment planning*

All the plans in this study were performed in Eclipse treatment planning system (TPS), version 10.0 (Varian Medical Systems, Palo Alto, USA) using 6 MV photon beam. A dose rate of 600 MU/min was opted for all the arcs used, but the final dose rate was decided by the optimization algorithm. All the plans were optimized by a progressive resolution optimizer 3 (PRO3, Second generation).[28] In this algorithm full arc is optimized at 178 control points progressively in four phases. At every iteration level it optimizes multi-leaf collimator (MLC) position and monitor unit (MU) weight within limitations (MLC speed, gantry speed, dose rate, and mechanical limits) of the delivery unit.[4] During optimization, dose calculation is performed with a simplified multi resolution dose calculation (MRDC) algorithm. In order to mitigate the leakage due to tongue and groove effect, collimator rotated to 30° from the