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Dosimetric characteristics and day-to-day performance of an amorphous-silicon type electronic portal imaging device

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HIGHLIGHTS

- To exam and verify that aSi-1000 panel is available for daily QA in long term period.
- Correlation test shows the EPID is significantly correlated with ion chamber based daily device.
- Measurement, comparison and conclusion of dosimetric characteristic of a-Si EPID.
- The ±1% dose variance in total of 165 daily output measurements when using EPID.

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ABSTRACT

This study investigated the dosimetric characteristics of an amorphous-silicon (aSi) electronic portal imaging device (EPID) and the utility and consistency of its daily output. This investigation utilised the portal dose prediction function of aSi-1000 EPID panel to test the panel for linearity, field size, dose rate and source to detector distance (SDD). To check daily output consistency, to acquire fluence by aSi EPID and reading calibration unit (CU) value every working day. Percentage variance of daily output also was measured using alternative two different types of dosimeter, EBT3 film and a multiple-channels output check device. Total of 165 daily output readings of EPID showed an average variance of 0.36% ± 0.53 from July 2014 to February 2015. The other two results between EBT3 film with BeamChecker Plus were −0.17% ± 2.36 and 0.35% ± 0.14, respectively. From correlation analysis, results of EPID is significantly correlated with BeamChecker Plus's (0.625, $p << 0.001$). Furthermore, the dosimetric characteristic of EPID indicated that CU values were a linear function of monitor units (MUs). When field size or dose rate varied, the panel's response was within 2%. The inverse square relation was between variable SDD and responding signal of panel. As compared with other dosimeters, the daily output monitor of aSi EPID was found to be reasonably consistent with commercial daily output device and replace with complex film-based procedure.

1. Introduction

A strict and complete quality assurance (QA) program is essential to guarantee quality and safety of the treatment. A daily regular control of linear accelerator (Linac) is one of the important component of QA program. The daily tests include dosimetric, geometric and safety issue. The monitoring of output is checked inherent ion chamber when Linac is started treating every day. Output constancy affects patient's dose directly and means stable performance of Linac output. In principle, the variance of daily output constancy has to within ±3% been recommended by the AAPM Task Group (TG) reports No. 40 and 142 both for modern medical linear accelerators (Klein et al., 2009; Kutcher et al., 1994). There are several detectors which can be used testing for output constancy of treatment units comprehensively including ion chamber, diode and scintillator (Alaei et al., 2006; Peng et al., 2011).

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Luketina et al. used NE2571 ion chamber to check output constancy of 2100CD Linac over 4.5 years and the total variation was ±0.3% (Luketina and Greig, 2004). The drawback is setting complicity of ion chamber and solid water phantom which same as monthly dose calibration. Connection between chamber and dosimeter by extension cable is the labor work and time consuming, in addition, warm-up time is necessary. Alternative, DCT 444 plastic Scintillator device was investigated for daily QA of radiation beams by Das et al. (1996). The disadvantage of DCT444 was showed varied signal losses possibly due to radiation damage in long term stability studied over 25 months. The general purpose of an Electronic portal imaging device (EPID) is not only to acquire treating portal images but also can be used to correct treatment positions for patient (Hurkmans et al., 2001; Kroonwijk et al., 1998; Pouliot and Lirette, 1996; van Lin et al., 2003). Actually, its advantages as compared with film are better image quality, dose reduction, and without processing necessary (Kruse et al., 2002; Vetterli et al., 2004). In practice, the EPID was a mature imaging guidance tool and also has been developed for dosimetric QA. Its efficiency and speed is achieved through a set of QA tools that are mounted on a single platform, which is designed to adapt in the robotic arm of the medical Linac. It is available to decrease labor work for therapists or physicists when acquiring images or setting for QA. An amorphous-silicon (aSi) EPID is also a pretreatment dosimeter to verify dose delivery of intensity modulated radiotherapy (IMRT) or arc radiotherapy (Fuangrod et al., 2015; Liu et al., 2013; Matsumoto et al., 2013; Podesta et al., 2014; Woodruff et al., 2013). Before dosimetric application, the panel should be processed by appropriate QA procedure to make sure of accuracy (Jomehzadeh et al., 2014). Although the aSi EPID can itself perform certain QA functions including light and radiation-field coincidence checks, flatness and symmetry of field size tests, and multileaf collimator mechanical and dosimetric test (Liu et al., 2002; Mamalui-Hunter et al., 2008; Parent et al., 2006; Polak et al., 2013; Vial et al., 2008). However, measuring Linac daily photon output consistency using EPIDs in long term capability was not been reported previously. The present study investigated the feasibility of a-Si EPID using for daily photon output consistency check and its dosimetric characterisation. The consistency of daily photon output was also obtained by EBT3 film and multiple channels ion camber device two dosimeters. Our results provided evidence to support that an a-Si EPID can be a stable dosimeter in long term period and also be utilised repeatedly for daily photon output checks on linear accelerators.

2. Materials and methods

2.1. Electronic portal imaging device (EPID) – VARIAN aSi-1000 amorphous silicon panel

The VARIAN EPID aSi-1000 panel used in our assessment. Its effective measurement area was 40 × 30 cm^2 at SDD 100 cm, resulting in 1024 × 768 pixels image size with spatial resolution of 0.39 mm. The panel was mounted on an R-arm and exacted out when images were acquired. To ensure the correctness of the daily setup and repeatability of position accuracy for the panel, the researchers placed a mark on the EPID's top cover. The R-arm was extended so as to open a distance of 105 cm from source to detector. In regard to the daily photon output of the VARIAN 6EX which equipped with a 6 MV X-ray only. The study was designed to test the uniformity of intensity inside the 10 × 10 cm^2 field size, given a total delivery of 394 MU at a dose rate of 400 MU/min. The uniformity of intensity was measured using a portal dosimetry algorithm and the acquisition of an integrated image every morning for 165 working days. After acquisition, portal dosimetry was determined using a built-in portal dosimetry software function that read calibration unit (CU) values at the centre of the integrated image. The portal dosimetry is an algorithm that converts pixel value to CUs, and was developed for pre-treatment verification of IMRT (Sharma et al., 2010). After energy calibration, following the previous procedure, the measured CU value was used as the reference value for daily output consistency.

2.2. Film – calibration curve and daily exposure

Cutting an 8 × 10in EBT3 film into twenty pieces results in a useable area of 5 × 5 cm^2 per piece. Each piece was marked such that it could be kept in the same orientation during scanning. Film was irradiated by a 6 MV beam at source-at-axis distance (SAD) 100 cm and 5 cm depth in RW3 solid water phantom. For counting backscatter accurately, the area below the film had to contain 5 cm solid water. Six pieces of film were irradiated separately with six different dose levels, i.e., 50, 150, 300, 500, 600 and 800 cGy at a dose rate of 400 MU/min. The absolute dose associated with each dose level at the centre of the 10 × 10 cm^2 field was confirmed using an IBA FC-65p 0.6 c.c. ion chamber. After irradiation the film was stored for at least 24 h and scanned with an EPSON PERFECTION™ V750 PRO flat panel scanner afterwards. The scanning parameters were set to professional mode 48-bit colour (RGB) and 75 dpi (Matney et al., 2010). The region of interest selected was the centre 50 × 50-pixel area of the film, i.e., 2500 pixels of data in total. The calibration curve was built using the red channel, as a function of net optical density related to the dose. The analysis of film image conducted using imageJ version 1.47 open source software. The procedure and set-up condition used for daily exposures was same with that used in building the film calibration curve. The only one 500 cGy was delivered for daily.

2.3. Daily check device – BeamChecker plus

QA BeamChecker Plus, was manufactured by the Standard Imaging Company, is a commercial daily output check device with multiple detector channels. Inside the measurement plate there are eight ion chambers, and each detector is 1.4 cm in diameter with a volume of 0.6 cm^3. When BeamChecker Plus was used to check daily output consistency, the light field size was first opened to 20 × 20 cm^2 and the cross marker of the detector aligned with the crosshairs of the light field. The source-to-device surface distance (SSD) was 100 cm, and the total delivery was 200 MU at a dose rate of 500 MU/min. After measurement, the machine recorded the data immediately and plotted daily data using its own software. After monthly output calibration, BeamChecker Plus was used to acquire signal reference values for the daily checks.

2.4. Dosimetric characteristics

There are several factors of dosimetric characteristic for dosimeters should be exam. The factors included linearity, inverse square law, output factor (field size) and dose rate. The measuring condition of factors followed setting of output constancy for each dosimeter.

2.5. Statistics

For statistical analysis, these results were compared with the correlation (Pearson) and nonparametric correlation (Spearman) tests. The threshold p values < 0.05, with two tail, considered to be significant. All statistical analysis was performed using SPSS software Version 22.0 (SPSS Inc., Chicago, IL).