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Original research article

Commissioning and Acceptance Testing of the existing linear accelerator upgraded to volumetric modulated arc therapy

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A R T I C L E I N F O

Article history:
Received 13 December 2012
Received in revised form
17 April 2013
Accepted 8 July 2013

Keywords:
Volumetric modulated arc therapy
Dynamic MLC
EDR2 film
Film dosimetry
EPIQA
Portal dosimetry

A B S T R A C T

Aim: The RapidArc commissioning and Acceptance Testing program will test and ensure accuracy in DMLC position, precise dose-rate control during gantry rotation and accurate control of gantry speed.

Background: Recently, we have upgraded our linear accelerator capable of performing IMRT which was functional from 2007 with image guided RapidArc facility. The installation of VMAT in the existing linear accelerator is a tedious process which requires many quality assurance procedures before the proper commissioning of the facility and these procedures are discussed in this study.

Materials and methods: Output of the machine at different dose rates was measured to verify its consistency at different dose rates. Monitor and chamber linearity at different dose rates were checked. DMLC QA comprising of MLC transmission factor measurement and dosimetric leaf gap measurements were performed using $0.13\,cm^3$ and $0.65\,cm^3$ Farmer type ionization chamber, dose 1 dosimeter, and IAEA $30\,cm \times 30\,cm \times 30\,cm$ water phantom. Picket fence test, garden fence test, tests to check leaf positioning accuracy due to carriage movement, calibration of the leaves, leaf speed stability effects due to the acceleration and deceleration of leaves, accuracy and calibration of leaves in producing complex fields, effects of interleaf friction, etc. were verified using EDR2 therapy films, Vidar scanner, Omnipro accept software, amorphous silicon based electronic portal imaging device and EPIQA software.[1–8]

Results: All the DMLC related quality assurance tests were performed and evaluated by film dosimetry, portal dosimetry and EPIQA.[7]

Conclusion: Results confirmed that the linear accelerator is capable of performing accurate VMAT.

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http://dx.doi.org/10.1016/j.rpor.2013.07.008

1. Background

Our institute has been functional since 2007 with a Varian linear accelerator capable of performing IMRT with 6 and 15 MV photons. Recently, we have upgraded this existing linear accelerator with an Image guided RapidArc facility. RapidArc or volumetric modulated arc therapy is a novel treatment planning and delivery system that has recently been made available for clinical use.

The idea of using a traditional linear accelerator gantry for a rotational IMRT treatment was first suggested by Yu et al. in 1995 as an alternative to tomotherapy, which necessitated specialized equipment and struggled with abutment problems between treatment slices at that time. Yu's alternative was called intensity modulated arc therapy (IMAT) and utilized a large field size, traditional linear accelerator, continuous gantry rotation, and dynamic MLC. To create an intensity distribution, IMAT was delivered in multiple overlapping arcs. Each arc delivered only one level of intensity; therefore, multiple arcs were required for multiple levels of intensity. The two-dimensional intensity distribution at each angle was a composition of multiple radiation fields of uniform intensity with different shapes and sizes. Developments in rotational delivery capabilities of traditional linear accelerators in the last few years, specifically variable dose rate and variable gantry speed, have sparked a new interest in rotational IMRT delivery and IMAT. Volumetric modulated arc therapy (VMAT) has been developed using the basic principles of IMAT, coupled with these new machine capabilities.

VMAT offers potential dosimetric and efficiency advantages by being able to deliver modulated cone-beam radiation from a single or multiple arc. During a VMAT treatment, MLC leaves dynamically shape the beam to treat the entire volume of the planning target volume (PTV) with every rotation, and the dose rate and/or gantry rotation speed is continuously varied as the gantry of the linear accelerator rotates around the patient. Three key components of VMAT rotational delivery are dynamic MLC, variable dose rate and gantry speed. The MLC leaf speed is kept within a prespecified maximum tolerance of 2.5 cm/s during the optimization. The gantry speed is then maximized at 4.8°/s unless the required MU per degree exceeds the maximum dose rate of 400 MU/min, in which case the gantry slows down to accommodate the required MU/degree. VMAT treatments must use a dynamic MLC because the beam is on during the entire treatment as the gantry rotates around the patient. For VMAT treatment, the MLC leaves move as a function of gantry position, not time. The leaves reposition according to where the gantry is located in its rotation and each angle of rotation sees only one segment shaped by the MLC. In short, VMAT delivery combines varying leaf motion with varying dose rate and/or gantry rotation speed to modulate beam intensity.[1–6]

The introduction of advanced irradiation techniques into a radiotherapy clinic requires extensive dose verification measures that go beyond current routine clinical practice. Amorphous silicon electronic portal imaging devices (*a*-Si EPIDs) were originally designed for patient set-up verification; however, their use has been extended to dose verification over the past few years, since portal images also contain dosimetric information. EPID can be a powerful tool in the reduction of treatment setup errors and the quality assurance and verification of complex treatments. Film imaging is time consuming and labor intensive.

Portal imaging systems are therefore developed to provide both geometrical and dosimetric information. Compared to previous systems, the amorphous silicon-based EPID provides better quality portal images. The aS500 EPID consists of a 1 mm Cu top plate, a 0.3 mm Gd oxysulphide phosphor screen, and a 0.18 mm polyester reflector as an active element. The light generated in the scintillator is detected by a 40,330 cm^2 (512 × 384 pixel, 0.78 mm × 0.78 mm pixel pitch) array of amorphous-Si photodiodes. Each diode is connected to a thin-film transistor and can be read out separately. The image acquisition system acquires images by scanning each row of the detectors sequentially. By averaging a large number of frames, an EPID can continuously scan the matrix of silicon detectors during the irradiation of a field, sum all acquired frames and send an averaged image to the console computer upon completion of radiation delivery. A separate dose image prediction algorithm Portal Dosimetry Image Prediction (PDIP) is part of the Eclipse Treatment Planning System. It converts the pixel data to absolute dose.[8–11]

Several studies of dose–response characteristics have shown that *a*-Si EPIDs are suitable for dose verification. These studies have shown that the pixel signal is approximately linear with dose and can be converted to absolute dose by measuring the response over a wide range of parameters. In addition, the response of the *a*-Si EPID is stable within ±0.5% over long periods, up to at least 2 years, provided there are no electronic failures. EPID measurements are simple to perform with minimum set-up requirements, they can be repeated easily and digital data is obtained immediately, unlike films which require additional time for developing and digitizing. Once an EPID is calibrated for a certain linac and energy, EPID images can be immediately converted to absolute dose images, whereas each film batch requires a new calibration, involving additional measurements. So, we did all the 2D fluence measurements on film as well as the EPID, so that once we finished calibrating, we could use EPID for regular quality assurance of VMAT.

Epiqa is a program that allows to convert a dosimetric image acquired by an EPID into a dose map and to compare the dose map with a reference dose distribution. It is possible to utilize Epiqa for verification of static as well as intensity modulated fields, including RapidArc® fields. The portal dosimetry image conversion to dose map is based on the GLAaS algorithm – an absolute dose calibration algorithm for an amorphous silicon portal imager. The verification with EPIQA helps us to cross check the PDIP measurements.[7–11]

2. Aim of the study

In VMAT, there are three interrelated machine parameters that are allowed to vary: the MLC leaf speed, the gantry speed and the dose rate. The installation of VMAT in the existing linear accelerator is a tedious process which requires many quality assurance procedures before a proper commissioning of the facility. For RapidArc, gantry was calibrated for continuous