REPORTS OF PRACTICAL ONCOLOGY AND RADIOTHERAPY 23 (2018) 242–250

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.elsevier.com/locate/rpor

Original research article

Absolute dose verification of static intensity modulated radiation therapy (IMRT) with ion chambers of various volumes and TLD detectors

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ARTICLE INFO

Article history:
Received 10 October 2016
Received in revised form
12 January 2018
Accepted 8 April 2018

Keywords:
IMRT
Absolute dose
TLD
Ion chamber

ABSTRACT

Aim: This study aims at examining absolute dose verification of step-and-shoot intensity modulated radiation treatment (IMRT) of prostate and brain patients by use of ion chambers of two different volumes and thermoluminescent detectors (TLD).

Background: The volume of the ion chamber (IC) is very important for absolute dose verification of IMRT plans since the IC has a volume average effect. With TLD detectors absolute dose verification can be done measuring the dose of multiple points simultaneously.

Materials and methods: Ion chambers FC65-P of volume 0.65 cc and semiflex of volume 0.125 cc as well as TLDs were used to measure the central axis absolute dose of IMRT quality assurance (QA) plans. The results were compared with doses calculated by a treatment planning system (TPS). The absolute doses of off axis points located 2 cm and 4 cm away from the isocenter were measured with TLDs.

Results: The measurements of the 0.125 cc ion chamber were found to be closer to TPS calculations compared to the 0.65 cc ion chamber, for both patient groups. For both groups the root mean square (RMS) differences between doses of the TPS and the TLD detectors are within 3.0% for the central axis and points 2 cm away from the isocenter of each axis. Larger deviations were found at the field edges, which have steep dose gradient.

Conclusions: The 0.125 cc ion chamber measures the absolute dose of the isocenter more accurately compared to the 0.65 cc chamber. TLDs have good accuracy (within 3.0%) for absolute dose measurements of in-field points.

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https://doi.org/10.1016/j.rpor.2018.04.001

1. Background

IMRT provides dose distribution conforming to target volumes with complex geometries, by modulating beam intensities. The use of IMRT has been very useful for optimizing radiotherapy treatment by increasing the dose to the target volume and reducing it to the surrounding healthy tissues. The conformal dose distribution is obtained by use of multileaf collimators (MLC) located in the head of the linear accelerator (linac). Contrary to conformal radiotherapy (3D-CRT), the dose intensity of each IMRT field is changed in a complex way. There are two main types of IMRT; static (or step-and-shoot) and dynamic. With the static IMRT technique, modulated beams are obtained by use of multiple subfields (segments) with different shapes and intensities, whereas in dynamic IMRT such beams are obtained by modulation of leaf velocities while the beam intensity is constant.[1] Due to the complexity of both IMRT techniques, dosimetric verification of patient-specific IMRT plans has become necessary.[2] A quality assurance process for IMRT plans is typically carried out through verification of both the absolute dose given to the reference point and the two dimensional (2D) planar isodose distributions.[2,3]

Verification of IMRT dose distribution is a relative evaluation and has to be done with suitable two dimensional dosimeters, such as 2D array matrix detectors and films. Commercial array detectors consist of ICs or diodes. The 2D array detectors have advantages such as time saving, easy setup and direct readout of results. However 2D array detectors have low spatial resolution (usually > 7 mm) and this limits their usage for initial commissioning of IMRT QA. Dosimeters with high resolution such as radiographic or radiochromic films have to be used for QA of pre commissioned IMRT.[4] Earlier studies have investigated some properties of diode and chamber arrays such as linearity, reproducibility, output factors and dose rate dependence and reported that these arrays could be used for the measurement of fluence maps in IMRT plan verification.[5,6] Both types of array dosimeters have previously been examined for use in verification of IMRT fields.[7,8] By using 2D array detectors, each non uniform field in the IMRT plan can be measured either separately or superposed.

The planar dose validation can be carried out with radiochromic EBT or radiographic Kodak XV2 and EDR 2 films. Compared to array systems, film dosimetry has the advantage of high spatial resolution but at the same time has a disadvantage in terms of time consumption. The characteristics of Kodak XV2 and EDR2 films for verification of IMRT dose distribution have previously been examined. It was concluded that both could be used.[9–11] Use of radiochromic films has increased, since they are almost tissue equivalent and do not require processing in order to acquire optical density. Gafchromic EBT, EBT2 and EBT3 have been used in order to evaluate their characteristics for patient specific QA in different cases.[12–14] However, neither Radiochromic nor Gafchromic films should be used for absolute dose verification of IMRT fields.[4]

Although absolute dose verification of the reference point can be performed with different kinds of detectors such as ICs, semiconductor detectors, TLDs, and MOSFET,[15] IC detectors are still the ones used most often for this purpose.[16] In the static IMRT technique, each intensity modulated beam consists of small subfields (beamlets or segments) in order to obtain a non-uniform dose distribution, which can have an area as large as $1 \times 1\,cm^2$. Therefore ICs with small volumes should be used especially when carrying out absolute dose measurements of small fields. Leybovich et al. reported that both 0.6 and 0.125 cc ICs can be used for absolute dose measurements for the step-and-shoot IMRT without any leakage correction.[17] TLD detectors can be used to measure the absolute doses of multiple points simultaneously and when the phantom geometry is not suitable for insertion of an IC.[4] Davidson et al. compared IMRT doses calculated by two different heterogeneity calculation algorithms of the Pinnacle TPS with doses measured with TLD-100 LiF: Mg, Ti powder. TLD powder capsules were placed into the IMRT anthropomorphic phantom in order to measure absolute dose values of contoured structures like PTV and OAR.[18] Kry et al. used TLD-100 powder capsules, inserted into an Imaging and Radiation Oncology Core (IROC)-Houston head and neck phantom, to investigate the dosimetric accuracy of the patient specific IMRT QA. They took into account the volume of the TLD capsules and compared the measured dose with the dose of the corresponding volume of interest in the TPS.[19]

2. Aim

The purpose of this study is to investigate the absolute dose verification of step-and-shoot IMRT plans for brain and prostate cases, which have different number of segments, by use of ICs of different volumes and TLD detectors.

3. Materials and methods

3.1. *IMRT treatment planning and QA plans*

Eight prostates and seven brain IMRT plans were selected for this study. Target volumes and healthy tissues for each patient group were contoured according to ICRU 62[20] by two different radiation oncologists. IMRT plans were obtained with the step-and-shoot technique from a CMS Xio TPS (Computerized Medical Systems, St. Louis, MO, USA) using an inverse planning optimization. All optimization procedures associated to doses were done with this algorithm except from the delineation of energy, gantry angles and number of beams, which were user-defined. Both IMRT groups were planned with 6 MV photon energy in a supine position. All prostate and brain cases were planned with a seven field configuration (gantry angles: 0, 45, 90, 135, 225, 270 and 315°) and five coplanar beams (gantry angles changes depending on the location, size and shape of the target volume) on a Siemens Oncor linac (Siemens Medical Solutions, Concord, CA, USA). Doses of approximately 75 Gy/25 fractions and 54 Gy/27 fractions were determined for prostate[21] and brain[22] cases respectively. With the step-and-shoot IMRT technique, subfields (segments) can have small monitor unit (MU) values depending on the inverse treatment plane optimization procedure and the algorithm of the TPS. Therefore, MU values must be checked before inverse planning. Monitor unit stability of the linac, regarding absolute dose, should be established before producing IMRT