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EPID in vivo dosimetry in RapidArc technique

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ABSTRACT

Aim: The aim of the study was to estimate the dose at the reference point applying an aSi-EPID device in the course of patient treatment.

Materials and methods: The method assumes direct proportionality between EPID signal and dose delivered to the patient reference point during the treatment session. The procedure consists of treatment plan calculation for the actual patient in the arc technique. The plan was realized with an elliptic water-equivalent phantom. An ionization chamber inside the phantom measured the dose delivered to the reference point. Simultaneously, the EPID matrix measured the CU distribution. EPID signal was also registered during patient irradiation with the same treatment plan. The formula for in vivo dose calculation was based on the CU(g) function, EPID signal registered during therapy and the relation between the dose and EPID signal level measured for the phantom. In vivo dose was compared with dose planned with the treatment planning system.

Irradiation was performed with a Clinac accelerator by Varian Medical Systems in the RapidArc technique. The Clinac was equipped with an EPID matrix (electronic portal image device) of aSi-1000. Treatment plans were calculated with the Eclipse/Helios system. The phantom was a Scanditronix/Wellhöfer Slab phantom, and the ionization chamber was a 0.6 ccm PTW chamber.

Results: In vivo dose calculations were performed for five patients. Planned dose at the reference point was 2 Gy for each treatment plan. Mean in vivo dose was in the range of 1.96–2.09.

Conclusions: Our method was shown to be appropriate for in vivo dose evaluation in the RapidArc technique.

1. Introduction

Verification of dynamic methods in radiotherapy (RT) is a critical step in medical physicist practice. Despite many available methods, dose verification in dynamic techniques presents a challenge to the quality assurance team.

The present range of verification methods in intensity modulated radiotherapy (IMRT) allows one to perform pretreatment dose control rather than in vivo dosimetry.

The methods individually are insufficient to assure accurate dose delivery verification.[1]

Traditional treatment verification can be done by single-point measurement in a phantom. Additionally, dose

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distribution control can be accomplished by testing of agreement between calculated and measured dose distribution in corresponding planes. For this purpose largely utilized are amorphous silicon electronic portal imaging devices (aSi-EPID).[2–9]

Although acquisition of a fluence map itself does not provide absolute dose measurements, it is capable of providing relative dose measurement. Correlation of the portal dosimetry and ion chamber dosimetry enables precise determination of the dose. For in vivo dosimetry purposes, dosimetric properties of EPID and point dose measurement worked together are used. Namely, the image from the EPID can be converted into the absolute dose.[10]

Characteristics of aSi-EPID and its usefulness for IMRT dosimetric purposes have been quite extensively discussed. Linearity of dose response, field size dependence and independence on beam energy have been proven.[3–7,9,11,12]

A novel solution of dose delivery is offered in the RapidArc technique. It is an extension of IMRT, where the dose is optimized during inverse planning and then realized in a single dynamically modulated arc. While the gantry is rotating, MLC leaves are moved, modulating dose distribution continuously.[10,13] This new modality demands a reliable form of verification process. Therefore substantial questions are: is RapidArc a safe delivery method, and what approach is required for RapidArc IMRT delivery verification?

According to the preliminary reports RapidArc is an appropriate technique in some tumour locations and increases flexibility in generating highly conformal treatment. Reducing the overall treatment time, increased conformity and organs at risk (OARs) sparing are mostly emphasized.[14–19] The first reports on dose verification indicate auspicious abilities of portal dosimetry conducted for RapidArc fields.[10,13]

In this paper the authors have tried to demonstrate the usefulness of aSi-EPID for RapidArc dosimetric verification.

The signal detected by EPID is expressed in calibration units (CU).[4,12,20] First, the relation between the signal and the dose delivered from the photon beam was measured. The signal was registered with the presence of an absorbent (layers of the phantom). The number of CU was described as a function of the absorbent thickness, located between the source and the EPID cassette. These data were then used for assessment of the dose absorbed in patient tissues. In order to do that, an assumption was made that there is proportionality of the EPID signal measured during the treatment session and the dose absorbed in the patient's body.

Plans calculated for the patients are transferred to the phantom shape and realized in accordance with calculated geometry. During the gantry rotation the EPID signal is acquired and the absolute dose at the reference point in the phantom is measured using the ion chamber. Then the patient is irradiated with EPID signal acquisition simultaneously. The concept of dose determination in the patient is based on the following issues that need to be considered: (i) the dependence between EPID signal and absorbing layers' thickness, (ii) the relationship between dose measured by the ion chamber in the phantom and EPID signal, and finally (iii) EPID signal measured during patient treatment session. These three elements allow one to carry out in vivo dosimetry with the help of a portal cassette.

The aim of the study was to estimate the dose at the reference point (in the patient's body) applying the aSi-EPID device in the course of patient treatment with the RapidArc technique.

2. Materials and methods

Our method enables us to perform in vivo dosimetry in the RapidArc radiotherapy technique. In general, in vivo dosimetry in teleradiotherapy is performed indirectly, with detectors located on the body surface. In our study an EPID cassette was used to evaluate the dose delivered to a specific point located in the patient's body (reference point) during arc therapy. The experiment of in vivo dose evaluation was performed in three steps. First, the dosimetric characteristic of the EPID detectors was estimated; then, the relation between the absolute dose measured with the ion chamber in a water-equivalent phantom and EPID signal registered during phantom irradiation was evaluated; and finally, the EPID signal was measured during an actual radiotherapy session. The analysis of the measured quantities led to the formula for calculation of the in vivo dose delivered during treatment.

2.1. *EPID dosimetry—basic assumptions*

In this part of the experiment we tested the linear relation between treatment time, dose at the reference point and EPID signal. We also measured the EPID signal's dependence on the thickness of absorbent located between the source and the detector's matrix.

In our experiment we assumed that the dose at point P (the reference point) located inside the patient's body is directly proportional to the number of monitor units (MU) and calibration units (CU—the level of the EPID signal) (Fig. 1).

This assumption is valid only for a homogeneous density of the irradiated volume. The patient's body consists of different tissue types of varied density. However, assuming that the gantry and EPID cassette make a 360-degree turn on the accelerator axis we may approximate that density of the patient's body is homogeneous. The in vivo dosimetry method reported in this paper can be applied under the condition that the treatment plan is realized in one 360-degree turn. During the entire gantry rotation each point in the patient is located between the EPID and the reference point (Fig. 2).

In vivo dosimetry and dose calculations with the portal cassette require knowledge of the dosimetric characteristics of the EPID detectors. Therefore, the actual experiment was preceded with measurement of the EPID signal as a function of MU and irradiation field size. EPID signal was found to be directly proportional to MU number for different field sizes and for different photon energies.[12] The graph shown in Fig. 1 presents the linear relation between MU and CU.

2.2. *EPID signal dependence on the absorbent thickness*

The EPID signal depends on the monitor unit and is also correlated with the radiation absorption in the patient's body. To apply the EPID for in vivo dosimetry we need to test the