

Epid cine acquisition mode for in vivo dosimetry in dynamic arc radiation therapy

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Abstract

In this paper the cine acquisition mode of an electronic portal imaging device (EPID) has been calibrated and tested to determine the in vivo dose for dynamic conformal arc radiation therapy (DCAT). The EPID cine acquisition mode, that allows a frame acquisition rate of one image every 1.66 s, was studied with a monitor unit rate equal to 100 UM/min. In these conditions good signal stability, $\pm 1\%$ (2SD) evaluated during three months, signal reproducibility within $\pm 0.8\%$ (2SD) and linearity with dose and dose rate within $\pm 1\%$ (2SD) were obtained.

The transit signal, S_t , (due to the transmitted beam below the phantom) measured by the EPID cine acquisition mode was used to determine, (i) a set of correlation functions, $F(w, L)$, defined as the ratio between S_t and the dose at half thickness, D_m , measured in solid water phantoms of different thicknesses, w and with square fields of side L , (ii) a set of factors, $f(d, L)$, that take into account the different X-ray scatter contribution from the phantom to the S_t signal as a function of the variation, d , of the air gap between the phantom and the EPID. The reconstruction of the isocenter dose, D_{iso} , for DCAT was obtained convolving the transit signal values, obtained at different gantry angles, with the respective reconstruction factors determined by a house-made software. The method was tested with cylindrical and anthropomorphic phantoms and the results show that the reconstructed D_{iso} values can be obtained with an accuracy within $\pm 2.5\%$ in cylindrical phantom and within $\pm 3.4\%$ for anthropomorphic phantom.

In conclusion, the transit dosimetry by EPID was assessed to be adequate to perform DCAT in vivo dosimetry, that is not realizable with the other traditional techniques. Moreover, the method proposed here could be implemented to supply in vivo dose values in real time.

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1. Introduction

Based on the steepness of the dose-response relations, both for local tumor control and for normal tissue compli-

cations, a number of groups has formulated an accuracy requirement of 4%, one standard deviation (1 SD), in the absorbed dose delivery [1,2] for radiotherapy in daily clinical practice. However, systematic errors in dose delivery for an individual patient can arise due to the influence of the modification of patient's contour, mobility of the patient, tissue inhomogeneities and internal organ motion

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[3–6]. Therefore, it is recommended by several national and international organizations [7–9] that in vivo dose measurements should be made.

Electronic portal imaging devices (EPIDs) have been developed to provide visual inspection of the target volume [10]. However, nowadays an increased interest is in using EPIDs for dosimetric applications such as pre-treatment fluence verification for intensity modulated radiation therapy (IMRT) [11–13], transit dosimetry [14–16], portal dose verification during treatment [17–21] and 3D dose reconstruction [22,23].

Several different EPID systems have been utilized, including scanning liquid ion-chambers, CCD-based camera systems and amorphous silicon (a-Si) flat-panel detectors [3,12,21–27].

The a-Si EPID has shown good characteristics for dosimetric purpose, it has a linear response to dose and dose rate, it is stable with time [28], it can acquire images in real-time at a high frame rate and it was also demonstrated that the a-Si EPID signal can be calibrated in terms of absolute absorbed dose [29].

In the field of the transit dosimetry using EPIDs, Pasma et al. [14] presented a simple method to verify the calculated number of MU for a treatment beam. For each beam, the measured portal dose D_p is used to derive the corresponding on-axis patient dose at 5 cm depth D_5 , which is then compared with the predicted dose as determined with the relative dose distribution calculated by the Treatment Planning System (TPS).

Boellaard et al. [3] derived midplane dose distributions (2D) from measured portal dose images (PDIs). Their method did not require Computed Tomography (CT) data; the radiological thickness of the patient is determined from the ratio of a PDI acquired with and without the patient in the beam. Besides requiring an extra EPID measurement for each field, this method has the drawback that it assumes inhomogeneities to be symmetrically positioned with respect to the patient's midplane.

Piermattei et al. [15] proposed a method for the in vivo determination of the isocenter dose, D_{iso} and mid-plane dose, D_m , that uses the transmitted signal, S_t , measured by the dosimetric acquisition mode of an aSi-based EPID and the CT scan, needed to determine the water equivalent thickness of the patient. This method has been applied for static beams to check the conformal radiotherapy of pelvic tumors and it allowed to point out disagreements between stated and measured doses higher than $\pm 4\%$.

Because of the good results obtained by Piermattei et al. [15], in the present paper the same method has been applied to the D_{iso} determination of dynamic conformal arc therapy (DCAT) technique [30] by using the signal S_t obtained by the EPID cine acquisition mode that supplies one image every 1.66 s during the treatment. In particular a dosimetric characterization of the cine acquisition mode in terms of signal stability and reproducibility, signal linearity with dose, dose rate and arc length, was performed for a Varian a-Si EPID. A house-made software allowed the use of the

images acquired by the cine acquisition mode for the in vivo determination of the D_{iso} values. Finally the method was tested for DCAT with cylindrical and anthropomorphic phantoms.

2. Material and methods

2.1. The therapy unit

The measurements were performed by using a linear accelerator (Linac) Clinac 2100/CD Varian (Varian Medical System, Milpitas, CA, USA) that can supply 6 MV and 15 MV X-ray beams. The linac is equipped with a multi leaf collimator and an a-Si EPID (aS500, Varian Medical Systems) that can rotate around the patient together with the linac gantry (Fig. 1).

The linac supplies pulsed radiation beams with pulse duration equal to 4 μ s and pulse frequencies between 60 Hz and 360 Hz that correspond to Monitor Unit (MU) rates between 100 and 600 MU/min. The MUs are proportional to the signal measured by an ion-chamber positioned at the beam exit window in the linac gantry. Setting a number of MUs at the linac console, allows the linac to supply an amount of radiation corresponding to a given signal of the linac ion-chamber after which the beam is turned off automatically. Therefore, the MUs are generally calibrated to have a reproducible dose to water per MU at a reference point in water phantom that cannot be obtained by selecting only an irradiation time.

The Clinac 2100/CD can supply radiation beams in Static Irradiation Mode (SIM) and in Dynamic Irradiation Mode (DIM). In SIM the beam is delivered with the gantry of the linac head positioned at a fixed angle with respect to the vertical position, in DIM the beam is delivered during the gantry rotation around a point called isocenter that is positioned at 100 cm from the source.

The DIM has a maximum gantry angular speed, ω , equal to 5°/s. Therefore, if the selected MU, gantry arc and rate of MU require ω greater than 5°/s, the linac sys-

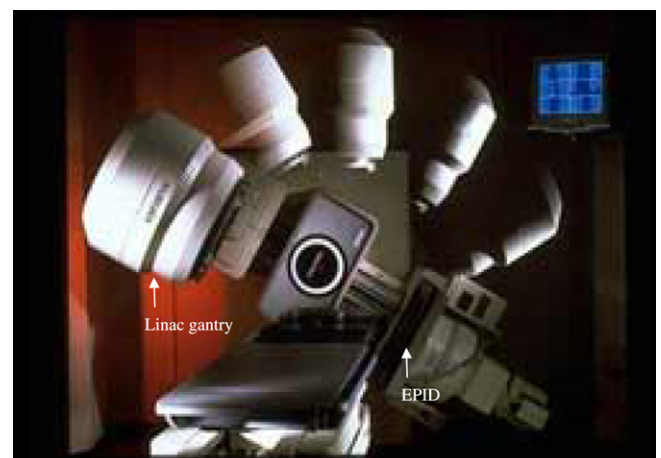


Fig. 1. Linac gantry and EPID rotation during a dynamic irradiation.

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