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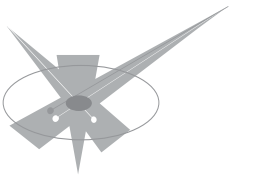

Original Paper

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EPID dosimetry – configuration and pre-treatment IMRT verification

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Aleksandra Grządziel[ABCDEFG], Barbara Smolińska[BE], Roman Rutkowski[B], Krzysztof Ślosarek[AC]

Radiotherapy and Brachytherapy Planning Department, Centre of Oncology – Maria Skłodowska Curie Memorial Institute, Branch in Gliwice, Gliwice, Poland

Summary

Background The electronic portal imaging device (EPID) is used for patient setup during radiotherapy sessions. Dosimetric verification is done using ion chambers, diodes and thermoluminescence detectors. In intensity-modulated radiation therapy (IMRT) the dosimetry is a sophisticated and time-consuming task. The simultaneous use of amorphous silicon (aSi) detectors and the transit dosimetry (TD) option in the treatment planning system (TPS) (Eclipse, Varian) enables dosimetric pre-treatment verification of the IMRT plans.

Aim The purpose of this study was to calibrate the EPID and TPS and to evaluate the usefulness of that method for dose verification in IMRT technique.

Materials/Methods The first step was calibration of the aSi EPID mounted on three linear accelerators (Clianc23EXS, Varian). Afterwards, configuration of the calculation algorithm in TPS was carried out.

Then dosimetric characteristics of the EPID were investigated. The EPID response depending on the beam mode, treatment time and static square field size was measured. The same measurements were repeated twice for three accelerators and analyzed.

Additionally, three IMRT plans were treated for the pre-treatment dose evaluation. The calculated dose matrix was compared with the delivered one. The similarity of the calculated and measured fluency maps was evaluated by means of gamma index and score factor in Eclipse.

Results The linearity of the EPID signal was proven. For both beam modes EPID response is proportional to treatment time and field size, within the considered field size range.

Conclusions The gamma evaluation indicates good correlation between predicted and acquired EPID image, although some differences in a high gradient area were found. We found the EPID-based pre-treatment IMRT verification method to be a good quality assurance (QA) procedure. Quite frequent control of the method and periodic recalibration of the used device are required.

Key words IMRT • aSI EPID • treatment plan verification • QA

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Author's address: Aleksandra Grządziel, Centrum Onkologii – Instytut im. M. Skłodowskiej-Curie, Oddział w Gliwicach, Zakład Planowania Radioterapii i Brachyterapii, Wybrzeże A.K. 15, 44-101 Gliwice, Polska, e-mail: alexag@io.gliwice.pl

Background

The quality assurance (QA) procedure in radiotherapy generally demands dose measurement as well as patient positioning check. In conventional techniques the dosimetric verification is based on well-tried methods carried out mostly during treatment sessions. For that, ion chambers, diodes or thermoluminescence detectors are routinely used. At the same time, the electronic portal imaging device (EPID) used on the accelerator is utilized for visualization and patient setup check. Another approach is required for IMRT delivery. Mostly plan verification is made in the phantom before real patient irradiation [1–4]. The complexity of IMRT plans and non-uniform dose distribution caused a new effective and reliable form of plan verification to be sought. In order to achieve that the application of EPID was extended [5–7]. Additionally, the implementation of new amorphous silicon (aSi) detectors and transit dosimetry (TD) in the treatment planning system (TPS) allowed verification methods to be developed. Due to both tools working together there is a possibility to predict dose matrix and to detect dose matrix delivered during irradiation. There are an increasing number of publications on aSi EPID detectors and their dosimetry applications. The literature reports good digital image quality, shorter exposure time and dosimetric properties of aSi EPID [8–18].

In this study, first the calibration problems of the method with regard to different kinds of device components are described. Also the dosimetric features of the detector, such as linearity, field size dependence, accuracy and reproducibility discussed in the literature were investigated [8,12,13,16,17].

Finally, the last part of the study focuses on IMRT plan verification. A first clinical application is discussed. Examples of three selected plans with a dynamic multileaf collimator (dMLC) are used to demonstrate the facility of the method.

Contemporary commercially available software enables comprehensive analysis of the acquired data. So, the predicted dose represented by a calculated fluency map can be quantitatively compared with the corresponding acquired dose – real fluency map. Dose evaluation can be made by dose matrix comparison with isodose delineation, point dose and profile measurements or gamma index calculation [19,20]. Individual criteria for plan evaluation can be defined depending on the clinical case.

Aim

The aim of the present study was to calibrate the aSiEPID devices and TPS calculation algorithm for IMRT dose prediction and measurement. The second aim was to evaluate dosimetric properties of aSiEPID and the usefulness of that method for dose verification in IMRT technique.

Materials and Methods

Dosimetric tools calibration

The EPID system consists of an image detector unit (IDU), image acquisition system (IAS) and PortalVision workstation. The IAS electronics and interface read out and store data from the IDU. The IDU is an array of photodiodes with a scintillating layer above [8,21].

Calibration was executed for EPID type aS500, two types of IAS: IAS2 and IAS3, and two types of mechanical portal imager arms: RArm and EArm. The following three device sets were tested:
- A: Clinac23EXS-IAS2-aS500-RArm,
- B: Clinac23EXS-IAS2-aS500-EArm,
- C: Clinac23EXS-IAS3-aS500-EArm.

The machine named "A" is equipped with an 80-leaf dMLC while "B" and "C" are 120-leaf dMLC machines.

Within the calibration process a mechanical cassette adjustment due to the isocenter of the

accelerator was done. Next image calibration was performed. As part of that, the dark field and flood field had to be taken and beam profile correction of the signal was made. The next step was configuration of a calculation algorithm for dose prediction. In order to do that, the sequence of measurements and calculations precisely determined by the manufacturer was made [8,21]. As a result of the calibration the predicted and measured fluency map can be expressed in calibrated units (CU).

The essentials of EPID-based dosimetry are the accuracy of the imager calibration and the calculation algorithm. Any inaccuracy in that process could lead to inconsistency between the predicted and measured dose.

Linearity of response

The measurements of dose response were performed for two photon beam energy modes, 6MV and 20MV, at source-portal surface distance (SSD) of 105cm. This distance is recommended by the manufacturer. The portal cassette was irradiated with 7 field sizes, 3×3cm, 5×5cm, 7×7cm, 10×10cm, 15×15cm, 20×20cm, 30×30cm, with different monitor units (MU): 2, 3, 4, 5, 8, 10, 50, 100, 150 200, 250, 300MU. The clinical routine accelerator mode 300MU/min was set up. Accelerator mode corresponds to dose rate defined in reference conditions. With the following parameters the dose rate of 1Gy/min is represented: 300MU/min accelerator mode, at 5cm depth, 10cm square field size and SSD of 100cm. The same measurements were performed three times with the same conditions on three machines. The data obtained in this manner were collected and the mean value of the EPID signal was calculated.

Field size dependence

For the second test, the dependence of the portal dose as a function of field size was evaluated. The applied SSD and dose rate were 105cm and 300MU/min respectively. Again both photon beam energies and three accelerators were investigated. A square field size ranging from 3×3cm to 30×30cm was tested. Measurements in the range of 2 to 300 MU were performed. Mean detector readouts for 6MV and 20MV for all machines were also calculated.

The stability of the imaging device and reproducibility were evaluated when the above test was made. The linearity and field size dependence were assessed over three sessions during 4 months.

Portal dose prediction

Pre-treatment verification was performed in 15 head and neck cancer patients. For all of them two kinds of plans were evaluated: large fields and boost. In order to assess these treatment plans, the delivered dose distribution was compared to that predicted by the TPS. For presentation 3 cases were used. In the first patient 14 large fields and 6 boost fields were assessed, in the second patient 14 and 8, while in the third patient 10 and 6 fields respectively were analyzed.

In these measurements, the detector was positioned at SSD=105cm. The data were acquired at 0° gantry position and 0° collimator position. The dose rate used in measurements was 300MU/min.

The accuracy of delivered fluency maps versus those generated in TPS was assessed by mean of gamma index and score calculated in TPS too. The score is an overall result of gamma evaluation of the image. The criteria of gamma evaluation (dose difference of 3% and distance-to-agreement (DTA) of 2mm) were set on the basis of clinical experience and publication data [2,8,19,20,]. In the literature, one can mostly find values of 3% and 3mm respectively. In the present study, a lower value of 2mm was used to provide even more restrictive plan evaluation, which is demanded in IMRT techniques. Additionally the overall score considering whole portal image pixels was taken into assessment.

RESULTS

Linearity of response

Figure 1 shows the average EPID signal as a function of irradiation time measured for machine "B". The linear response was observed over the measured irradiation time range from 2 to 300MU for three tested accelerators. The methodological error is ±0.001CU. For presentation, only results measured for 3×3cm, 10×10cm and 30×30cm were chosen. The same linearity was observed for the other analyzed fields.

Higher uncertainties in the measured signals were found for the bigger field sizes rather than for the small fields and more for shorter irradiation times than for long ones. The highest error

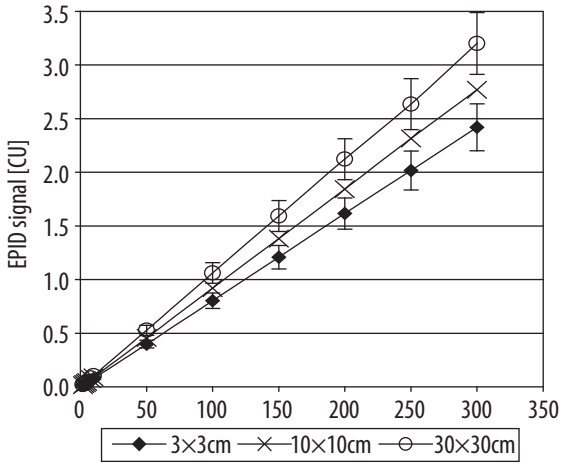

Figure 1. EPID response – function of dose for different square field sizes, averaged for three measurements performed for machine "B". Data acquired at 6MV. Data acquired at 20MV represent the same values in the range of measurement error 9%. CU – calibration unit, MU – monitor unit.

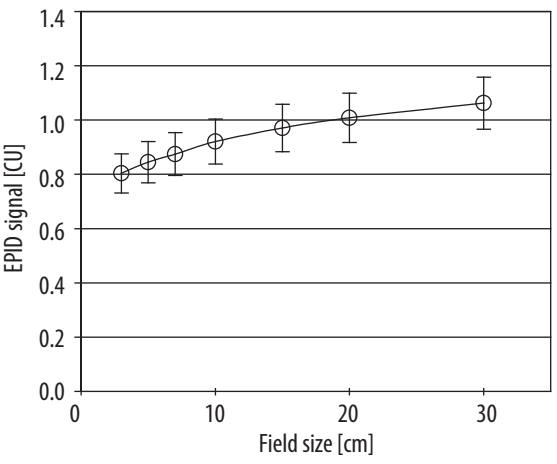

Figure 2. EPID response – function of field size. Measurements performed on machine "B" for irradiation time 100MU, averaged over three sessions. Data acquired at 6MV. Data acquired at 20MV represent the same values in the range of measurement error 9%. CU – calibration unit, MU – monitor unit.

value of 9.0% was achieved at 20MV on machine "B". For the others the error is lower: 6.7% for machine "A" and 8.3% for machine "C". In this work the highest maximal error value over three sessions of 9% for machine "B" was established as the measurements error for all machines.

In parallel, in the course of these tests the independence of beam energy was proven. This is consistent with results reported in the literature [8,16].

Field size dependence

The field size dependence is given in Figure 2. The results for machine "B" were chosen for presentation. For illustration data obtained for 100MU were selected. The EPID signal is proportional to field size within the considered field size range from 3×3cm to 30×30 cm. These results can be observed for both analyzed energies.

Analogically to signal linearity, when comparing the field size dependence over three measurements, discrepancies of about 9.0% were found.

The extensional functions were fitted to the measured data. The mean fit index (R^2) is over 0.986 for all evaluated energies and accelerators.

Portal dose prediction

308 fields (30 treatment plans, 2 plans per patient) for 15 head and neck cases were evaluated. The obtained data were grouped into two categories: large fields and boost. Average gamma index and the overall image score were analyzed. The analysis was based on the criterion of both 3% dose difference and 2mm distance difference. Good results are represented by low value of average gamma (close to zero value) and high value of score (close to unity). For each case the mean values of average gamma index and score were calculated in two categories. For presentation three patients were chosen. The obtained results of a dosimetry evaluation for 6 treatment plans are given in Table 1. This table contains only mentioned mean values. Table 1 generally shows good agreement between measured and calculated dose distribution found in both categories. The data achieved for the large fields suggest that in all cases the correspondence between delivered and predicted dose is slightly worse in that category than in boost. The mean gamma values in large fields are within the range of 0.212 to 0.484. In the boost category, mean gamma values fluctuate between 0.084 and 0.273.

The best result over 15 patients was achieved in the boost category. It is 0.084. The corresponding mean score value is 0.998. The highest obtained mean gamma value is 0.484 in large fields. It corresponds with a mean score value of 0.961.

Discussion

Since the first use of the flat panel detector, increased use of the amorphous silicon EPID as a

Table 1. Dosimetry evaluation in three IMRT head and neck plans.

Patient number	Field category	Mean average gamma	Mean score
1st	Large fields	0.259	0.953
	Boost	0.114	0.976
2nd	Large fields	0.305	0.934
	Boost	0.220	0.965
3rd	Large fields	0.405	0.915
	Boost	0.193	0.982

dosimetric tool is reported. Nowadays it is obvious that aSi-based EPID has not only good features serving portal imaging but also IMRT verification.

The similarity between the results of our work and those from previous publications has been shown [8,12,13,16,17]. In the present study the data demonstrate that the signal response is linear with exposure time and proportional to open field size. It should be emphasized that the measurements show similar behaviour for different energy modes – results do not depend on photon energy. Moreover, the presented results do not deviate significantly for accelerators that are equipped with almost identical yet different imaging devices. However, the maximal measurement deviation of about 9% was detected in the course of three sessions with several-week intervals. In another publications lower detector reproducibility (e.g. 1%, 2% or 4%) was reported [8–10]. This suggests that frequent and conscientious dosimetric calibration is required.

IMRT plans can be evaluated with the help of portal dosimetry. Considering the results of pre-treatment plan verification we conclude that the obtained dose differences are dependent on field size category. The large field treatment plans were clearly treated with higher uncertainty than small fields. This may be caused by the fact that there are local high gradient spots more often than in boost. Some authors emphasize that maximum error increases linearly with leaf speed [17].

With the aim of daily IMRT plans control improvement, the mean values of average gamma and score index were calculated for each field category. More advanced statistical methods will be used in subsequent works which are under preparation. The present study shows the first results and preliminary analysis after a short time of experience with the system. In future, with a growing number of verified plans, clear criteria for IMRT plan acceptance should be established.

In this work the pre-treatment plan verification procedure is described. This method is carried out before patient treatment sessions. Nowadays *in vivo* EPID dosimetry is possible too. However, it is not universally applied in radiotherapy. It requires the implementation of advanced calculation programs, considering patient tissue densities, involving problems of geometry, patient thickness, etc [3]. In the Centre of Oncology in Gliwice such kind of *in vivo* dosimetry is being worked on. Meanwhile, the pre-treatment verification method is performed.

A potential limitation of EPID dosimetry is the limited size of the flat panel and lengthy duration of the process [9].

Conclusions

The general conclusion can be drawn that aSi-based EPID and transit dosimetry option of TPS is appropriate for static and dynamic dose measurements. For the future, the development of a viable clinical strategy for application of this new verification method is necessary.

Acknowledgements

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