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DETERMINATION OF RADIOTHERAPY OUTPUT DOSE USING ELECTRONIC PORTAL IMAGING DEVICE

ODREĐIVANJE IZLAZNE RADIOTERAPIJSKE DOZE POMOĆU ELEKTRONSKIH UREĐAJA ZA PORTAL IMIDŽING

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Ključne reči
EPID, izlazna doza, transkutana terapija, medicinski linearni accelerator, dozimetrija

Abstract

Electronic Portal Imaging Device (EPID) is an integral part of medical linear accelerators. The main aim of our investigation was to establish and verify method for output dose determination in external beam therapy using EPID with fluorescence screen. Output dose measurements were performed for 4 MV photon energy and various field sizes, phantom depths and phantom-detector distances. Measurements were performed by cylindrical ionization chamber under the same geometrical conditions. Results showed good linearity of the applied method and confirmed its implementation in *in vivo* dosimetry.

INTRODUCTION

Input field image obtained during therapy dose application can be used for the verification of the planned treatment. All errors in patient set-up on the table will result in a lower dose to the tumor volume while the dose to healthy tissue increase. Radiographic film is traditional method for check the matching of input fields. This method is successful but time-consuming and can not be used on-line. Electronic portal imaging device was developed in early eighties and commercially used from the nineties.[1,2] Today these are the equipment units that is routinely supplied with medical accelerators. EPID is also valuable in QA and QC programs in radiotherapy particularly for devices with multileaf collimators.[3,4] The basic idea about application of EPID in dosimetry was launched in 1986 and is based on the application of known patient geometry for the calculation of total output dose below the therapeutic field.[5] This "on-line" dosimeter could be used to stop the linear accelerator when the planned dose reached or when the wrong wedges were applied. It was also showed that appropriate configuration of EPID could be used for output *in-vivo* dose determination.[3] In this paper we gave some results obtained by ELEKTA iView device in our own clinical mode which were compared with some results taken from the literature.

Radiotherapy patients are increasingly treated with advanced techniques, such as intensity modulated radiotherapy (IMRT). By using optimized, modulated 2-D fluence distributions from each beam direction, the delivered dose distribution can often be shaped more closely to the tumor volume compared with conventional radiotherapy, especially for concave-shaped targets. For reliable application of these techniques, often combined with high tumor doses, a patient-specific quality control programme is currently being developed in our clinic. It is mainly based on measurements with electronic portal imaging devices (EPIDs) for the verification of the patient positioning and the dose delivery before and during the actual patient treatment. During each treatment fraction the patient is positioned with a finite accuracy on the treatment couch, indicating that there is some displacement of the patient relative to the intended set-up used in the treatment planning. Electronic portal images (EPIs) acquired during treatment are well suited to verify the accuracy of patient positioning.

In this paper, the EPID used for geometric and dosimetric verification of treatment delivery is described.

For EPID dosimetry, the calibration should ensure that all pixels have a similar response to a given irradiation, so we began our research by obtaining the calibration curves.

MATERIAL AND METHODS

Output dose was measured by electronic portal imaging device type iView, manufactured by ELEKTA presented at figure 1. Scheme of EPID is given at Figure 2. This EPID consist of a fluorescent screen, a front-surface mirror, a Peltier-cell cooled charged-coupled device (CCD) camera and a computer with a frame grabber. X rays that are transmitted through an absorber (patient or phantom) and hit the detector screen generate visible light in the fluorescent layer, which is viewed by the CCD camera. The system is well suited for both geometric verification of patient set-up and for accurate absolute dosimetric measurements for both conformal

and IMRT fields. Long-term dose–response reproducibility is within 0.5% (1 SD) that can accurately be described with a quadratic function, independent of photon beam energy, dose rate and integration time. Integration of signal is simultaneous in all 1024×1024 pixels

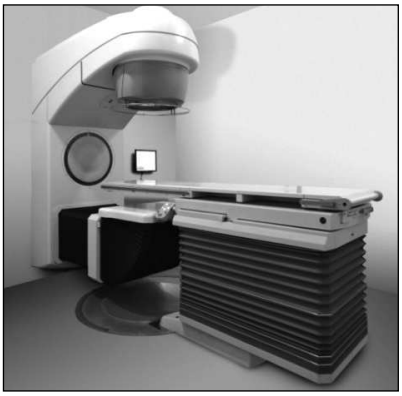

Figure 1. iView EPID, ELEKTA

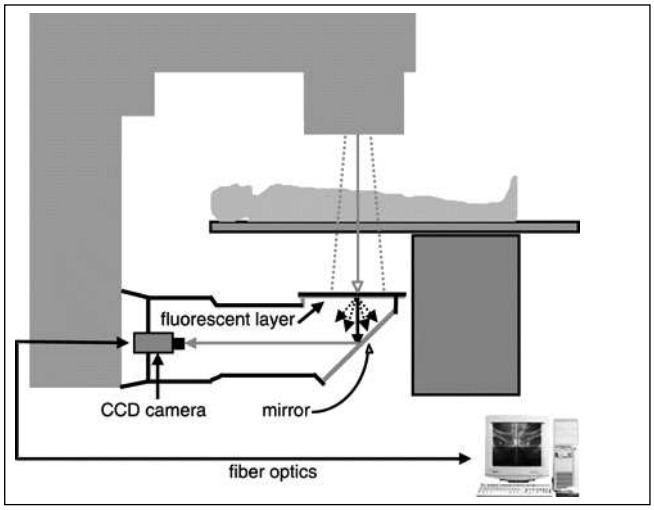

Figure 2. Scheme of EPID, ELEKTA

Measurement conditions are given in Table 1.

Table 1. Measurement conditions

Measurement condition	Value
Photon energy	4 MV nominal accelerator potential
Field size	5cm x 5cm; 10cm x 10cm; 15cm x 15cm and 19cm x 21cm
Focus-fluorescent screen distance	160 cm
Fluorescent screen material	Gadolinium oxy- sulfide
Pixel size	0.35 cm x 0.35 cm
Phantom thickness	10 plates, 1 cm each (10 cm in total)
Phantom material	PMMA
Detector-output phantom surface distance	20 cm, 30 cm, 40 cm and 50 cm
Irradiation time	20 MU

Image obtained by MV photon beam was detected by fluorescent screen and two millar mirrors placed in detector arm. This CCD camera has 1024×1024 pixels covering a field of view of about 19 cm×24 cm at isocentre level. During a selectable time (from 40 ms to 1280 ms), the signal can be integrated on the CCD chip, after which this signal is digitized using a 12 bit frame grabber.

Optical cable transmits the image in an adjacent room to the workstation (Intel Pentium, Operating system is Windows NT, version 4.0) where all corrections are applied and image is inverted to be displayed on 21- inch monitor. Resolution is (1024 x 1280) pixels with 256 gray level. At each image we defined Region of interest (ROI) 1cm x 1cm in size (Patchwork pattern), symmetrically to

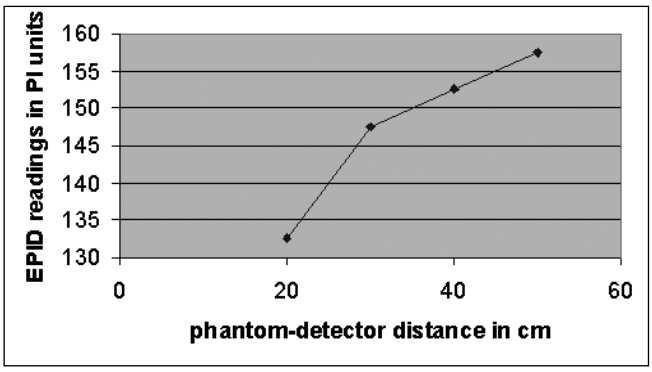

Figure 3. Output dose obtained by EPID as a function of phantom thickness

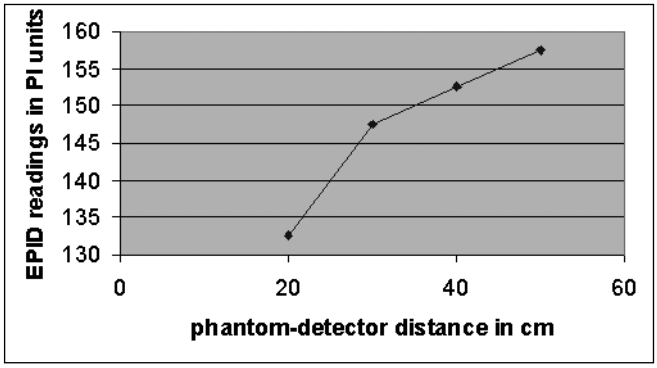

Figure 4. Readings of EPID in PI units as a function of phantom-detector distance

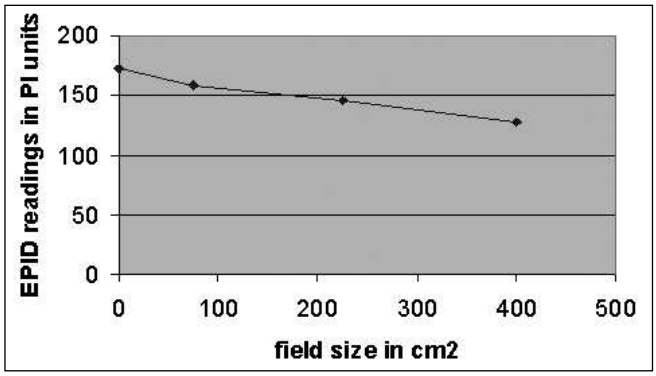

Figure 5. Readings of EPID in PI units as a function of a field size

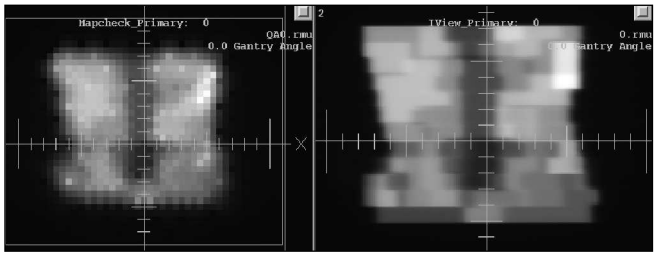

Figure 6. Therapy fields integrated with MapCheck diode array and with the ELEKTA EPID system.

the beam axis for which we calculated the mean value of (brightness) pixel. During the measurements we changed Detector-output phantom surface distance, Field size and thickness of the phantom.

All measurements were repeated under the very same geometrical conditions using cylindrical ionization chamber type NE 2571 (Electrometer Ionex 2500/3). Ionization chamber was verified by Federal Bureau of Measures and Precious Metals and was traceable to the national primary standard and further to the SI unit.

All measurements were performed at the Department of Oncology, Military Medical Academy in Belgrade.

RESULTS

According to preset measurements conditions we obtained a families of curves that represent the values of the output dose determined under various input conditions. At Figure 3. we presented values of output dose depending on the phantom thickness.[6] EPID readings as a function of detector-phantom distance and field size are given at figure 4. and 5. respectively.[6]

DISCUSSION AND CONCLUSION

Our measurements were aimed at obtaining the set of calibration curves for various parameters used for output dose determination in any irradiation geometry. These parameters represent field size, A/P patient diameter and distance from detector and they can vary during the therapeutic dose delivery. All measurement should be repeated for greater number of variables. Additionally, calibration curve related to the output dose as a function of EPID readings in terms of PI units should be determine. All obtained results are in expected limits.

Generally, it would be interesting to compare the results obtained from EPID and some newer techniques. Just as an example we used results of comparison between 3D dose reconstruction using the MapCheck diode array as an input device versus using the higher resolution Elekta EPID system. This case was supplied courtesy of the University of Toledo, Toledo, Ohio. At the figure 6. therapy fields integrated with MapCheck diode array and with ELEKTA EPID system are given. On the left is one of seven IMRT fields integrated with the MapCheck diode array, and on the right is the same field integrated with the Elekta EPID system. Although the MapCheck diode array has a much lower resolution, we must remember that the patient acts like a low pass filter in regard to the resulting dose distribution due to scatter within the patient.

Reliable application of advanced external beam techniques for the treatment of patients with cancer, such as intensity modulated radiotherapy, requires an adequate quality assurance programme for the verification of the dose delivery. Owing to the increased complexity of the treatment planning and delivery techniques, verification of the dose delivery before and during the actual patient treatment is equally important. For this purpose, a quality assurance programme has to be established in the clinic that is primarily based on measurements with electronic portal imaging devices. Dosimetric measurements are also performed during patient treatment to derive the actually delivered fluence maps. By combining this information with knowledge on the patient set-up, the delivered 3-D dose distribution to both the tumor and sensitive organs may be assessed. As part of our quality control programme for IMRT verification, portal dose measurements are performed before delivering the first treatment fraction to a patient.

Electronic portal imaging is a powerful tool for the verification of the patient set-up and the dose delivery at the treatment unit. With a limited workload, errors in patient positioning are detected in the first treatment fractions and corrected for in the subsequent fractions. In addition, accurate dose measurements are performed both before and during patient treatment. A limitation of portal imaging is that changes in (internal) patient geometry cannot always be derived with sufficient accuracy to allow for accurate dose reconstruction. In these cases, the dosimetric application of portal imaging should be combined with the acquisition of a (cone-beam) CT at the treatment unit. Each of these quality assurance procedures will contribute to a reduction of uncertainties in the entire radiotherapy treatment dose delivery chain and to a reliable application of advanced treatment techniques in large patient groups.[7]

Investigations should be extended using numerical simulations for EPID response studies due to better understanding of the detector behavior and an accurate prediction of EPID response. Monte Carlo simulations will give satisfactory solutions. It also gives the possibility of energy efficiency assessment as the EPID response is significantly correlated to the number of photons striking the detector and to the proportion of photons below 1 MeV.

Monte Carlo is powerful tool for understanding EPID behavior under specific conditions which gives accurate results but with slow calculation time.

Apstrakt

Elektronski uredjaji za portal imidžing (EPID) se rutinski isporučuju uz medicinske linearne akceleratore. Osnovni cilj naših istraživanja bio je ustanovljavanje i verifikacija metode za određivanje izlazne doze u transkutanoj radioterapiji pomoću EPID sa fluorescentnim ekranom. Merenja izlazne doze su urađena za fotonski snop od 4 MV i za različite veličine polja, dubine fantoma i rastojanja fantom-detektor.Merenja su izvršema cilindričnom jonizacionom komorom pri istim geometrijskim uslovima. Rezultati prikazuju dobru linearnost primenjene metode i potvrđuju njenu primenu u *in-vivo* dozimetriji.

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