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Using an electronic portal imaging device for exit dose measurements in radiotherapy

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Purpose. To present a method of determining the exit dose with the use of an electronic portal imaging device (EPID).
Materials and methods. The device used was the Portal Vision LC250 (Varian).The EPID signals on the central beam axis have been related to the exit dose. The exit dose measurements were performed with the ionisation chamber in the slab phantom at the distance of dose maximum from the exit surface of the phantom. EPID reading was investigated as a function of field size, phantom thickness and source-detector distance.
Results. The relation between dose rate and the EPID reading is described with empirical functions applicable to the obtained data. The exit dose is calculated from the EPID reading as a product of the calibration factor and appropriate correction factors.
Conclusion. The determination of the exit dose rate from the EPID signal requires the knowledge of many parameters and earlier determination of essential characteristics.

Zastosowanie systemu Portal Vision do pomiaru dawki wyjściowej w radioterapii

Cel. Przedstawiona publikacja ma na celu zaprezentowanie metody pomiaru dawki wyjściowej przy użyciu elektronicznego systemu obrazowania wiązki promieniowania – EPID (Electronic Portal Imaging Device).
Materiały i metody. Do pomiarów dawki używano EPID – Portal Vision LC250 firmy Varian. Sygnał pochodzący z detektora EPID na osi wiązki promieniowania odnoszono do wartości dawki wyjściowej. Pomiary dawki wyjściowej wykonywano komorą jonizacyjną w fantomie płytkowym w odległości d_{max}, liczonej od punktu wyjścia wiązki z fantomu. Sygnał z EPID-u badano w funkcji rozmiaru pola, grubości fantomu i odległości źródło-detektor.
Wyniki. Relacja pomiędzy mocą dawki i odczytem EPID-u została opisana funkcją empiryczną, ze współczynnikami otrzymanymi na drodze dopasowania do danych pomiarowych. Wartość dawki wyjściowej jest obliczana na podstawie odczytu EPID, współczynnika kalibracyjnego i odpowiednich współczynników korekcyjnych.
Wnioski. Określenie wartości dawki wyjściowej na podstawie sygnału detektora EPID wymaga znajomości wielu parametrów i wcześniejszego wyznaczenia istotnych charakterystyk.

Key words: Electronic Portal Imaging Device (EPID), exit dosimetry
Słowa kluczowe: EPID (Electronic Portal Imaging Device), dawka wyjściowa

Introduction

In many oncology centres the Electronic Portal Imaging Device (EPID) is used for the verification of patient setup during radiation treatment session. In some institutions this system is also used for dose measurements [1-3]. The EPID allows to obtain direct information about the exit dose distribution. From the clinical point of view, the knowledge of the exit dose may not be very interesting but the combination of two measurements – the entrance dose e.g. measured with semiconductor diodes and the exit dose (measured using the EPID) could be useful, as it may allow to calculate the midplane dose [4].

The aim of this paper is to present a method of determining the exit dose with the use of the Electronic Portal Imaging Device.

Materials and methods

The Electronic Portal Imaging Device

At the Institute of Oncology in Gliwice we use the commercial EPID – Portal Vision™ LC250 system (Varian). The image detector is essentially a matrix of 256x256 straight wire electrodes enclosed in a chamber filled with a special hydrocarbon liquid (isooctane). Polarising high-voltage is applied to each of the electrodes

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along one axis in turn, while the electrodes along the other axis are scanned and very small ionisation currents measured, thus forming an image of 65536 pixels. The matrix has a sensitive area of 32.5 x 32.5 cm^2 and a pitch of 1.27 mm. The scatter material (build-up layer) exists above the upper electrode plate. The standard acquisition mode was used for our measurements without corrections.

With the aid of a special computer program, data from the EPID was exported to the matrix of numbers (256 x256) for further processing. In this paper the mean value of signal I_{mean} from the area 11x11 pixels around the beam axis is assumed as a reading on the central beam axis. These readings have been related to doses from the ionisation chamber. All measurements were carried out for the CLINAC 600 CD (Varian) accelerator at the accelerating potential of 6 MV.

The ionisation chamber

The dose rate measurements were performed with an ionisation chamber (0.6 cm^3) NE 2571 in combination with electrometer PTW-UNIDOS and in slab phantom made of metaplex.

The exit dose measurements were performed in the phantom on the central beam axis, at the distance of dose maximum d_{max} =1.5 cm from the exit surface of the phantom.

Measurements

The schematic view of the measurement setup is presented in Figure 1. For the purpose of calibration, we assumed the following reference conditions: effective point of measurements of the ionisation chamber placed at 1.5 cm (d_{max} for 6 MV) from the exit surface of the phantom, on the central beam axis (source-chamber distance $SCD=f_0$ = 100 cm), field side S_0= 10 cm (at the isocenter f_0), phantom thickness 12 cm (d_0). EPID measurements were performed behind the phantom at the distance of h_0=18.5 cm from the phantom (120 cm from the source, $f_{0E}=f_0+d_{max}+h_0$), the field side at the EPID level is 12 cm ($S_{0E}=S_0 \cdot (f_{0E}/f_0)$.

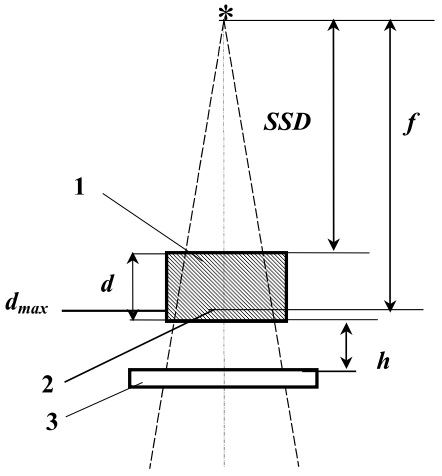

Figure 1. Schematic view of the measurement setup (1) – phantom, (2) – the ionisation chamber, (3) – EPID, *SSD* – source-phantom surface-distance, *f* – source-chamber-distance, *d* – thickness of phantom, *h* – phantom-EPID-distance, d_{max} – depth of measurements

The dose rate used for determining the relation between the dose rate and the pixel value (readings of the EPID) range from 0.4 cGy/MU to 0.7 cGy/MU by changing the SSD from 120 to 150 cm for EPID and from 100 to 130 cm for the ionisation chamber, the phantom – EPID distance is constant: h_0.

In order to determine the relation between the field side size and the EPID signal, the field side size at the isocenter was varied (6-24 cm) for 5 phantom thicknesses (6-20 cm), the chamber and EPID were placed in reference distances (f_0,f_{0E}).

The influence of source-EPID distance on the relationship between the exit dose rate and EPID signal was investigated for various phantom-EPID distances *h* (18.5-48.5 cm) and for 3 different field sizes S (6, 10, 18 cm).

Method

In our method, we assumed that the exit dose rate DR can be obtained from the EPID using suitable calibration factor F_C:

$$DR(S,d,f)=F_c(S,d,f,h) \cdot R(S_E,d,f,h) \quad (1)$$

where: $DR(S,d,f)$ – exit dose rate measured by the ionisation chamber,
$F_c(S,d,f,h)$ – calibration coefficient,
$R(S_E,d,f,h)$ – EPID signal.

It is well known that the dose rate measured by ionisation chamber can be written as:

$$DR(S,d,f)=DR(S_0,d_0,f_0) \cdot q_{s,d}(S,d) \cdot q_f(f) \quad (2)$$

where: $q_{S,d}(S,d)$ – field side size and thickness phantom correction coefficient (eq.3),
$q_f(f)$ – source-chamber distance correction factor (eq.4),

$$q_{S,d}(S,d)=\frac{DR(S,d,f_0)}{DR(S_0,d_0,f_0)} \quad (3)$$

$$q_f(f)=\frac{DR(S_0,d_0,f)}{DR(S_0,d_0,f_0)} \quad (4)$$

By analogy to Eq.2, we assume a similar equation for EPID:

$$R(S_E,d,f,h)=R(S_{E0},d_0,f_0,h_0) \cdot q_{ES,d}(S_E,d) \cdot q_{Ef,h}(f,h) \quad (5)$$

Therefore, calibration factor F_c for any conditions can be written as follows:

$$F_c(S,S_E,d,f,h)=\frac{DR(S_0,d_0,f_0) \cdot q_{S,d}(S,d) \cdot q_f(f)}{R(S_{E0},d_0,f_0,h_0) \cdot q_{ES,d}(S_E,d) \cdot q_{Ef,h}(f,h)}=$$

$$=F_{c0} \cdot C_{s,SE,d}(S,S_E,d) \cdot C_f(f,h) \quad (6)$$

Coefficients $C_f(f,h)$, $C_{S,SE,d}(S,S_E,d)$ are obtained by dividing the appropriate chamber and EPID factors:

$$C_{S,SE,d}(S,S_E,d) = \frac{q_{S,d}(S,d)}{q_{ES,d}(S_E,d)} \quad (7)$$

$$c_f(f,h) = \frac{q_f(f)}{q_{Ef,h}(f,h)} \quad (8)$$

From Eq.1 and Eq.6 we have:

$$DR(S,d,f) = F_{c0} \cdot C_{s,SE,d}(S,S_{E,d}) \cdot C_f(f,h) \cdot R(S_E,d,f,h) \quad (9)$$

F_{c0} denotes the calibration factor for reference conditions:

$$F_{c0} = \frac{DR_0(S_0,d_0,f_0)}{R_0(S_{0E},d_0,f_0,h_0)} \quad (10)$$

where:

DR_0 is exit dose rate for reference conditions measured by the ionisation chamber ($f = f_0 = 100$ cm; $d_0 = 12$ cm; $S_0 = 10$ cm),

R_0 – is EPID signal for reference conditions ($h = h_0 = 18{,}5$ cm; $d_0 = 12$ cm; $S_{0E} = 12$ cm; $f_0 = 100$ cm).

Results

The determination of exit dose with the EPID requires the knowledge of the calibration coefficient and suitable correction factors. The value of calibration factor F_{C0} was periodically checked. The variation in F_{C0} values could result from changes in the sensitivity of the ionisation chambers. A small increase, less than 1%, was observed for 6 months during our measurements.

Coefficient $C_{S,d}(S,d)$ describes the relation between the EPID signal and the exit dose rate as a function of field size and phantom thickness. Figures 2 and 3 present coefficients $q_{SE,d}(S_E,d)$ and $q_{S,d}(S,d)$ for EPID and the ionisation chamber, respectively. The correction factor $C_f(f,h)$ depends on the source chamber distance and phantom-EPID distance. The changes of the $C_f(f,h)$ are presented in Figure 4.

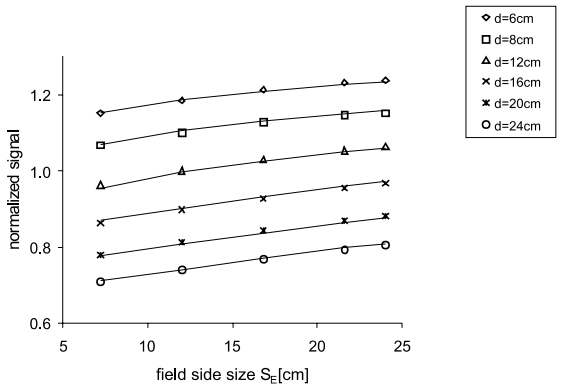

Figure 2. EPID signal as a function of field side size at the EPID level S_E for different phantom thickness d (lines – function, measurements – points)

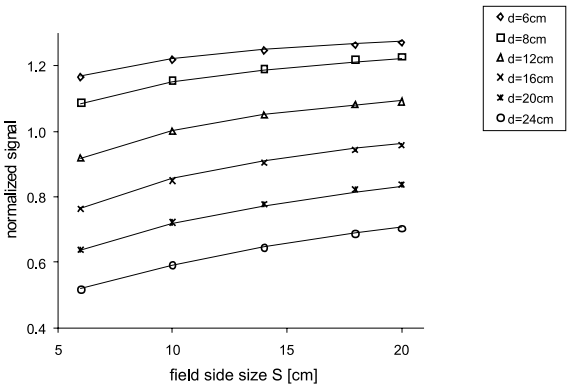

Figure 3. The dose rate measurements by ionisation chamber as a function of field side size S at the isocenter for different phantom thickness d (lines – function, measurements – points)

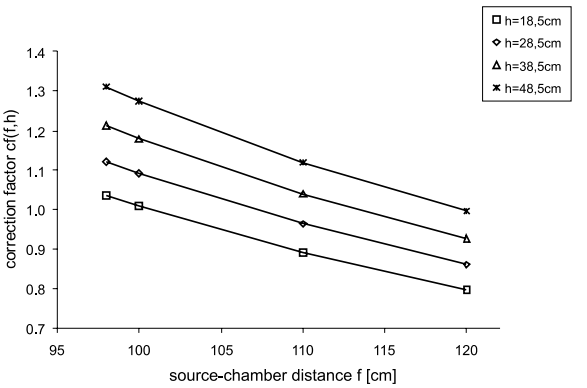

Figure 4. Correction factor $c_f(f,h)$ as a function of source-chamber (f) distance (straight lines – function, measurements – points)

For all coefficients, empirical functions fit the measured data (Eq.11,12,19).

$$q_{S,d}(S,d) = a_1 \cdot ln(S) + a_2/S + a_3 \quad (11)$$

$$q_{ES,d}(S_E,d) = b_1 \cdot ln(S_E) + b_2/S_E + b_3 \quad (12)$$

where:

$$a_i = A_{i1} \cdot e^{-A_{i2} \cdot (d-A_{i3})^2} + A_{i4}$$

$$b_i = B_{i1} \cdot e^{-B_{i2} \cdot (d-B_{i3})^2} + B_{i4} \qquad i = 1..3$$

Parameters A_i, B_i calculated with the least-squares method are listed in Table I.

Table I. List of parameters for Eq.11 and 12

	i=1	*2*	*3*	*4*
A_{1i}	-0.3020	0.0019	2.2839	0.3404
A_{2i}	-2.2096	0.0047	10.4830	1.5732
A_{3i}	2.0939	0.0016	0.8170	-0.8478
B_{1i}	-0.0769	6.4860	0.0199	0.1519
B_{2i}	-0.8308	7.8806	0.0190	0.8838
B_{3i}	0.8270	1.8880	0.0057	0.2393

The correction factor $C_{S,d}(S,d)$ is obtained by dividing Equations 11 and 12.

Correction for different distances is described by the equation:

$$c_f(f,h) = a_1 \cdot h + a_2 + \frac{1}{b_1 \cdot f - b_2 \cdot h + b_3} \qquad (19)$$

where: $a_1 = 0{,}0024$; $a_2 = -0{,}2162$;
$b_1 = 0{,}0092$; $b_2 = 0{,}0039$; $b_3 = -0{,}0065$.

The variation of the EPID signal with field size was investigated for different source-EPID distances.

Our measurements show that this relation is not dependent on the source distance (Figure 5). We also found that the EPID signal (normalised to reference distance f_{0E}=120 cm) as the function of the source-EPID distance does not depend on phantom thickness (Figure 6).

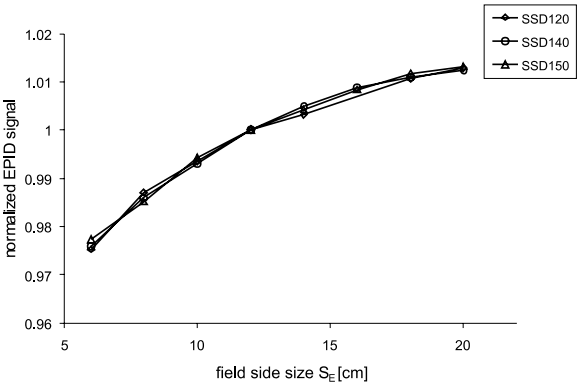

Figure 5. The variation of the EPID signal with field side size investigated for different source-EPID distance

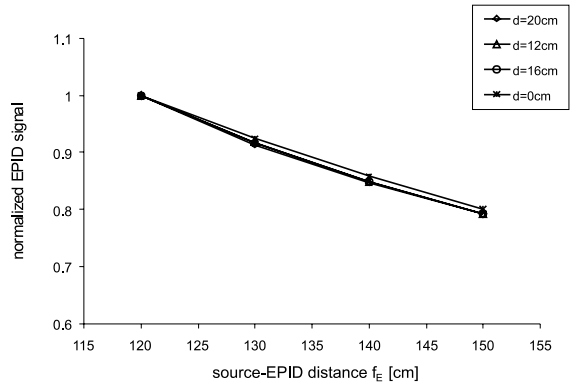

Figure 6. Normalized EPID signal as a function of source-EPID distance f_E for different phantom thickness

The results of the comparison between the measured and calculated values of dose rates for different values of *S,d,f,h* are presented in Table II.

The average difference between the exit dose rate measured by the ionisation chamber and the dose rate determined with the EPID is -0.8 %, standard deviations are 1.4 %.

Table II. Comparison between the measured and calculated dose rate for different conditions

f_{0E}	f	S_E	d	DR(chamber) (cGy/MU)	DR(EPID) (cGy/MU)	differences (%)
140	100	8.4	6	0.939	0.917	-2.39
140	100	20	10	0.923	0.909	-1.48
130	100	18	14	0.808	0.793	-1.88
140	114.5	25.2	14	0.616	0.602	-2.34
130	104	18.2	16	0.667	0.664	-0.42
130	110	11.8	12	0.652	0.654	0.31
150	100	12	10	0.835	0.839	0.49
130	100	15.6	18	0.654	0.657	0.52

Conclusions

Our measurements show that the Portal Vision is suitable for dosimetric purposes. The method described above allows obtaining the exit dose rate from the EPID signal.

The calibration procedure involves the determination of all significant characteristics.

The determination of the exit dose rate from the EPID signal requires the knowledge of many parameters: source-EPID distance, field side size at the EPID level, phantom thickness.

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