Proceedings of the Second International Workshop on EGS, 8.-12. August 2000, Tsukuba, Japan
KEK Proceedings 200-20, pp.264-271

Variation of Dose Distribution by Detectors for Narrow Beam

T. Fujisaki, H. Saitoh[1], T. Inada, S. Abe, M. Fukushi[1] and K. Fukuda[1]

Ibaraki Prefectural University of Health Sciences
4669-2, Ami, Ami-Machi, Ibaraki 300-0394 Japan
[1] *Tokyo Metropolitan University of Health Sciences*
7-2-10, Higashi-Ogu, Arakawa-Ku, Tokyo 116-8551 Japan

Abstract

Percentage depth dose (PDD) is the essential parameter for the absorbed dose determination. Since precise measurement is required for the narrow beam especially, several kinds of detectors are commonly used to measure dose distribution for narrow beam. However, the variation of response caused by kinds of the detectors has not been investigated precisely.

In this study, PDDs were measured using several kinds of detectors, such as ionization chambers, silicon diode detectors and films. Furthermore, the absorbed dose of these detection materials in water was calculated using Monte Carlo simulation.

As a result, it was shown that the response of ionization chambers (air-gas) was higher than diode detectors (silicon) and a film (photoemulsion). Therefore, the depth dose curves changed by kinds of the detector (materials).

1 Introduction

Percentage depth dose (PDD) is the essential parameter for the absorbed dose determination. Since precise measurement is required for the narrow beam especially, several kinds of detectors, such as ionization chambers, silicon diode detectors and films, are commonly used to measure dose distribution[1, 2, 3, 4].

Furthermore, the absorbed dose of these detection materials in water was calculated using Monte Carlo simulation. The variation of response caused by kinds of the detectors was investigated.

2 Methods

2.1 Measurements

The experiments were carried out at the IPU in Ibaraki, using the 10 MV X-ray beam from a linear accelerator (Mitsubishi Electric, EXL-15SP). Four different ionization chambers, two different silicon diode detectors and a photographic film detector were used;

1. a 30001 standard chamber (PTW-Freiburg),
2. a IC-10 standard waterproof chamber (Wellhoffer Dosimetrie),
3. a IC-04 small volume waterproof chamber (Wellhoffer Dosimetrie),
4. a PPC-05 markus shape waterproof chamber (Wellhoffer Dosimetrie),
5. a EDD-5 entrance and exit dose p-Si photon detector (Scanditronix Medical),
6. a EDD-2 risk organ monitoring p-Si photon detector (Scanditronix Medical)

7. a XV-2 high spatial resolution film detector (Kodak).

Important parameters of these detectors are given in Table1. The ionization chambers and the diode detectors were connected for a WP700 computerized 3D scanning water phantom system (Wellhoffr Dosimetrie) using special connectors.

The measurements of PDD using the ionization chambers and the diode detectors were initially done in the scanning water phantom at 100 cm source to surface distance (SSD). Measured PDD curves were normalized at 10 cm depth in water according to the recommendation[4]. The measurement using the XV-2 film was performed in a water-equivalent phantom (Kyoto-Kagaku, WE). The film was placed perpendicularly to the radiation beam axis at 100 cm SSD. The optical density was measured with a dosimeter (Wellhofer Dosimetrie, WP102) at an aperture radius 0.8 mm. Net optical density was converted to absorbed dose using a calibration curve, which calibrated with an ionization chamber at a 10×10 cm^2 field and 5 cm depth.

2.2 Monte Carlo simulations

The calculation of the absorbed dose in water was done with the user code "in-hom_slab. mortran", the EGS4[5] and PRESTA code[6]. This code enables deposit energy sampling of cylindrical volumes divided into multi layers with arbitrary materials.

Figure 1 shows the geometry of simulation for deposit energy sampling. The absorbed dose were calculated from deposit energy in cylindrical volume made of the detection material, it was air-gas (element and relative amount of atoms in the compound by weight C; 0.0124 % N; 75.5268 % O; 23.1781 % Ar; 1.2827 %, density 0.001205 g/cm^3)[7] in ionization chambers, silicon (Si; 100 %, density 2.33 g/cm^3) in diode detectors and photo emulsion (H; 3.05 % C; 21.07 % N; 7.21 % O; 16.32 % Br; 22.28 % Ag; 30.07 %, density 3.815 g/cm^3) in a film. The cylindrical volume with 1 cm diameter and 1 cm thick were positioned at 2.5, 5.0, 10, 15 and 20 cm depth. The 10 MV X-ray, which has an energy spectrum by Mohan et al.[8], was simulated to be a square field of 1×1 cm^2 and 5×5 cm^2. The total number of histories were varied from 5×10^6 to 1×10^7 for each fields. The energy thresholds for photon and electron trajectory were set to 0.01 MeV (PCUT=0.01 MeV, ECUT=0.521 MeV). The fractional energy loss per electron step was set to 5 % (ESTEPE=0.05). Computations were performed using a ULTRA SPARC ENTERPRISE 450 (Sun Micro Systems).

3 Results and Discussion

Figure 2 shows measured PDDs using several ionization chambers for 5×5 and 1×1 cm^2 fields and lower column shows the curve normalized at 10 cm depth. The measured PDDs using cylindrical chamber are closely matched. But the PDD using parallel chamber is approximately 2 % higher at deeper points for a 1×1 cm^2 field.

Figure 3 shows the relative depth dose curves normalized at 10 cm depth using diode detectors and IC-10 ionization chamber and lower column shows the ratio of diode detectors to IC-10 ionization chamber. Figure 4(A) shows the relative depth dose curves normalized at 10 cm depth using XV-2 film and IC-10 ionization chamber, and (B) shows the ratio of film to ionization chamber. The gradient of relative depth dose curves of the diode detectors and XV-2 film were steeper than ionization chamber.

Figure 5 shows the calculated depth dose curves normalized at 10 cm depth using air-gas, silicon and photoemulsion. The response of air-gas was higher than silicon and photoemulsion in deeper depth and for smaller field.

As the results, the depth dose curves changed by kinds of the detector (materials). In the future, it is necessary to examine the change of response by the geometrical structure, shapes and size etc.

References

[1] C. F. Serago, P. V. Houdek, G. H. Hartmann, D. S. Saini, M. E. Serago and A. Kaydee, "Tissue maximum ratios (and other parameters) of small circular 4, 6, 10, 15 and 24 MV x-ray beams for radiosurgery", *Phys Med Biol* **37**(1992)1943-1956.

[2] P. Francescon, S. Cora, C. Cavedon, P. Scalchi, and S. Reccanello, "Use of a new type of radiochromic film, a new parallel-plate micro-chamber, MOSFETs, and TLD 800 microcubes in dosimetry of small beams", *Med Phys* **25**(1998)503-511.

[3] C. McKerracher and D. I. Thwaites, "Assesment of new small-field detectors against standard-field detectors for practical stereotactic beam data acquisition", *Phys Med Biol* **44**(1999)2143-2160.

[4] IAEA: The use of plane parallel ionization chambers in high energy electron and photon beams; An international code of practice for dosimetry, IAEA, No. 381, 1997.

[5] W. R. Nelson, H. Hirayama and D. W. O. Rogers, "The EGS4 code system", , *SLAC report-265*, 1985.

[6] A. F. Bielajew and D. W. O. Rogers, "PRESTA, The "Parameter Reduced Electron Transport Algo-rithm" for electron Monte Carlo transport", National Research Council of Canada report *PIRS-0042*, 1987.

[7] International Commission on Radiation Units and Measurements (ICRU): Tissue Substitutes in Radiation Dosimetry and Measurement, Report 44 of the ICRU, 1989.

[8] R. Mohan, C. Chui, and L. Lidofsky, "Energy and angular distributions of photons from medical linear accelerators", *Med Phys* **12**(1985)592-597.

Table 1 Physical parameters of the ionization chambers and silicon detectors (courtesy of the manufacturers).

ionization chamber

Type	Active volume (cm^3)	Outer electorode			Inner electorode		
		Material	Thick (mm)	Inner radius (mm)	Material	Radius (mm)	Length (mm)
30001	0.6	PMMA	0.45	3.05	Al	0.5	21.2
IC 10	0.14	C-552	0.4	3.0	C-552	0.5	3.8
IC 04	0.03	C-552	0.4	2.0	C-552	0.5	2.1
PPC 05	0.04	Front window: C-552 Collecting electrode: diameter 10 mm, PPE, graphite					

diode detector

Type	Active volume (mm)	Build-up cap		Detector	
		Material	Thick (mm)	Material	Thick of the Si chip(mm)
EDD-5	$2.5\text{x}2.5\text{x}0.06^t$	Polystyrene	2.5	p-type Si	0.50 ± 0.02
EDD-2	$1.5^{\phi} \times 0.06^t$	Polyuretan Epoxy plastic	0.1 0.3	p-type Si	0.50 ± 0.02

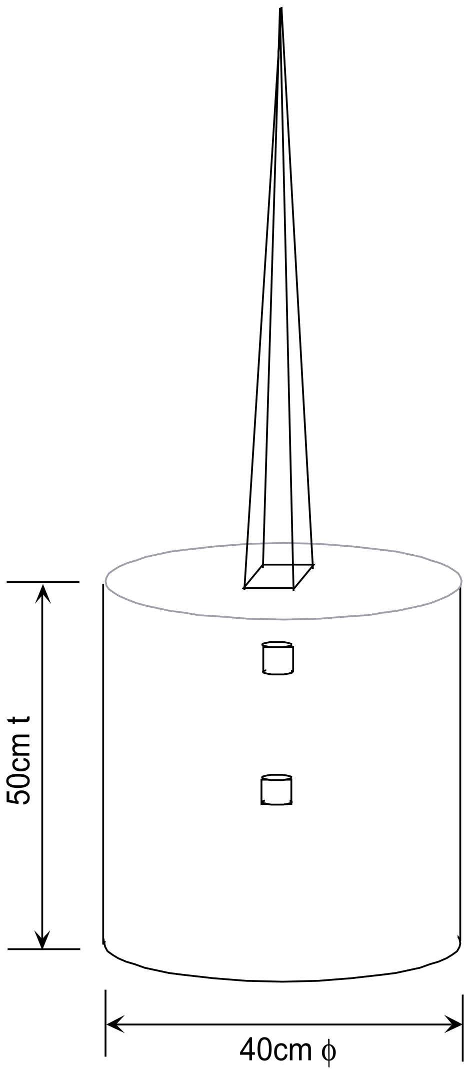

Figure 1: Geometrical arrangement of Monte Carlo simulation for deposit energy sampling. The incident photons impinged vertically on a concentric circular cylindrical water phantom model (element and relative amount of atoms in the compound by weight H; 11.2 % O; 88.8 %, density 1.0 g/cm^3) of 40 cm diameter and 50 cm thickness.

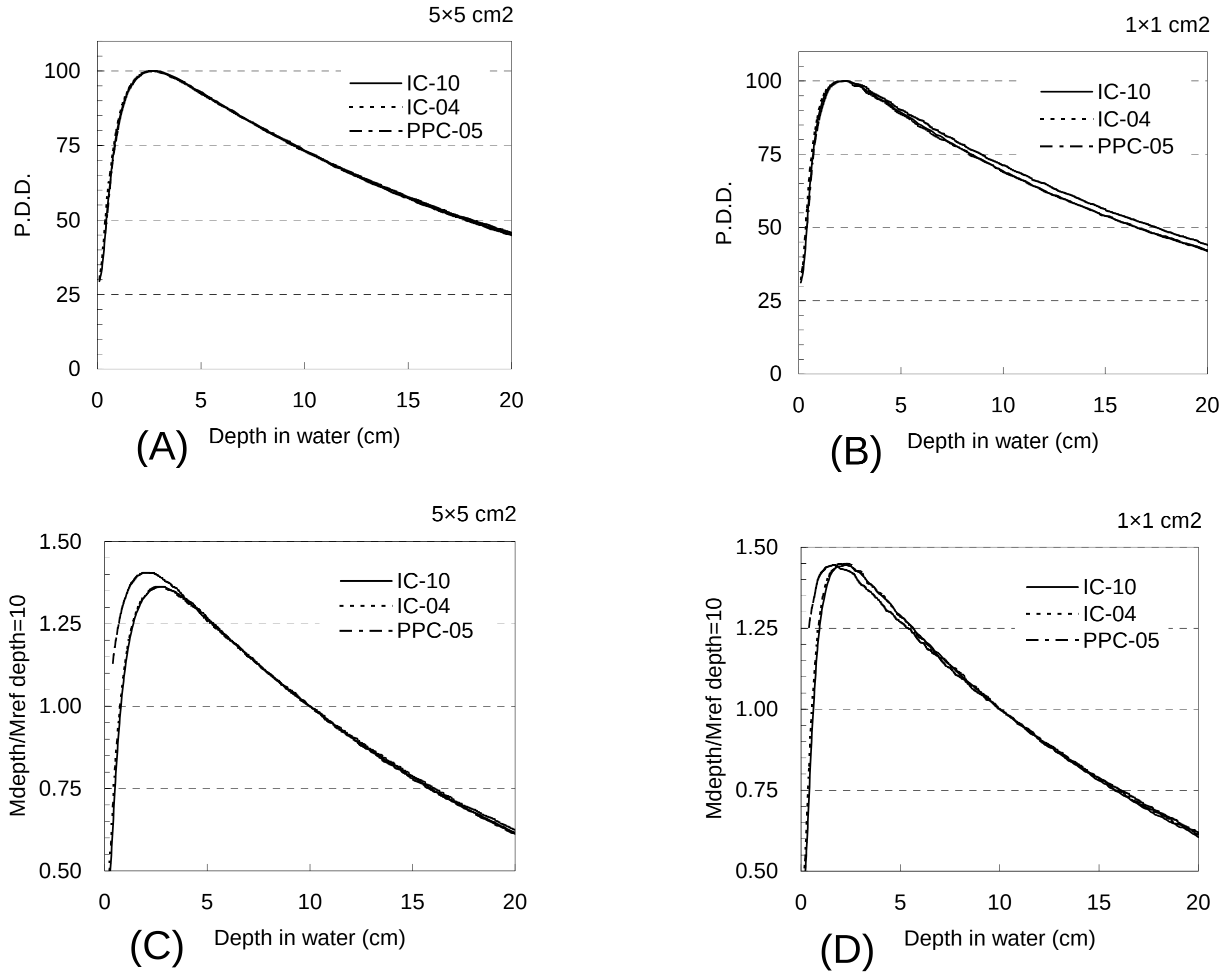

Figure 2: Measured PDDs using several ionization chambers for 5×5 and 1×1 cm^2. Lower column shows the curve normalized at 10 cm depth.

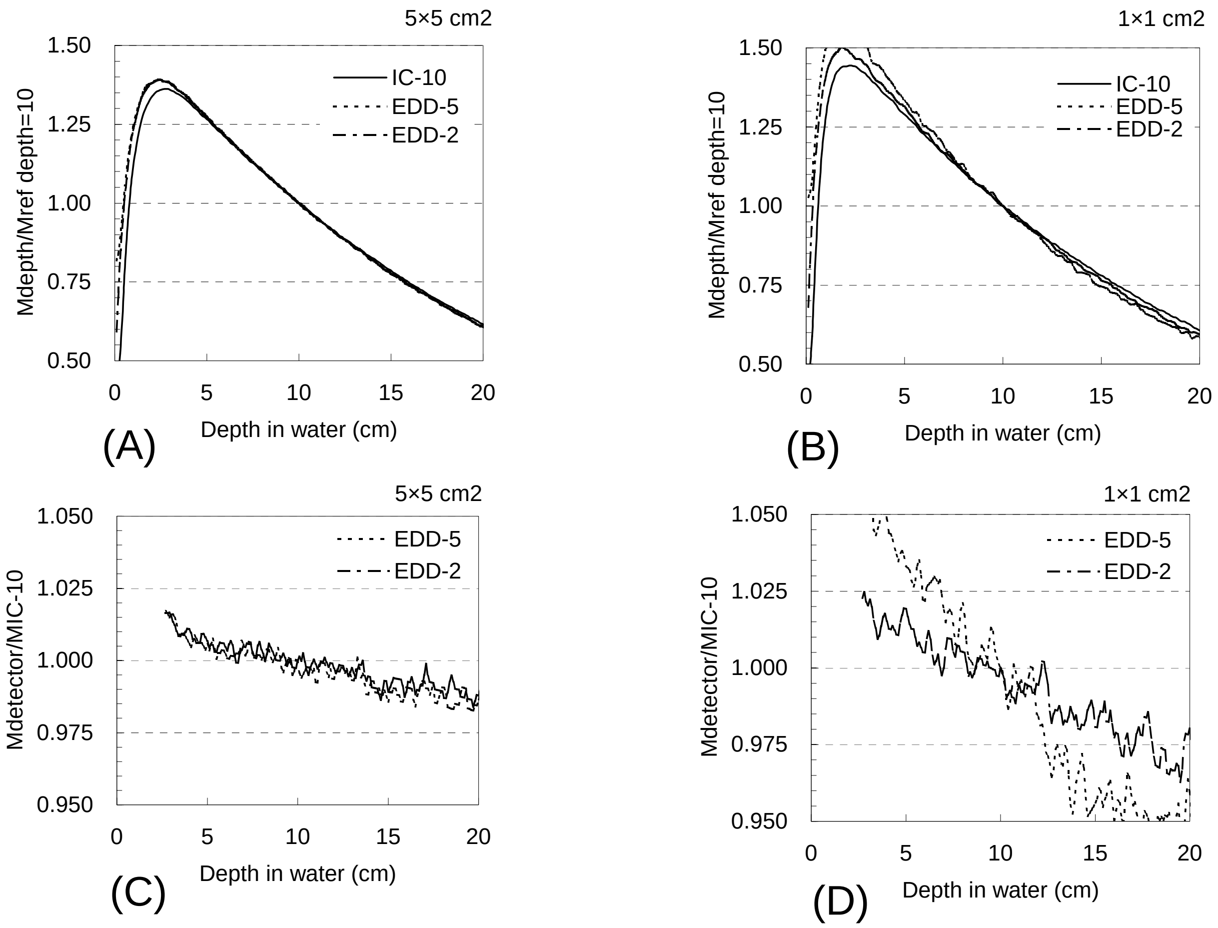

Figure 3: Relative depth dose curves normalized at 10 cm depth using diode detectors and IC-10 ionization chamber. Lower column shows the ratio of diode detectors to ionization chamber.

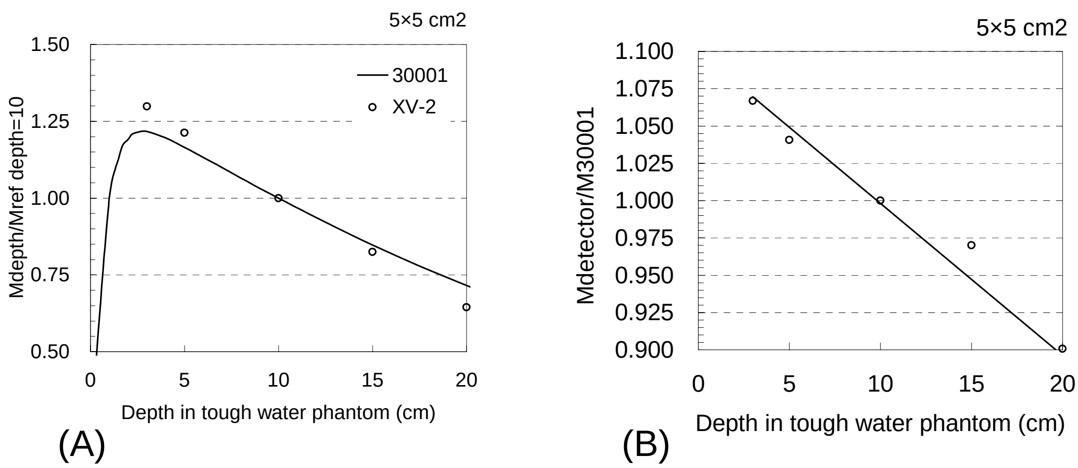

Figure 4: Relative depth dose curves normalized at 10 cm depth using XV-2 film and 30001 ionization chamber. (B) shows the ratio of film to ionization chamber.

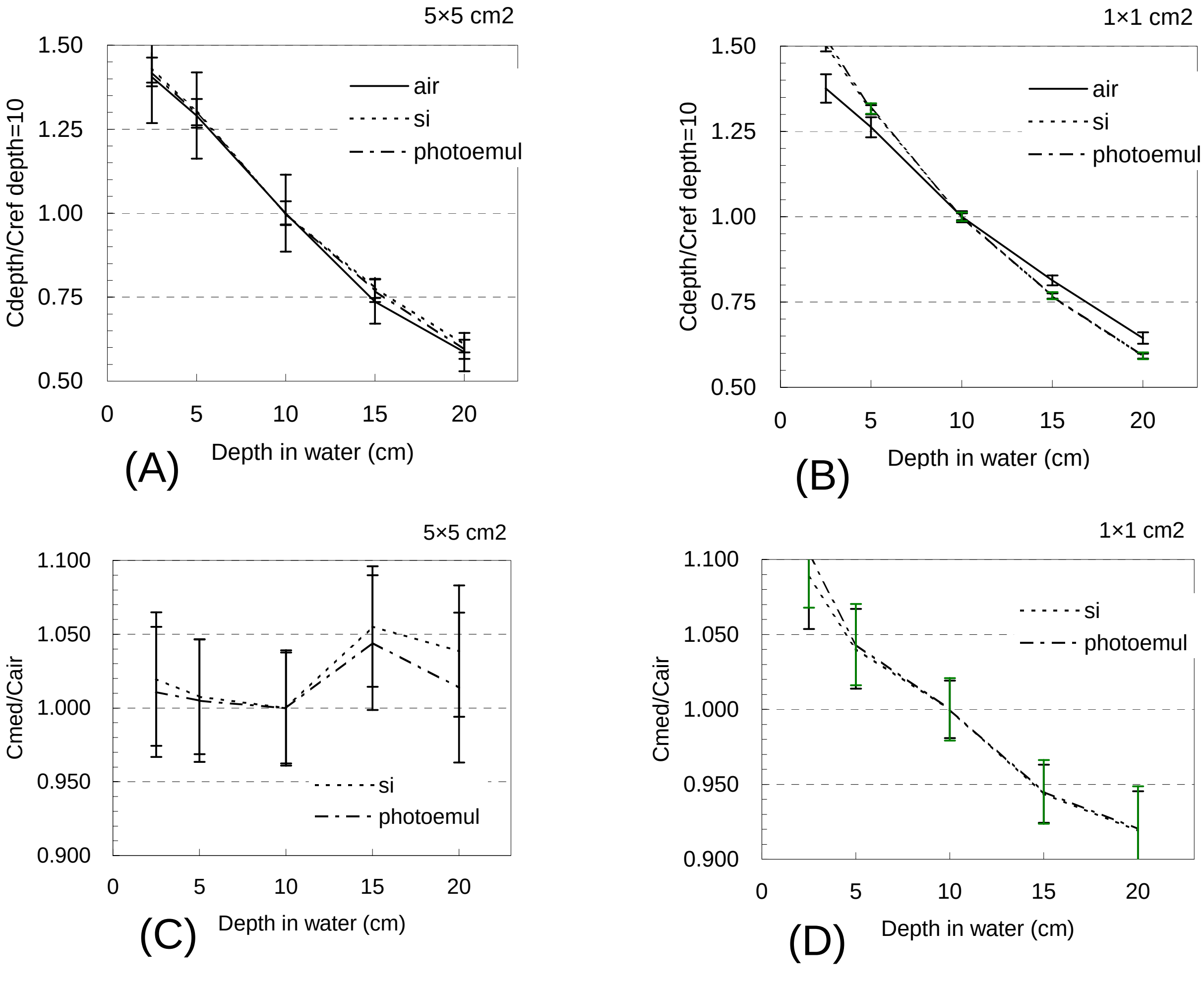

Figure 5: The calculated depth dose curves normalized at 10 cm depth using air-gas, silicon and photoemulsion.