A New Method for Measuring the Dose Distribution of the Radiotherapy Domain using the IP

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ABSTRACT

Knowing the dose distribution in a tissue is as important as being able to measure exposure or absorbed dose in radiotherapy. Since the Dry Imager spread, the wet type automatic processor is no longer used. Furthermore, the waste fluid after film development process brings about a serious problem for prevention of pollution. Therefore, we have developed a measurement method for the dose distribution (CR dosimetry) in the phantom based on the imaging plate (IP) of the computed radiography (CR). The IP was applied for the dose measurement as a dosimeter instead of the film used for film dosimetry. The data from the irradiated IP were processed by a personal computer with 10 bits and were depicted as absorbed dose distributions in the phantom. The image of the dose distribution was obtained from the CR system using the DICOM form. The CR dosimetry is an application of CR system currently employed in medical examinations to dosimetry in radiotherapy. A dose distribution can be easily shown by the Dose Distribution Depiction System we developed this time. Moreover, the measurement method is simpler and a result is obtained more quickly compared with film dosimetry.

Keywords: CR Dosimetry, Dose Distribution Depiction System, IP, DICOM

1. INTRODUCTION

A method for measuring the dose distribution with an x-ray film (film dosimetry) has been used for measuring relative dose distribution for many years. Film dosimetry with high resolution can also measure the dose distribution of the minimum irradiation field used for stereotactic radiosurgery etc., and it is one short-time irradiation. A two-dimensional dose distribution in the combination of more than two beams is obtained by one film sheet. Using film dosimetry, even if change of the development processing conditions of the film after irradiation does not give rise to a serious problem in the diagnostic domain, it brings about a large density difference in dosimetry and affects the dose distribution. The film dosimetry has problems in accuracy and complexity of its processes[1-3]. This time we have developed a measurement method for the dose distribution (CR dosimetry) in the phantom based on the imaging plate (IP) of the computed radiography (CR). We examined the possibility and usefulness of the CR dosimetry.

2. MATERIALS AND METHODS

2.1. Development of Dose Distribution Depiction System

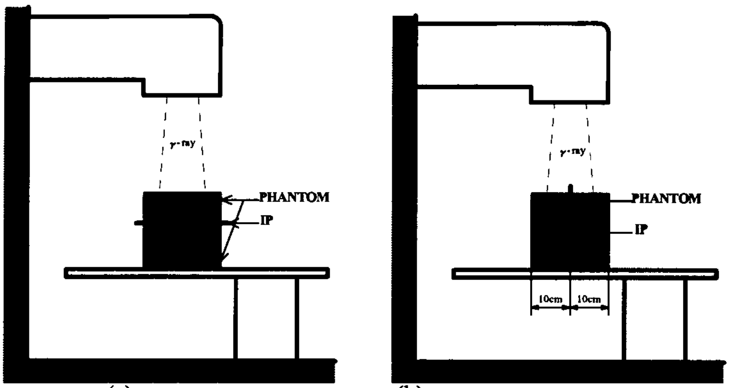
The CR dosimetry was performed by the following method. After irradiation, the IP (Fuji Film Medical Corp., ST-VN) was read with CR reading equipment (Fuji Film Medical Corp., FCR AC-3), and the obtained image data were transmitted to a personal computer in DICOM form[4] by the DICOM picture communication system (Image and Majormento Corp., POP-Net). We have developed the program, Dose Distribution Depiction System, which can carry out direct processing of the CR value in the obtained DICOM image data on a personal computer with 10 bits using Visual Basic 6.0 (Microsoft Corp.). In addition, to avoid the influence of Cherenkov radiation by the phantom (Kyoto Science Corp., Tough Water Phantoms, 30cm×30cm) and other light, the IP was shaded during the experiment, and irradiated with gamma-rays from ^{60}Co teleradiotherapy equipment (Shimadu Corp., RTGS-21).

2. 2. Measurement of the basic data by CR dosimetry

The CR reading equipment currently used for experiments is designed for diagnosis[5-6]. (The exposure is assumed as about 2.58×10^{-9} to 2.58×10^{-5}C/kg.) The CR dosimetry is an application of equipment for larger exposure (7.67×10^{-5} - 3.835×10^{-4}C/kg) for radiotherapy. Therefore it is necessary to obtain the relation between IP dose (absorbed by IP) and CR value. We used 10-bit data without image processing. This operation was repeated six times and the relation between the CR value and IP dose was obtained by an approximation formula with a logarithmic function.

2. 3. Measurement of the percentage depth dose

The probes in the phantom used for the dosimeter (Oyogiken Corp., AE-132a), a shallow ionization chamber (Oyogiken Corp., C-134A) and a thimble ionization chamber (Oyogiken Corp., C-110), were irradiated with ^{60}Co teleradiotherapy equipment. Changing the thickness of the phantom on the IP of the CR dosimetry as shown in Fig.1(a), we irradiated the gamma-rays perpendicularly onto the IP and measured the percentage depth dose. Moreover the IP was sandwiched between two phantoms with a thickness of 10cm and the gamma-rays were irradiated in parallel to the IP as shown in Fig.1 (b).



(a) (b)

Fig.1 The measurement method of percentage depth dose (distance between the source ^{60}Co and the surface phantom: 80cm, irradiation field: $10\times10cm^2$). (a) IP placed perpendicular. (b) IP placed parallel.

2.4. Comparison of the film dosimetry and the CR dosimetry

The IP shown in Fig.1 (b) was replaced by a film (Kodak Co., X-Omat V READY PACK) and the gamma-rays were irradiated in parallel to the film. After development processing the film was measured with a density recorder (Konishiroku Co., PDI-10) and the dose distribution was obtained. The film dosimetry method was based on that of Leonard[2)]. The dose distribution of CR dosimetry was compared with that of film dosimetry.

3. RESULTS

3.1. Dose Distribution Depiction System

The display monitor of the Dose Distribution Depiction System is shown in Fig.2. Operation processing was carried out between the basic data inputted as CR values, and the percentage depth dose (10-100%) converted from CR values was displayed. The percentage depth dose could also be changed into arbitrary values.

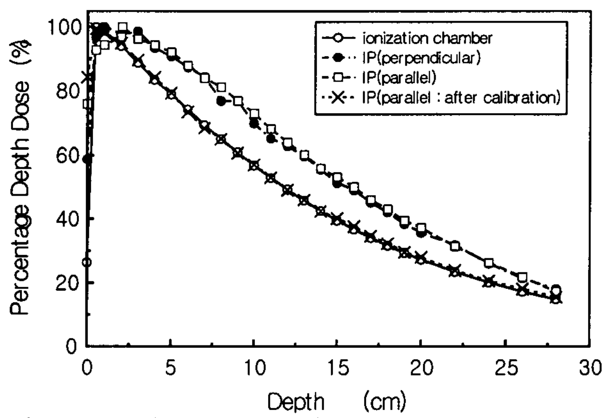


Fig.3. Comparison of percentage depth of the based on ionization chamber system and that based on IP.

3.2. Basic data of CR dosimetry

From measurement results, we could express an approximation relation between CR value (CRV) and relative exposure (RD) as follows.

$$CRV=409.74\times\log_{10}RD+374.28 \quad (1)$$

The RD was defined as 1 when the exposure was 7.67×10^{-5} C/kg. The approximation formula was obtained by a logarithmic function and the coefficient of determination was 0.9989.

3.3. Percentage depth dose

The percentage depth dose is shown in Fig.3. There was hardly any difference between results obtained from IP irradiated with the perpendicular and parallel gamma-rays. The percentage depth dose based on the IP irradiated with the parallel gamma-rays were calibrated using that by ionization chambers. The peak position in CR dosimetry was about 1cm deeper than that in the case of the ionization chamber systems; moreover the dose at 10cm depth in CR dosimetry was 28% higher than that in the ionization chamber systems. However, when the depth was more than 10cm, the difference gradually became smaller.

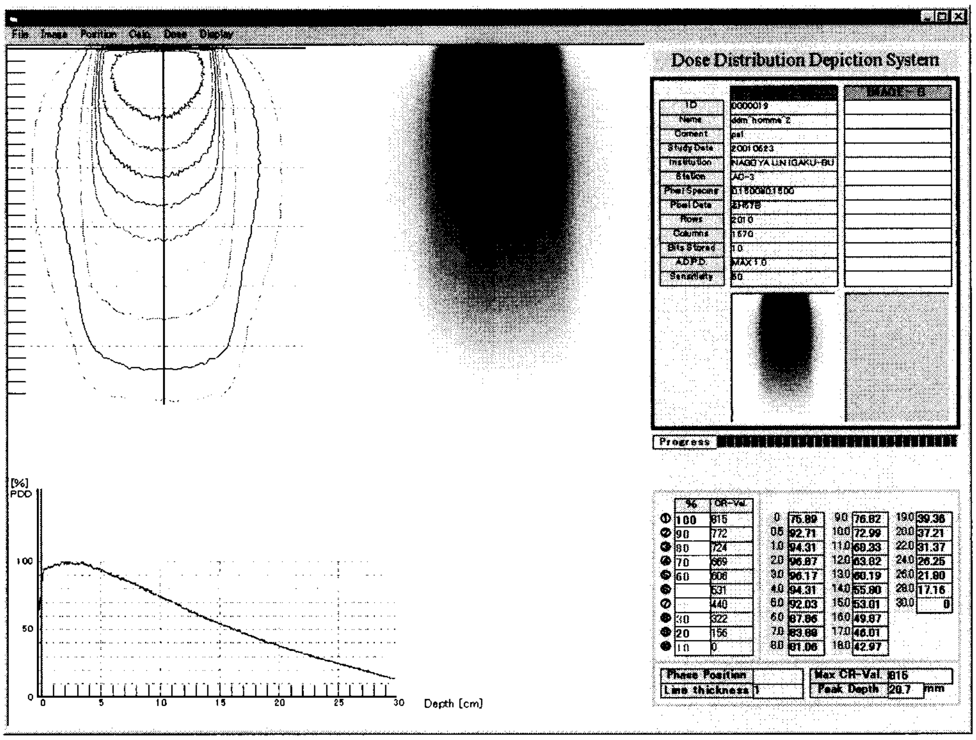


Fig.2. Dose Distribution Depiction on the CRT.

3.4. Dose distribution

Fig.2 shows the result from the IP irradiated with the parallel gamma-rays. The isodose curve near the irradiation field edge in CR dosimetry expanded outward and the maximum dose in CR dosimetry was about 28% higher than that in film dosimetry.

4. DISCUSSION

The general-purpose software which processes image data of DICOM form as 8 bits is useful. However, when bits omission begins, the density resolution falls. Thus, we developed the Dose Distribution Depiction System to treat image data as 10 bits without bits omission, and the resolution of density is better than that obtained by general-purpose software. Moreover, it can process image data of the DICOM form from various other CR systems. The approximation formula of the relation between exposure and CR value is expressed by the logarithmic function and the coefficient of determination is 0.9989. The CR reading equipment for diagnosis (about 2.58×10^{-9} - 2.58×10^{-5}C/kg) is currently recognized to be applicable for higher exposure (7.67×10^{-5} - 3.835×10^{-4}C/kg). It turns out that CR dosimetry can be used for measurement of absorbed dose. Compared with film dosimetry or the ionization chamber systems, results of the percentage depth dose and dose distribution using CR dosimetry were overestimated. Moreover, the 20% isodose area of CR dosimetry was swollen compared with the film method and should be studied in more detail from now on. The results of the beam irradiation perpendicular to the IP were compared with those of the parallel case; hardly any difference was seen. Thus when the gamma-rays is irradiated in parallel, we do not need to consider the self-absorption and direction dependability of the IP. Moreover, the IP used for the CR dosimetry has remarkably high sensitivity in the very low energy region of scattered rays. Thus, the influence of scattered rays with very low energy in CR dosimetry is more apparent as compared with the film method etc.

5. CONCLUSIONS

The CR dosimetry is one application of the CR system currently used for diagnosis. The CR dosimetry with the Dose Distribution Depiction System which can obtain pictures from the CR system in the DICOM form was developed this time and the method is easily implemented. The CR dosimetry has very simple measurement operation as compared with film dosimetry. Reproducibility is good, and measurement results are acquired immediately. By performing calibration processing inside the Dose Distribution Depiction System, it is possible to unite the results of CR dosimetry with the results of film dosimetry or the ionization chamber systems. From now on, when an irradiation field is changed or moving beam irradiation is performed, we should examine whether CR dosimetry is useful. IP used for CR dosimetry might be applied for detecting the absorbed dose. It is necessary to carry out further research into the influence of scattered rays with very low energy using film dosimetry or the ionization chambers.

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