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ARTICLE

Measurement of dose distribution during combined IVR procedure using the film method

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Computed tomography (CT)-guided interventional radiology (IVR) for treatment hepatocellular carcinoma has the advantage of verifying three dimensional location of a tumor. However, it is considered that radiation exposure to patients is increasing with the utilization of CT. Therefore, to evaluate the cumulative absorbed dose of the skin by combined IVR procedure is very important. In this study, the dose distribution of the combined exposure of IVR-CT system has been evaluated using a film method. We selected low-sensitivity films (XV-2, Kodak) that conventionally used in radiotherapy to detect an absorbed dose. These films were placed at three cross-sectional places (posterior side, center, and anterior side) of slab phantom. Irradiation by fluoroscopy, digital subtraction angiography (DSA), and CT was performed with normal clinical parameters. The density of those films was converted to absorbed dose with the conversion curve. The maximum dose was 943.9 mGy on the posterior side with combined all procedures. This film method can be used to detect hot spots of the absorbed dose in combined IVR procedure.

Keywords: combined IVR procedure; dose distribution; radiation exposure; radiation reduction; film method

1. Introduction

Recently, therapeutic procedures with interventional radiology (IVR) for various diseases have expanded. IVR procedure provides low invasive curative treatment. One such case is hepatocellular carcinoma (HCC) mostly caused by hepatitis C virus. The number of patients with HCC in Japan is higher than that of in Western countries. Two of treatments procedures for HCC are percutaneous ethanol injection therapy (PEIT) and transarterial chemoembolization (TACE) with IVR.

The purpose of angiography has shifted from diagnosis to therapy [1, 2].With regards to using the IVR-Computed Tomography (CT) /angiography system to treat HCC, CT is generally useful for visualizing three-dimensional position in addition to performing diagnosis with conventional angiography and IVR [3]. However, due to the sophistication and complexity of the method and the expansion of its application, exposure dose for patients is important [4]. There are many reports of exposure dose and radiation injury resulting from medical procedures [5-7]. For example, the US Food and Drug Administration have reported the skin injuries in patients after undergoing IVR [8]. Furthermore, in 2001, International Commission on Radiological Protection (ICRP) introduced the guidelines named "Avoidance of Radiation X-ray-induced Skin Injuries from Medical Interventional Procedures"[9]. These reports propose that it is important to visualize and evaluate the patient dose in IVR procedures. There have been several reports concerning absorbed dose evaluation during angiography [10, 11]. There have been several reports regarding the distribution of absorbed dose for the skin in the case of CT examination [12]. There was, however, no report which evaluated the dose distribution of combined exposure by angiography and CT simultaneously. The present study has evaluated the dose distribution of combined exposure in IVR-CT/angiography with a film method.

2. Materials and methods

There has been reported that a maximum skin dose reaches about 5 Gy in IVR procedure [13]. In high dose

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level, X-ray films generally used in the diagnosis X-rays is unsuitable for measurement. In order to avoid the saturation of the film density, we selected a low-sensitivity film (XV-2, Kodak Japan Ltd., Tokyo, Japan) [11], which generally are used for radiation therapy.

Film analysis software (FDS-2000, Chiyoda Technol Co., Ltd., Tokyo, Japan) was used for the analysis of film density. We used patient skin dosimeter (PSD; Unfors Co., Ltd., Billdal, Sweden) as the monitoring dosimeter. This PSD is a device developed to display the entrance surface dose at the time of IVR.

2.1. Acquisition of conversion curve for film density to absorbed dose

First, we acquired the conversion curve for film density to absorbed dose. The film was set on the bed of an IVR-CT/angiography system (Aquilion 4DAS, Toshiba Medical Systems Co., Ltd., Tokyo, Japan). Exposure parameters were set as follow; tube voltage and tube current were fixed at 80 kV and 400 mA respectively. Film-focus distance (FFD) was fixed at 60 cm. We changed X-ray exposure time. At the same time, the PSD elements were irradiated. These obtained films were scanned by a high definition scanner to read its density. The region of interest (ROI) was set into area with homogeneous density. Finally, we created a conversion curve.

2.2. Measurement of dose distribution

An experimental setup is shown in **Figure 1**.We assumed the thickness of the human body to be 20 cm, and reproduced it by solid water phantom (Kyoto Kagaku Co., Ltd. Kyoto, Japan). The low-sensitivity films used for measurement were set at different distances: the posterior side, the center, and the anterior side. We measured the dose distribution of six kinds of procedures, which are as follow; (1) fluoroscopic X-rays, (2) DSA (frontal view), (3) DSA (RAO 30° view), (4) non-enhanced CT, (5) enhanced CT, and (6) combined exposure of these 5 types.

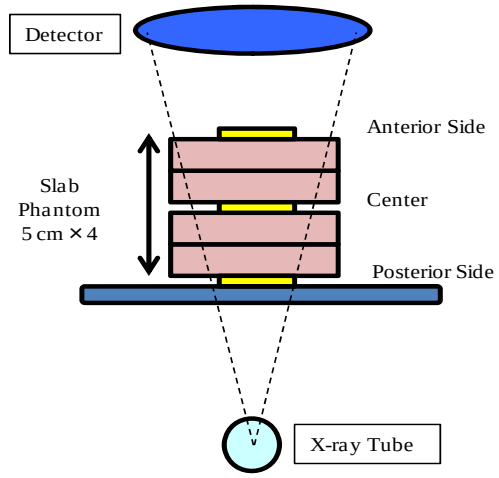


Figure 1. An experimental setup for measurements.

The exposure parameters of the images are shown in **Table 1** and **Table 2**. We determined these parameters in consideration of the result of 30 or more cases carried out at Chiba University Hospital. The films after exposed to fluoroscopic X-rays, DSA, and CT were read by film analysis software.

Table 1. X-ray exposure parameters for IVR.

	Fluoroscopy	DSA (frontal)	DSA (RAO,30)
Tube Voltage (kV)	78	80	82
Tube Current (mA)	50	500	500
Time	16 min	20 ms	48 ms
FSD (cm)	60	60	70
Frame Rate/Shots	7.5 fps	80 shots	80 shots

Table 2. X-ray exposure parameters for CT.

	Non-Enhanced	Enhanced (4 Phase)
Tube Voltage (kV)	120	120
Tube Current (mA)	200	300
Scan Range (cm)	20	20
Slice Thickness (mm)	5	1
Rotate Time (s)	0.5	0.5

3 . Results

3.1. Conversion curve for film density to dose

Figure 2 shows the result of the dose-density conversion curve. The vertical axis is the density of the film and the horizontal axis is the absorbed dose measured by PSD. The results reveal that film density becomes saturated over 40 mGy. Therefore, in this experiment, the parameter of each exposure was set to decrease the dose to one-tenth of the desired value, after converting the film density into absorbed dose, and it was thus considered that the absorbed dose was increased 10 times.

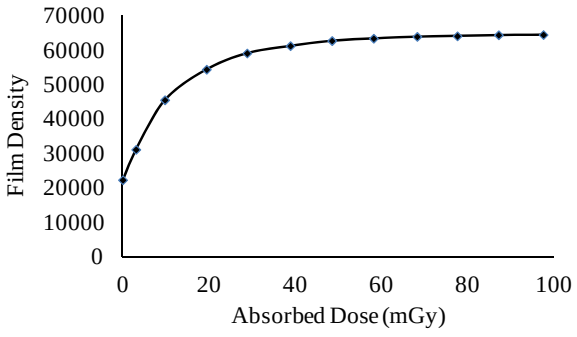
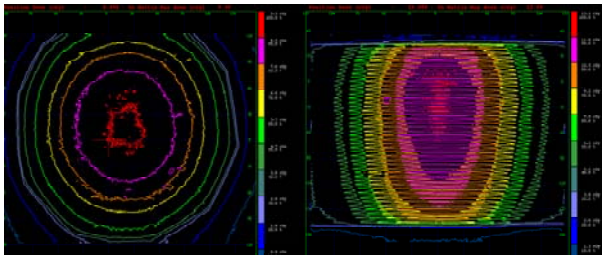


Figure 2. Conversion curve for film density to absorbed dose.

3.2. Distribution of absorbed dose for each procedures

Figure 3 shows the typical dose distribution irradiated by fluoroscopy and CT procedures. The dose distribution of fluoroscopy shows the concentric pattern, and that of CT shows the spiral pattern.



(a) Fluoroscopy (b) CT

Figure 3. Typical dose distribution for fluoroscopy and CT.

Figure 4 shows the comparison for maximum absorbed dose by individual procedures for IVR-CT. At the posterior side, the percentage of absorbed dose fluoroscopy and DSA occupies approximately 83.2% to total absorbed dose. It means that dose contribution by CT is relatively low. On the other hand, at anterior side, absorbed dose by CT occupies about 90.3% to the total absorbed dose.

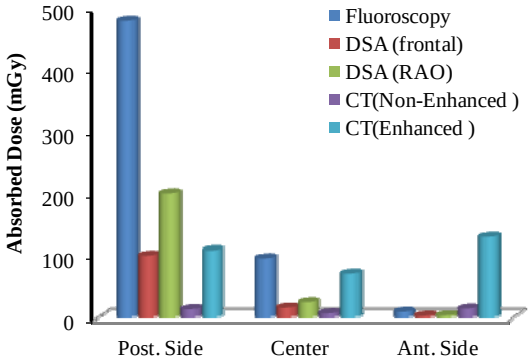


Figure 4. Comparison of maximum absorbed dose for each procedure.

The combined absorbed dose of all procedures from the 5 series is shown in **Figure 5**. The dose at the posterior side is very high, and the maximum absorbed dose is 943.9 mGy. At the center, the maximum absorbed dose is 219.1mGy while that for the anterior side is 152.8 mGy.

4. Discussions

In this study, we tried to get the dose distribution of IVR-CT/angiography procedures with low sensitive films. In IVR procedures, to realize the hotspots of dose is very important. We succeeded in acquisition of the dose distribution for various IVR-CT procedures.

4.1. Characteristics of PSD and low-sensitivity film

Although the coefficient of variation of PSD elements

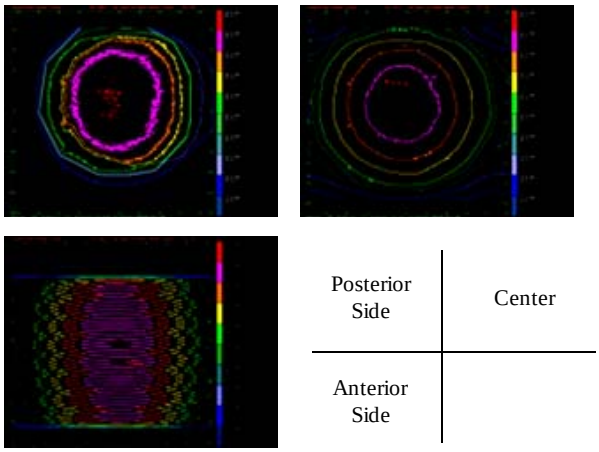


Figure 5. Detection of hot spots exposed by combined IVR-CT procedures.

used in this experiment differs slightly with X-ray energy, it is only about 14% at maximum [14]. Linearity is also maintained to the dose and the dose rate characteristics. The maximum error is about 2.9% in the former and 4.0% in the latter [14].

The film used by this study can be used to measure 800 mGy of a 10 MV-X-ray [5]. However, due to the energy dependence, this film has different response to low energy X-ray. In fact, the film density was saturated with about 150 mGy in this study. This shows that sensitivity is high to low energy X-rays. In this study, the parameter of each exposure was set to decrease to one-tenth of the usual value.

4.2. Necessity of evaluating for exposure dose in IVR

In order to prevent radiation injury in IVR, to evaluate the absorbed dose is very important. The exposure dose in IVR is determined by the entrance surface dose, which takes backscattering into consideration as provided by a guidance level in IAEA safety series No.115. Accordingly, the exposure dose is usually 25 mGy/min in fluoroscopy [15]. ICRP Publication 85 recommends 20 mGy/min [9]. On the basis of the above levels, the Medical Irradiation Guideline 2006 in Japan recommends that a dose rate has to keep 25 mGy/min or less for fluoroscopy in angiography and IVR [16]. In this study, the dose rate of fluoroscopy on the posterior side is about 30 mGy/min. This value exceeded the guidelines. Moreover, the longest fluoroscopic time in 30 cases examined by this study is 58 minutes. Therefore, the absorbed dose of skin in fluoroscopy is about 1.74 Gy. In ICRP Publication 85, the minimum dose for deterministic effects, such as radiation dermatosis or early transient erythema, is 2 Gy. In IVR, it is not rare for the skin dose to exceed the threshold dose. In such a case, the dose-abatement technique, which reduces the dose as much as possible, is also necessary. The IVR-CT/angiography system captures an abundance of image information by CT in addition to fluoroscopy and DSA. However, too many photographs can lead to increment for exposure doses.

4.3. Advantages of film method in IVR procedures

The pinpoint dosimeters, such as an ionization chamber or a semiconductor dosimeter, are detecting the dose at arbitrary point only. However, in IVR procedures, it is important to realize spatial distribution of the hotspots. It is difficult to obtain 2D dose distribution by pinpoint dosimeters. This film method can acquire 2D distribution easily.

5. Conclusion

We evaluated the dose distribution of the abdomen with IVR-CT/angiography procedures by the film method. In this study, we succeed to visualize some hotspots generated in IVR-CT/angiography procedures. This film method appears to be useful for verifying the dose distribution using with multiple modalities, which has not been possible until now.

The maximum dose by combined IVR-CT procedures is strongly reflected by total fluoroscopic time. Therefore, it is desirable to reduce the absorption with the skin by removing low energy X-rays using appropriate an additional filters.

References

[1] H. Nakamura, T. Hashimoto, H. Oi and S. Sawada,Transcatheter oily chemoembolization of hepatocellular carcinoma, *Radiology*. 170 (1989), pp. 783-786.

[2] O. Matsui, M. Kadoya, J. Yoshikawa, T. Gabata, K.Arai, H. Demachi, S. Miyayama, T. Takashima, M. Unoura and K. Kogayashi, Small hepatocellular carcinoma: treatment with subsegmental transcatheter arterial embolization, *Radiology.* 188 (1993), pp. 79-83.

[3] M. Yoshikawa, H. Kato, H. Umekita, K. Miyahara, F. Morita and H. Saisho, Clinical Application of IVR-CT high-speed multi-detector CT/Angio System in Abdominal Disorders, *Japanese Journal of Radiological Technology.* 57(2001), pp.896-900. [in Japanese]

[4] T. Ishiguchi, H. Nakamura, M. Okazaki, S. Sawada, Y. Takayasu, S. Hashimoto, N. Hayashi, S. Furui, S. Koyama and H. Maekoshi, Radiation exposure to patient and radiologist during transcatheter arterial embolization for hepatocellular carcinoma, *Nihon Igaku Hoshasen Gakkai Zasshi.* 60 (2000), pp. 839-844. [in Japanese]

[5] T.R. Koenig, D. Wolff, F.A. Mettler and L.K. Wagner, Skin injuries from fluoroscopically guided procedures: part 1, characteristics of radiation injury, *AJR Am J Roentgenol.* 177 (2001), pp. 3-11.

[6] T.R. Koenig, F.A. Mettler and L.K. Wagner, Skin injuries from fluoroscopically guided procedures: part 2, review of 73 cases and recommendations for minimizing dose delivered to patient, *Am J Roentgenol.* 177 (2001), pp. 13-20.

[7] T.B. Shope, Radiation-induced Skin Injuries from Fluoroscopy, *Radio Graphics.* 16 (1996), pp. 1195-1199.

[8] Food and Drug Administration (FDA), *Avoidance of serious X-ray-induced skin injuries to patients during fluoroscopically-guided procedures*, Food and Drug Administration-Important information (1994).

[9] International Commission on Radiological Protection (ICRP), *Avoidance of radiation X-ray-induced skin injuries from medical interventinal Procedures*, ICRP publication 85 (2001).

[10] E. Vano, L. Gonzalez, J.I. Ten, J.M. Fernandez, E. Guibelalde and C. Macaya, Skin dose and dose-area product values for interventional cardiology procedures, *The British J Radiol.* 74 (2001), pp. 48-55.

[11] E. Guibelalde, E. Vano, L. Gonzalez, C. Prieto, J.M. Fernandez and J.I. Ten, Practical aspects for the evaluation of skin doses in interventional cardiology using a new slow film, *The British J Radiol*. 76 (2003), pp. 332-336.

[12]H. Nishitani, M. Yasutomo, M. Tominaga, H. Fukui and H. Yagi, Radiation Exposure in CT, *Nihon Igaku Hoshasen Gakkai Zasshi.* 62 (2002), pp. 347-351. [in Japanese]

[13] T. Shohji, T. Ishibashi, Y. Murayama, T. Saguchi and M. Ebara, Radiation Exposure during Cerebral Artery Aneurysm Coil Embolization: the Current Situation and Measures to Prevent Radiation Injury, *Interventional Neuroradiology.* 13 (2007), pp. 73-83.

[14] T. Fujibuchi, H. Kato, M. Hashimoto, Y. Abe and T. Kikawa, Characteristic Evaluation of a Real-time Silicon Dosimeter and Measurement of Entrance Skin Dose at Radiography, *Nihon Hoshasen Gijutsu Gakkai Zasshi.* 62 (2006), pp. 997-1004. [in Japanese]

[15] International Atomic Energy Agency (IAEA), *IAEA safety series No.115*, 280 (1994), pp. 53-54.

[16] JSRT incorporated association,*Medical Irradiation Guideline 2006*, (2006)