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Effective Dose in Gastric X-ray Examination using a Flat-Panel Detector Compared with a Digital Radiography Image Intensifier

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Abstract: We evaluated the effective dose (mSv), dose area product (DAP: cGy cm^2) and entrance surface dose (ESD: mGy) of a flat-panel detector for fluoroscopy (FPD) for gastric cancer screening in Japan by comparing the values obtained in three settings: diagnostic workup, standard radiography I (population-based screening) and standard radiography II (opportunistic screening). We then compared the values obtained using the FPD with those obtained by a digital radiography image intensifier for fluoroscopy (DRII) in the standard radiography I and II settings. The effective dose of the FPD was 19.66 mSv for diagnostic workup, 13.86 mSv for standard radiography I and 14.85 mSv for standard radiography II. For standard radiography I, the effective dose was 12.70 mSv for the FPD and 4.71 mSv for the DRII; the corresponding values for standard radiography II were 14.29 mSv and 5.18 mSv. Thus, the FPD showed a higher effective dose in the order of diagnostic workup, standard radiography II and standard radiography I. Also, the FPD delivered a higher effective dose than the DRII.

Keywords: *Flat panel detector (FPD), Digital radiography image intensifier (DRII), Effective dose, Entrance surface dose (ESD), Dose area product (DAP)*

1. Introduction

Only a few studies have investigated radiation exposure during X-ray screening for gastric cancer. In one report, placing filters A, B and C into a mean dose area product (DAP) meter achieved dose reduction rates of 6.03%, 10.92% and 13.64%, respectively. Such reductions are possible for machines that use films, but not for digital devices[1-4]. Maruyama et al.[5,6] estimated an effective dose of 0.57 mSv in X-ray gastric cancer screening using phantoms and a survey. Nonetheless, the methods used in these previous studies differed from current techniques in terms of aspects such as the method used for X-ray fluoroscopy (condenser, film, flat panel detector [FPD], digital radiography image intensifier [DRII, computed radiography [CR], etc.), sensitivity of indirect film, imaging method, number of images, interpretation method (display case and image viewer), the concentration and viscosity of barium sulfate preparation and the quantity and ingestion method of foaming agent.

Although Yamamoto et al.[7] predicted higher exposure with high-concentration barium sulfate, they found no significant difference compared with a moderate concentration (3.44 mSv vs 3.39 mSv) by film methods. In their study, conditions were similar to those in the fluoroscopy A-2 methods (moderate-concentration barium sulfate) and new fluoroscopy methods (high-concentration barium sulfate), in which a fixed fluoroscopy system was used and imaging of the same patient was performed eight times. Following the Japanese New Gastric Radiography Guidelines, Revised Edition (2011)[8], Yamamoto et al. subsequently found that the effective dose of one examination using a DRII in radiography for population-based screening (standard radiography I) and opportunistic screening (standard radiography II) was 4.41 mSv and 5.15 mSv ($P < 0.05$)[9], respectively, suggesting that a DRII has a higher effective dose compared with film devices. When high-concentration barium sulfate was used, the results showed significant differences between standard radiography I and II. In addition, the effective dose of the FPD was high in standard radiography I and II, at 13.71 mSv and 14.73 mSv, respectively ($P < 0.05$) [10].

In recent years, X-ray fluoroscopy shifted from film radiography to DRIIs, and FPDs have now come into mainstream use. FPDs have less distortion compared with DRIIs, with better spatial resolution and no halation.

In this study, we calculated the effective dose of the FPD in three settings: diagnostic workup, standard radiography I (population-based screening) and standard radiography II (opportunistic screening). We also compared the effective dose of an FPD with that of a DRII.

2. Materials and Methods

2.1 Materials

Subjects were 9,510 patients who underwent X-ray-based gastric X-ray examination at the Osaka Center for Cancer and Cardiovascular Disease Prevention between 1 July 2015 and 31 August 2016. An FPD (Sonialvision G4, Shimadzu Corporation, Kyoto, Japan) was used for 1,672 of the patients. Of these, 488 underwent diagnostic workup, 270 underwent standard radiography I screening and 914 underwent standard radiography II screening (Table 1-a). In addition, exposure was compared between the FPD and a DRII (SREX-D32C Aitella, Canon Medical Systems Corporation, Otawara, Japan) in 396 patients who underwent standard radiography I screening with either device (each n = 198). Exposure was also compared in 1436 patients who underwent standard radiography II screening with the FPD or DRII (each n = 718). The sex ratio and the number of radiological technologists were similar for both standard radiography I and II (Table 1-b).

An area dosimeter (Diamentor M4-KDK, PTW, Freiburg, Germany) was used to measure DAP and ESD (without backscatter). We used BariBright CL (210w/v%; Kaigen Pharma Co., Ltd., Osaka, Japan) as the barium sulfate formulation and 5.0 g Bargin foaming granules (Kaigen Pharma Co., Ltd.).

Table 1-a Number of patients who underwent diagnostic workup, standard radiography I (SRI) and standard radiography II (SRII) with the FPD and DRII

	SRI	SRII	Diagnostic workup	Total
FPD	270	914	488	1,672
DRII	2,047	5,783	8	7,838
Total	2,317	6,697	496	9,510

SRI: Standard Radiography I FPD: Flat Panel Detectors

SRII: Standard Radiography II DRII: Digital Radiography Image Intensifier

Table 1-b Comparison of number of patients, sex ratio and number of radiological technologists between SRI and SRII using the FPD and DRII

	SRI		SRII	
	FPD	DRII	FPD	DRII
Number of people	198	198	718	718
Gender ratio	36 : 64	37 : 63	33 : 67	34 : 66
Radiological technologist	15	15	14	14

2.2 Methods

To calculate the effective dose, we entered mean DAP (cGy cm^2) into Monte Carlo simulation software (PCXMC, ver. 2.0.1.3, Radiation and Nuclear Safety Authority - STUK, Helsinki, Finland). The following comparisons were carried out:

1. Comparison of DAP, ESD (mGy) and effective dose (mSv) of the FPD between diagnostic workup, standard radiography I and standard radiography II.
2. Comparison of maximum, median and minimum effective doses between the FPD and DRII in standard radiography I and II.
3. Comparison of DAP, ESD and effective dose between the FPD and DRII in standard radiography I and II.
4. Comparison of effective dose between the FPD and DRII in standard radiography I.
5. Comparison of effective dose between the FPD and DRII in standard radiography II.

The imaging conditions of the FPD were 86 kV, 320 mA and 34.9 ms, and those of the DRII were 82 kV, 100 mA and 28 ms.

Standard radiography I consisted of 8 views, as follows: 1) supine double contrast; 2) supine right anterior oblique double contrast; 3) supine left anterior oblique double contrast; 4) prone double contrast (anterior wall); 5) prone double contrast (upper anterior wall); 6) supine right anterior oblique double contrast (distribution); 7) supine left anterior oblique double contrast (distribution); and 8) standing position supine right anterior oblique double contrast. Standard radiography II consisted of 16 views: 1) double contrast (upper and lower oesophagus, 2-split shooting), 2) prone right anterior oblique double contrast, 3) supine left anterior oblique double contrast (upper fornix) and 4) compression shooting (4-split shooting). Diagnostic workup consisted of various scan methods and 23 views.

2.3 Statistical analysis

We used one-way analysis of variance (ANOVA) followed by the Bonferroni test to compare various parameters between diagnostic workup, standard radiography I and standard radiography II. We used the t-test to compare standard radiography I and II. The significance level was set at $p < 0.05$. Analyses were performed using PASW Statistics, ver. 18.0J (IBM SPSS Statistics, Chicago, IL).

2.4 Ethics committee

The protocol for this study was approved by the Ethics Committee of the Osaka Center for Cancer and Cardiovascular Disease Prevention.

3. Results

1. Comparison of DAP, ESD and effective dose of the FPD between diagnostic diagnostic workup, standard radiography I and standard radiography II. The exposure dose was high for diagnostic workup (19.66 mSv), standard radiography II (13.86 mSv) and standard radiography I (14.85 mSv) (Fig. 1 and Table 2). DAP and ESD were significantly different among the three settings.
2. Comparison of maximum, median and minimum effective doses between the FPD and DRII in standard radiography I and II.

   Data were obtained from 396 patients who underwent standard radiography I screening using the FPD or DRII (each n = 198) and from 1436 patients who underwent standard radiography II screening using either device (each n = 718). Maximum, median and minimum effective dose of the FPD and DRII in standard radiography I and II are listed in Table 3.

3. Comparison of DAP, ESD and effective dose between the FPD and DRII in standard radiography I and II.

   The effective dose of the FPD in standard radiography I was 12.70 mSv, and that of the DRII was 4.71 mSv. In standard radiography II, the effective dose was 14.29 mSv and 5.18 mSv, respectively (Table 4). DAP and ESD were significantly different between the FPD and DRII in standard radiography I and II.

4. Comparison of effective dose between the FPD and DRII in standard radiography I.

   The exposure dose of the FPD was higher than that of the DRII in standard radiography I (Fig. 2).

5. Comparison of effective dose between the FPD and DRII in standard radiography II.

   The exposure dose of the FPD was higher than that of the DRII in standard radiography II (Fig. 3).

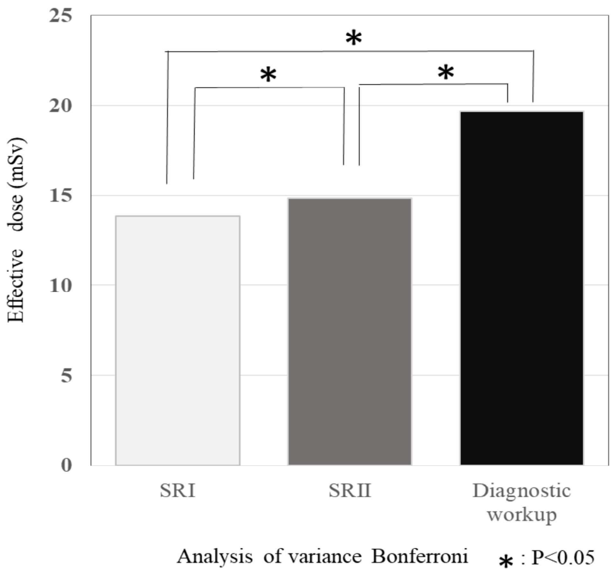

Figure 1. Comparison of effective dose of the FPD between diagnostic workup, SRI and SRII.

Table 2 Radiation doses of the FPD in diagnostic diagnostic workup, SRI and SRII

		SRI	SRII	Diagnostic workup
FPD	DAP (cGycm^2)	2,464.10	2,639.85	3,495.80
	ESD (mGy)	71.89	101.03	139.33
	Effective Dose (mSv)	13.86	14.85	19.66

DAP: Dose Area Product

ESD: Entrance Surface Dose

Table 3 Effective dose of the FPD and DRII in SRI and SRII

		SRI	SRII
FPD	maximum value	37.39	54.95
	median value	12.70	14.29
	minimum value	2.14	5.93
DRII	maximum value	21.29	28.82
	median value	4.71	5.18
	minimum value	0.70	0.63

(mSv)

Table 4 Radiation dose of the FPD and DRII for SRI and SRII

		SRI	SRII
FPD	DAP (cGycm^2)	2,259.00	2,570.70
	ESD (mGy)	69.09	100.27
	Effective dose (mSv)	12.70	14.29
DRII	DAP (cGycm^2)	1,047.62	1,151.64
	ESD (mGy)	36.40	48.50
	Effective dose (mSv)	4.71	5.18

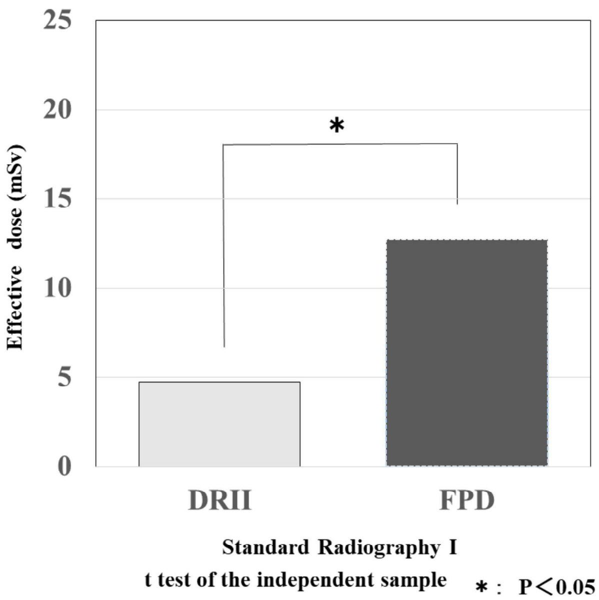

Figure 2. Comparison of effective dose between the FPD and DRII in SRI.

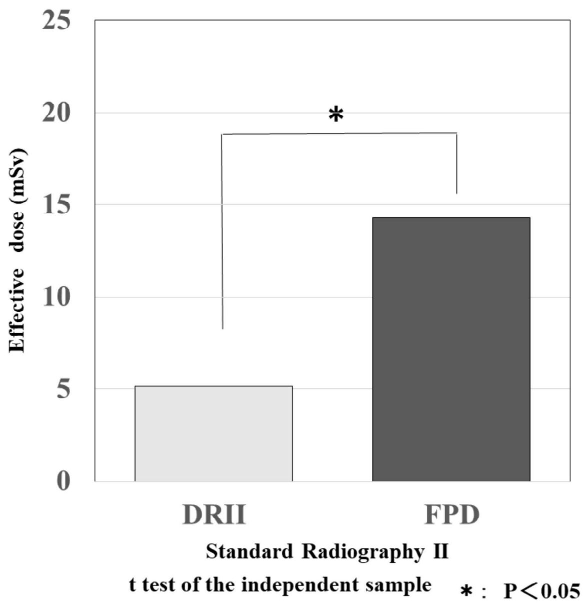

Figure 3. Comparison of effective dose between the FPD and DRII in SRII.

4. Discussion

Yamamoto et al.[1-4] performed film-based fluoroscopy by inserting filters A, B and C into a mean DAP meter, achieving dose reduction rates of 6.03%, 10.92% and 13.64%, respectively. However, such reductions are not currently possible for digital imaging. In 1995 and 1996, Maruyama et al.[5,6] reported a group effective dose of 4,000 Man Sv in mass screening of 7,000,000 cases. They estimated that the effective dose for each gastric X-ray evaluation was 0.57 mSv but did not report the number of images per subject. They estimated that the effective dose for each gastric X-ray evaluation was 0.57 mSv but did not report the number of images per subject. In addition, their method is not consistent with the present standard radiography I and II protocols; 0.57 mSv appears to be a low dose for one gastric X-ray examination. Yamamoto et al.[7] predicted that exposure during population-based screening radiography would be higher if high concentration, low-density barium preparations are used; however, there was no significant difference between fluoroscopy A-2 (3.44 mSv) and new (3.39 mSv), and the barium preparation did not lead to higher radiation exposure because the dose was mainly attributable to fluoroscopy. In a different study, Yamamoto et al.[9] demonstrated that the effective dose of one examination using a DRII in standard radiography I and II, calculated based on the New Gastric Radiography Guidelines, Revised Edition (2011)[8], was 4.41 mSv and 5.15 mSv, respectively ($P < 0.05$). In terms of patient factors, consideration needs to be given to 1) BMI, 2) methods of X-ray fluoroscopy (indirect and direct films, DRII, FPD, or CR), 3) imaging method (high concentration barium, foaming agent, etc.) and 4) experience of the radiological technologist.

In the present study, we found that the effective dose of the FPD was 19.66 mSv for diagnostic workup, 13.86 mSv for standard radiography I and 14.85 mSv for standard radiography II. Therefore, the effective dose of the FPD for gastric X-ray examination decreased in the order of diagnostic workup, standard radiography II and standard radiography I. In standard radiography I, the effective dose of the FPD was 12.70 mSv and that of the DRII was 4.71 mSv, while for standard radiography II, the respective values were 14.29 mSv and 5.18 mSv. As calculated according to the manufacturers' recommendations, the effective dose of the FPD was higher than that of the DRII in standard radiography I and II.

5. Conclusions

The effective dose of the FPD for gastric X-ray examination increased in the order of diagnostic workup, standard radiography II and standard radiography I. The effective dose of the FPD was higher than that of the DRII in standard radiography I and II.

Although radiation exposure was lower with the DRII than with the FPD for gastric X-ray examination, especially in the standard radiography I and II settings, doses must be further reduced for while maintaining image quality.

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Conflicts of interest

There are no conflicts of interest.

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