Average Glandular Dose and Entrance Surface Dose in Mammography

A. Kawaguchi [1*], M. Kobayashi [1], M. Suzuki [1], T. Otsuka[2], S. Hattori [3], S. Suzuki [3]

[1]Department of Radiology, Toyota memorial hospital, Aichi, 471-0821, Japan
[2]Department of Radiology, Daido hospital, Aichi, 475-8511, Japan
[3]School of Health Sciences, Fujita Health University, Aichi, 470-1192, Japan

Abstract: In general, dose evaluation for mammography uses average glandular dose (AGD). In mammography, entrance surface dose (ESD) is high, which is well known, but actual clinical data of ESD are not reported so much. This study investigated AGD and ESD for patients whose doses were estimated from 200 mammography examinations using European Organization for Quality-Assured Breast Screening and Diagnostic Services (EUREF) protocol. In addition, ESD is compared to breast surface dose for multidetector CT.

The digital mammography system (Amulet, Fujifilm Solutions) has full-field flat panel detector. This system uses an automatic exposure control system, which adjusts to exposure output in order to obtain appropriate image density in clinical practice. First of all, AGD and ESD for PMMA accrediting phantom were estimated, using automatic exposure control system, every 10 mm from 10 to 60 mm. Then, patient-based AGD and ESD were estimated from 200 women (the age of 40 to 70) who had a mammography in Toyota memorial hospital. Finally, breast surface dose in an anthropomorphic phantom was measured using thermoluminescent dosimeters during chest CT scan.

On examination of 40mm PMMA, the AGD and the ESD were 1.61 mGy and 6.06 mGy, respectively. The ESD was 3.8 times higher compared with the AGD. The result of calculating patient data shows that AGD and ESD per view averaged 1.71 mGy and 6.60 mGy. The breast surface dose for CT was measured 15.07 mGy. This dose was 1.1 times slightly higher compared with two-view mammography.

A mammography examination involves twice of exposure to obtain craniocaudal and mediolateral oblique views. The result of study indicates that a total ESD of a mammographic examination is equally high to breast surface dose of CT, the dose for mammography should be evaluated both AGD and ESD.

Key Words: *mammography; entrance surface dose; average glandular dose; quality control; chest CT scan*

1. Introduction

Mammography is high in radiation dose in diagnostic X-rays. Diagnostic X-rays are indicated that the radiation dose is as low as reasonably achievable while maintaining adequate image quality [1, 2]. In general, dose evaluation for diagnostic X-rays uses entrance surface dose (ESD). But for mammography, it estimates average glandular dose (AGD), because mammary glands have relatively higher sensitivity to some adverse effects of radiation than skin and fatty tissues. In Japan, the American College of Radiology (ACR) protocol [3] is commonly used as quality control procedures for mammography. And the ACR protocol recommends that AGD of an ACR accrediting phantom shall not exceed 3 mGy. Recently digital mammography systems such as computed radiography and flat panel detector have been increasing. Therefore, the European

*Presenting author, E-mail :ai_kawaguchi@toyota.co.jp

Organization for Quality-Assured Breast Screening and Diagnostic Services (EUREF) protocol [4, 5] has been used to evaluate exposure, too. The EUREF protocol establishes limiting values including acceptable level and achievable level for AGD every 10 mm Polymethylmethacrylate (PMMA) phantom from 20 to 70 mm. The ACR evaluates AGD of a specific phantom thickness and the EUREF evaluates AGD of each PMMA thickness. Since radiation dose in mammography is optimized under the condition of the levels of AGD and image quality, AGD has widely studied. And it is well known that ESD is high dose in mammography, but actual clinical data of ESD are not reported so much. This study investigated AGD and ESD for patients whose doses were estimated from 200 mammographic examinations, and compared ESD in mammography with breast surface dose for multidetector CT in order to assess the necessity of ESD for estimating the patient risk in mammography.

2. Materials and Methods

The digital mammography system, Amulet (Fujifilm Solutions) has full-field flat panel detector. This system determines target material, filtration and tube voltage by compressed breast thickness (CBT) and adjusts to exposure output (mAs) using an automatic exposure control (AEC) system to obtain appropriate image density in clinical practice. AGD is estimated from technical parameters, which are half value layer, entrance surface air kerma , CBT and breast tissue composition. Technical parameters to calculate ESD are entrance surface air kerma (without backscatter), CBT and backscatter factor. The half value layer was measured by a non-invasive analyzer, NERO mAx8000 (Victoreen) and entrance surface air kerma was measured by an ionization chamber, Model9015 (Radcal).

2-1. AGD and ESD every thickness for PMMA

AGD and ESD were estimated using PMMA phantom every 10mm from 10 to 60 mm in clinical practice. AGD and ESD were calculated according to the following equations (1), (2):

$$AGD = K_{gcs} \qquad (1)$$

Where K is the entrance surface air kerma (without backscatter) calculated at the upper surface. The factor g corresponds to a glandularity of 50%. The c-factor corrects for the difference in composition of typical breasts from 50% glandularity. The factor s corrects for differences due to the choice of X-ray spectrum. The factors are derived from the values calculated by Dance et al [6].

$$ESD = K * (BSF) \qquad (2)$$

Where K is the entrance surface air kerma (without backscatter) calculated at the upper surface. BSF is backscatter factor which is derived from the European Protocol on Dosimetry in Mammography [7].

2-2. patient-based AGD and ESD

This study collected technical parameters from 200 women (age 40 to 70) who had a mammography in Toyota memorial hospital, and estimated patient-based AGD and ESD in clinical practice by using equation

(1), (2). Women had no previous history of breast surgery and compression force exceeded 100N. A mammographic examination obtains four primary views (craniocaudal and mediolateral oblique views of each breast) and right mediolateral oblique view was used in this study.

2-3. Breast surface dose for chest CT scan

The computed tomography is AquilionONE (TOSHIBA). Thermoluminescent dosimeters (Kyokko, MSO-S) were placed on breast surface of an anthropomorphic phantom (Toyo medic) and were performed chest CT scan. And Table 1 shows the term of CT scan. The thermoluminescent dosimeters were measured by a thermoluminescent reader (Kyokko, Model 3000) and breast surface dose was calculated by multiplying the calibration constant.

Table 1. Terms of chest CT scan

	Scan mode	Tube voltage (kV)	Tube current (mA)	Slice thickness (mm)	Scan length (cm)	Tube rotation time (sev/rot)	Scan time (sec)	FOV (mm)	Helical pitch	CTDIvol (mGy)	DLP (Gy・cm)
Scano		120	10								
Scan	Helical	120	R233	0.5 (32.0)	350	0.5	7.8	320 (M)	53	13.2	327.7

3. Results

Figure 1 shows AGD and ESD for PMMA thickness from 10 to 60 mm. On examination of 40mm PMMA, the AGD and the ESD were 1.61 mGy and 6.06 mGy, respectively. The ESD was 3.8 times higher compared with the AGD. In 60mm PMMA, the AGD and the ESD were 3.38 mGy and 18.68 mGy, and the ESD was 5.5 times higher compared with the AGD.

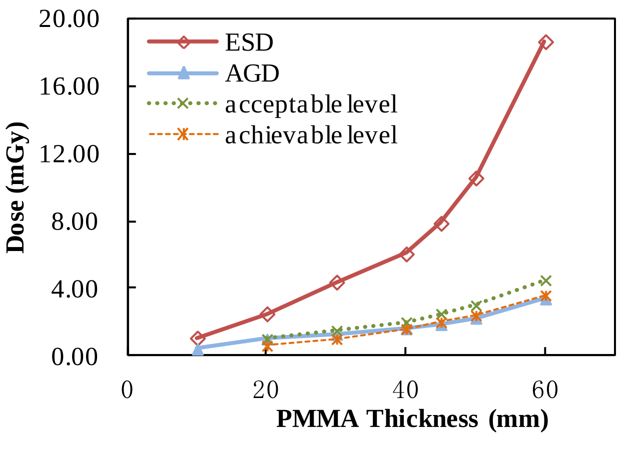
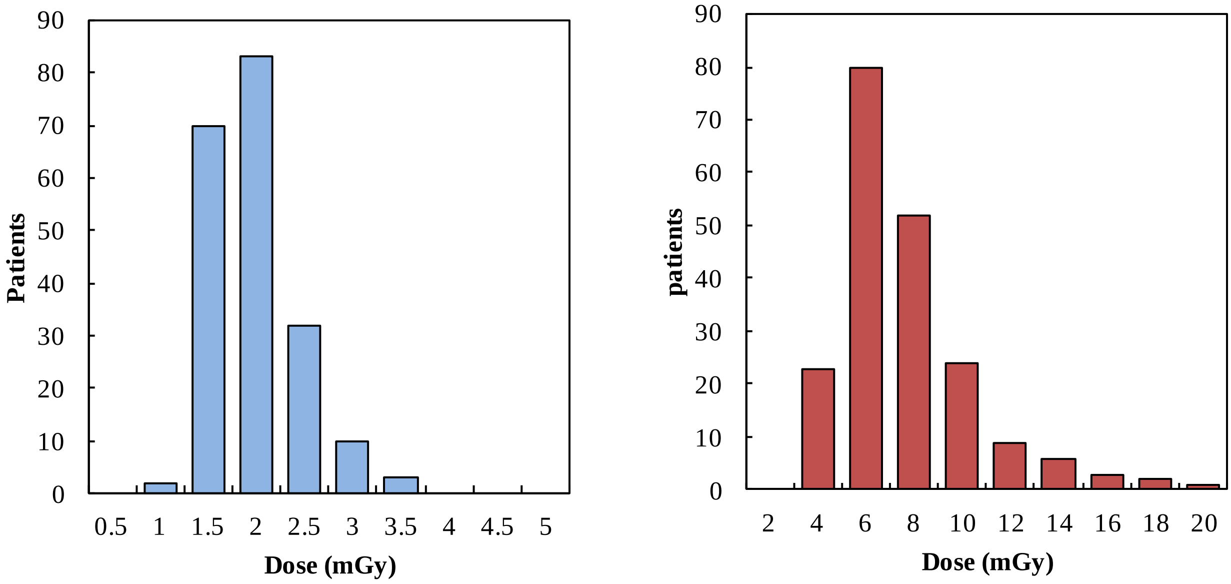


Figure 1. Average glandular dose (AGD) and entrance surface dose (ESD) every PMMA thickness and the limiting values (acceptable level and achievable level) for AGD by the European Organization for Quality-Assured Breast Screening and Diagnostic Services (EUREF) protocol

Figure 2 shows histograms of patient-based AGD and ESD. The peak in the AGD histogram was between 1.5 and 2 mGy, which is 77% of the total patients, and the peak in the ESD histogram was between 6 and 8 mGy, which is 66% of the total patients. The mean AGD was 1.71 ± 0.46 mGy and the mean ESD was 6.60 ± 2.88 mGy. The ESD was 3.9 times higher compared with the AGD. 21 patients exceeded ESD above 10 mGy, and the highest ESD was 18.96 mGy (the corresponding AGD was 3.23 mGy). Mean CBT in 200 patients was 36.89 ± 11.52 mm. Figure 3 shows distribution of patient-based AGD and ESD and line charts of AGD and ESD for a breast equivalent to each PMMA thickness. The patient-based AGD and ESD were higher than those for PMMA.



(a) average glandular dose (b) entrance surface dose

Figure 2. Histograms of average glandular dose (AGD) (a) and entrance surface dose (ESD) (b) for 200 patients.

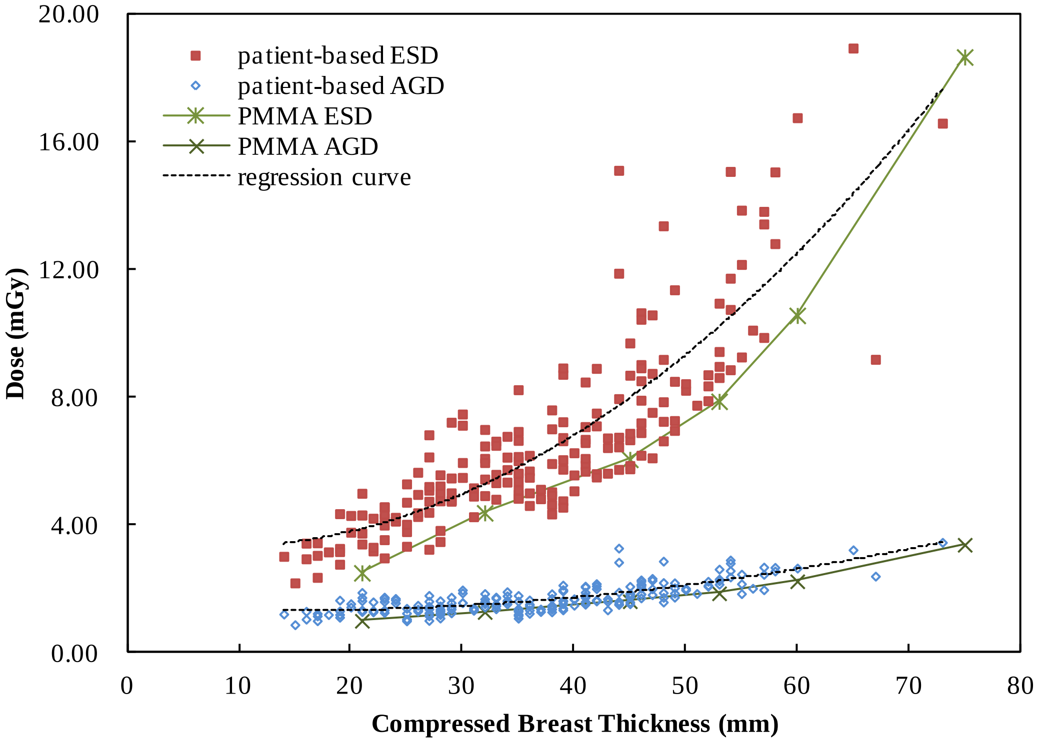


Figure 3. Distribution of patient-based average glandular dose (AGD) and entrance surface dose (ESD) for each compressed breast thickness (CBT), and line charts of AGD and ESD for a breast equivalent to each PMMA thickness

Table 2. Mean patient-based average glandular dose (AGD) and mean entrance surface dose (ESD) for compressed breast thickness (CBT) and coefficient of variation (CV)

Compressed breast thickness (mm)	n	Patient-based AGD		Patient-based ESD	
		Mean (mGy)	CV (%)	Mean (mGy)	CV (%)
10 ≦ CBT < 20	12	1.19 ± 0.19	16	3.10 ± 0.55	18
20 ≦ CBT < 30	49	1.43 ± 0.23	16	4.51 ± 0.88	20
30 ≦ CBT < 40	58	1.54 ± 0.24	15	5.89 ± 1.06	18
40 ≦ CBT < 50	54	1.91 ± 0.36	19	7.67 ± 2.08	27
50 ≦ CBT < 60	23	2.31 ± 0.31	13	10.62 ± 2.39	23
60 ≦ CBT < 70	3	2.76 ± 0.42	15	14.98 ± 5.12	34
70 ≦ CBT < 80	1	3.46	—	16.60	—
total	200	1.71 ± 0.45	27	6.60 ± 2.88	44

Table 3. Breast surface dose in chest CT scan and mean patient-based entrance surface dose (ESD) in mammography

Breast surface dose in chest CT scan (mGy)	Mean patient-based ESD in Mammography (mGy)	
	1 view	2 views
15.07	6.61	13.22

Table 2 shows the mean patient-based AGD and ESD every 10mm CBT from 10 to 80 mm. In the CBT between 40 and 50 mm, the mean AGD and ESD were 1.91 ± 0.36 mGy and 7.67 ± 2.08 mGy.

Breast surface dose in chest CT scan was compared with the mean patient-based ESD in mammography in Table 3. The breast surface dose in chest CT scan was measured 15.07 mGy. This dose was 2.3 times higher compared with the mean patient-based ESD per view. This result of CT 1.1 times slightly higher compared with the ESD in two-view mammography.

4. Discussion

The AGD over 45 mm PMMA satisfied the achievable level and every PMMA thickness was under the acceptable level (Fig 1). This unit satisfied the acceptable level by EUREF and was controlled exposure output lower than the standard levels as CBT increased.

The patient-based AGD was in the range of 0.5-3.5 mGy, the difference was approximately seven times, and the patient-based ESD was in the range of 2-20 mGy, the difference was approximately 10 times (Fig 2). The ESD was approximately four times higher than the AGD, and the ESD varied more widely than the AGD. Additionally, 10% of the total patients exceeded 10 mGy in ESD. These results suggested that ESD was needed to establish limiting values. Matsumoto et al [8] reported that mean CBT was 37.7 mm in Japan and this study was about the same in thickness.

The distribution of patient-based AGD and ESD were higher than those of PMMA for each thickness (Fig 3). Amulet determines the fixed HVL by CBT, and thus radiation dose depends on density of breast. The density of patient breast was probably more than that of PMMA for each thickness. The ESD varied more widely than the AGD as CBT increased without the range of 40-50 mm, which was barely high coefficient of variation (CV) 27%, in Table 2. This variation in the ESD suggested that the more CBT increased, the more widely the difference of exposure output controlled by density is.

Techniques controlling exposure output is different from mammography systems. Jamal et al [9] measured AGD and ESD of the ACR accrediting phantom for 30 mammography units by the ACR protocol and the AGD for all of units satisfied the limiting value of the ACR under 3.0 mGy (the mean AGD 1.23 mGy) but the ESD was such widely range as 1.34-15.05 mGy (the mean ESD 7.00 mGy). And Otsuka et al [10] found that 40 mm PMMA was equivalent to the ACR accrediting phantom. Therefore, in comparison with 40 mm PMMA in this study, the AGD of 40mm PMMA is barely higher than the mean AGD of the ACR accrediting phantom in 30 mammography units, but the ESD of 40mm PMMA is equal to the mean ESD of the ACR accrediting phantom. From the patient-based ESD for each CBT, it is useful in the quality control for patient dose to establish limiting values of ESD for each PMMA thickness as the same as those of AGD in the EUREF protocol. And further studies are needed to investigate different units and facilities for the establishment of ESD limiting values.

The ESD for two-view mammography was equal to breast surface dose in chest CT scan. As compared with the mean patient-based ESD for each CBT (Table 2), the mean ESD for two-view mammography over 40mm CBT was higher than breast surface dose in CT scan. As compared with other modality, ESD in a mammographic examination was clearly high.

5. Conclusion

The patient-based ESD in mammography averaged 6.60 ± 2.88 mGy/view and the mean patient-based ESD for two-view mammography was nearly equal to the breast surface dose in chest CT scan. The patient-based ESD varied the range of 2-20 mGy and was higher as CBT increased. This study suggests that it is useful for the quality control in mammography to establish limiting values of ESD for each PMMA thickness as well as AGD.

6. References

[1] IAEA: International Basic Safety Standards for protection against Ionization Radiation and for the Safety of Radiation Sources, Appendix 2. IAEA Safety Series, No.115, Vienna, 1996; 45-56.

[2] ICRP: 1990 Recommendations of the International Commission on Radiological Protection, ICRP Publication 60, Annals of ICRP 21(1–3), 1991.

[3] American College of Radiology Committee on Quality Assurance in Mammography: Mammography Quality Control Manual. American College of Radiology, 1999.

[4] Zoetelief J, Fitzgerald M, Leitz, et al: European Protocol on Dosimetry in Mammography. European Commission, Brussel, 1996.

[5] European Reference Organisation for Quality Assured Breast Screening and Diagnostic Services: European guidelines for quality assurance in breast cancer screening and diagnosis Fourth Edition. European Communities, The Netherkands, 2003.
[6] Dance DR, Skinner CL, Young KC, et al: Additional factors for the estimation of mean glandular breast dose using the UK mammography dosimetry protocol. Phys. Med. Biol 2000; 45, 3225-3240
[7] European Commission: European Protocol on Dosimetry in Mammography, Luxembourg, 1996.
[8] Matsumoto M, Nishizawa K, Akiyama Y, et al: The Mean Breast Thickness for Japanese Patients for Use in Estimating the Glandular Dose in Mammography. Journal of Japan Association of Breast Cancer Screening 2000; 9(1), 95-102.
[9] Jamal N, Ng KH, McLean D: A study of mean glandular dose during diagnostic mammography in Malaysia and some of the factors affecting it. British Journal of Radiology 2003; 76, 238-245.
[10] Otsuka T, Suzuki S, Ogura M, et al: Dose Evaluation in Mammography for Japanese Breast Thickness. Japanese Journal of Radiological Technology 2011; 67(5), 483-489.