

Invivo Dosimetry for Mammography with and without Lead Apron Using the Glass Dosimeters

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The purpose of this study is to see the usefulness of lead apron for critical organs near the breast under examining. For clinical experiment, 30 female volunteers who agreed to their participation in the experiments, were chosen and divided into two groups, 15 in group A and 15 in group B respectively. group A is to see whether each side of breast under mammography affects to other side glandular on the critical organs is same, because it is not allowed to scan the both breast for same person or to scan repeatedly. Group B is to see the effectiveness of lead apron during the mammography of right breast. Glass dosimeters were placed on the thyroid, the contralateral breast, and lower abdomen where near the breast during examining. The average glandular doses on the surface in mammography of the thyroid gland, the contralateral breast, the lower abdomen were 0.0692 mGy, 0.6790 mGy, and 0.0122 mGy, respectively, which was an extremely low level of glandular dose. In group B, as to the thyroid gland, average dose was decreased from 0.0922 mGy to 0.0158 mGy. The average dose of contralateral breast was decreased from 0.8575 mGy to 0.0286 mGy. The average doses of lower abdomen was decrease 0.0150 mGy to 0.0173 mGy. As to the lower abdomen, dose decreased from 0.0150 mGy before the use of an apron down to 0.0173 mGy after the use. As p-value was under 0.05, statistically significant difference was observed between the two groups. Wearing an apron can have the protective effects on the thyroid gland up to 20 times lower than not wearing one. Besides, it is also necessary to protect the other breast during the examination by wearing one.

Key Words: Lead apron, Mammography, Glass dosimeter, Invivo dosimetry

Introduction

During the mammography, even a low level of exposure may involve stochastic effects and it may cause harms to the human body.¹⁾ As the breast parenchyma is quite sensitive to

radiation, the risk of carcinogenesis is a consistent issue with regard to mammography, and the measurement of mean glandular dose (MGD) is an important item to assess the quality of the mammography.²⁾ Especially when the mammogram is used for breast diagnosis, some critical organs such as the thyroid gland and gonad (womb) may involve various side effects due to a low level of exposure to radiation.³⁾ In 2003, International Commission on Radiological Protection (ICRP) released the diagnostic reference level, in reference to which, the radiation exposure level can be measured in the mammogram for the nationwide application. International Atomic Energy Agency (IAEA): Basic Safety Standards (BSS) No.115 also recommends that the MGD in a craniocaudal projection should be under 3 mGy.⁴⁾ Accordingly, the research on the MGD has been con-

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ducted for domestic mammogram equipment and specified the diagnostic reference level (DRL) to 1.36 mGy. The study on reduction of the exposure level has continued.⁵⁾ MGD is managed by government according to the recommendation. On the contrary, the entrance surface dose (ESD) for each organ cannot be managed since the glandular dose of each person's major organs are vary depending on her breast thickness and breast parenchyma as well as her physical build.

The aim of this study is to evaluate the effectiveness of radiation lead apron for real patients' critical organs by in-vivo dosimetry.

Experimental Procedure

As to the study object, 30 female volunteers who agreed to their participation in the experiments, were chosen and divided into two groups, 15 in group A and 15 in group B respectively (Table 1). Group A is to see whether each side of breast under mammography affects to other side glandular on the critical organs is same, because it is not allowed to scan the both breast for same person or to scan repeatedly. Group B is to see the effectiveness of lead apron during the mammography of right breast.

The average age of group A was 52.8 years, the average tube peak voltage 27 kVp, and the tube current 121.2 mAs respectively. The average age of group B was 54.3 years, the tube peak voltage 27.3 kVp, and the tube current 124.2 mAs, respectively.

1. Calibration of the glass dosimeter

In order to calibrate the glass dosimeters (GD-304, ATGC, Japan) used in this study, the tube current was fixed, and the GD response value of the glandular dose depending on the tube voltages was measured while the tube voltage was fixed and the GD response value depending on the tube current was

measured.

In experiment, 4 sheets of boluses (15×15×1 cm³) which made of equivalent material to water, were build up to 4 cm thick. It is reported that most of native women have dense breasts and the thickness of a compressed breast is 3.8 cm on average.⁵⁾ The GDs were placed on the surface of it and irradiated. To assess MGD of volunteers, MGD values calculated at the device were recorded depending on the examination condition. With the medium values of the equipment 27 kVp and 120 mAs fixed, the tube current was set to 60~220 mAs and 120 mAs, and then the tube voltage of 24~32 kVp was examined at five different steps.

2. Bias test of left and right breasts

The effectiveness of lead apron was conducted only for mammography on the right breast. Therefore, it was necessary to see any differences between the right and the left breasts. The bias test was conducted to 15 volunteers in Group A. The mammography used in the experiment was the craniocaudal projection, which images the breasts in directions upward and downward with the person's body facing the mammography (Selenia, Lorad Hologic, USA).

In the examinations of the left breasts of 15 volunteers in Group A, GDs were placed on the right breasts (between the sternum and papillary), on the contrary, in the examination of the right breast, GDs were placed on the left breasts. The GDs were placed at the thyroid gland (2~3 cm below the thyroid cartilage, the projecting part over the neck area), and the lower abdomen (5 cm below the navel) in both cases (Fig. 1).

3. Effectiveness of lead apron

The other study was conducted for Group B to evaluate the difference in the doses depending on the use of a lead apron. The imaging was conducted over the right breast for 15 volunteers in group B, and the dose to the other breast (left), thyroid

Table 1. Characteristics of volunteers between Group A and B.

Group	Mean age (Y)	Rt. Breastmean thickness (cm)	Lt. Breastmean thickness (cm)	Mean tube peak voltage (kVp)	Mean tube current (mAs)
A	52.8	4.2	4.2	27	121.2
B	54.3	4.5	4.5	27.3	124.2

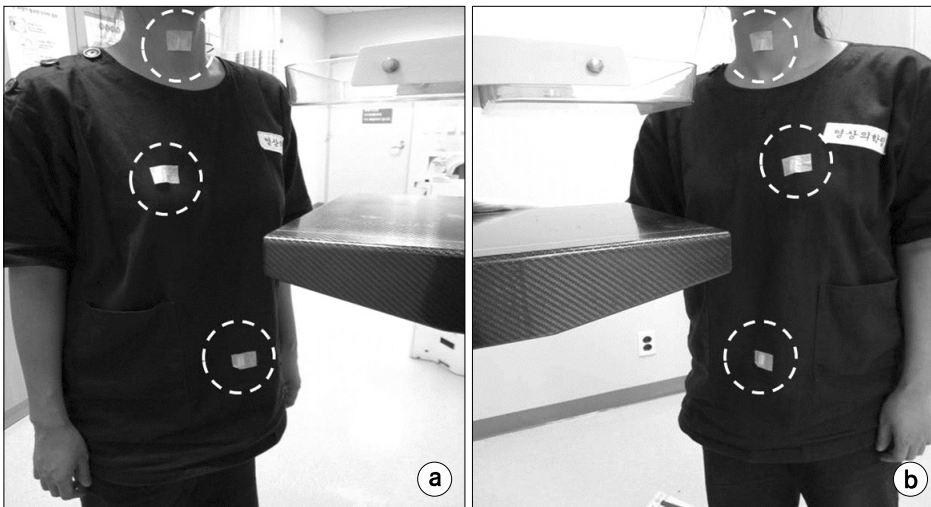


Fig. 1. Positions of GDs applied on the volunteers to see the bias of left and right mammography. Dotted circles indicate the positions of GDs. (a) GD positions of group A for mammography on the left cc view, (b) GD positions of group A for mammography on the right cc view.

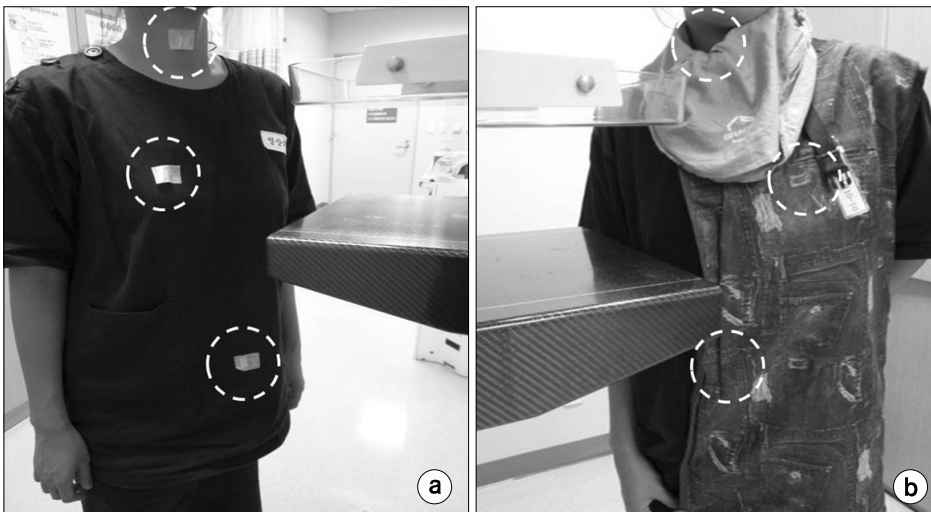


Fig. 2. Positions of GDs applied on the volunteers to see the effectiveness of apron. Dotted circles indicate the positions of GDs. (a) GD positions of group B for mammography on the left cc view, (b) GD positions of group B for mammography on the right cc view.

gland, and lower abdomen was measured to examine the performance of the lead apron. In the Lt CC view examination, no apron was applied with GD at the right breast, thyroid gland, and lower abdomen while in the Rt. CC view examination. An apron was used with GD at the left breast, thyroid gland, and lower abdomen. The imaging condition were Mo/Rh filter and auto exposure. During the examination, the volunteer was covered with the thyroid Shield (0.25 mmPb) and the apron (0.25 mmPb) (Fig. 2).

Results

The GDs were calibrated with same quality of x-ray as mammography unit. The dependency of GDs for tube current and voltage shows that the entrance surface dose (ESD) at the tube current of 60 mAs was 5.8 mGy, MGD 1.1 mGy, that at 220 mA 21.1 mGy, and MGD 3.9 mGy with 27 kVp fixed respectively. With 120 mAs fixed, ESD at the tube voltage of 24 kVp was 7.6 mGy, MGD 1.2 mGy and that at 32 kVp ESD 19.7 mGy, and MGD 4.2 mGy respectively.

Fig. 3 shows the correlation among ESD, MGD, and GD in graph depending on the given conditions. In this study, the ESD to GD ratio was measured 0.544 while the ESD to MGD

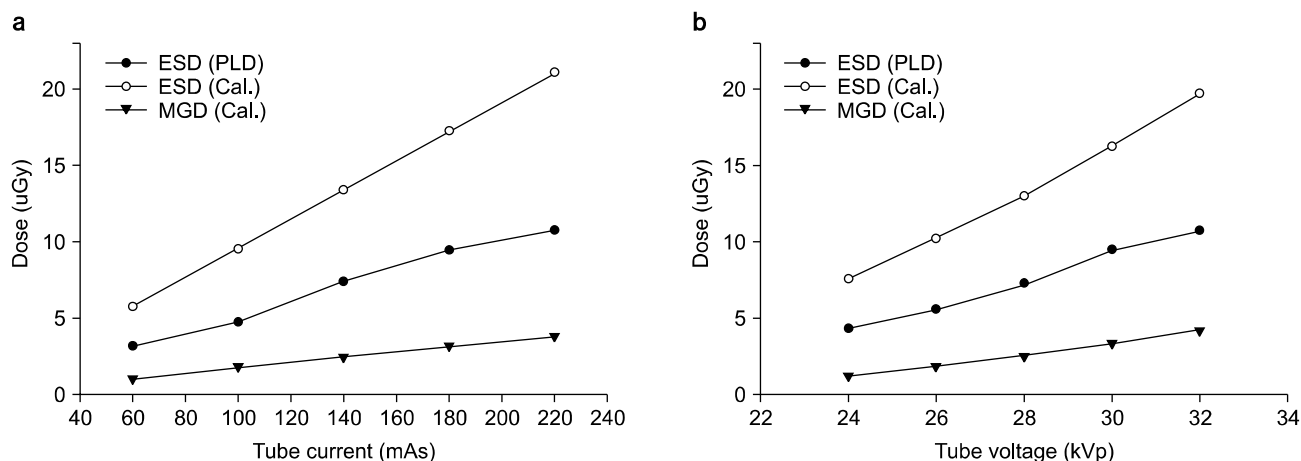


Fig. 3. Absorbed dose calculated from mammogram and measurements using glass dosimeter. (a) Tube current dependency when tube voltage at 27 kVp. (b) Tube voltage dependency when tube current at 120 mAs.

Table 2. Bias of left and right mammography; there are no differences between left and right.

	Left craniocaudal mammography (mGy)		Right craniocaudal mammography (mGy)		p-value
	SED (MGD)		SED (MGD)		
Thyroid	0.0692 (0.0129)		0.0607 (0.0113)		0.471
Left breast	N.A		0.4062 (0.0760)		0.565
Right breast	0.6790 (0.1270)		N.A		
Lower abdomen	0.0122 (0.0023)		0.0166 (0.0031)		0.617

Table 3. Difference between entrance surface doses with and without lead apron (average).

	Without apron (uGy)		With apron (uGy)		p-value
	ESD (MGD)		ESD (MGD)		
Thyroid	0.0922 (0.0172)		0.0158 (0.0030)		0.000
Left breast	0.8575 (0.1604)		0.0286 (0.0054)		0.015
Lower abdomen	0.0150 (0.0028)		0.0173 (0.0032)		0.734

ratio was 0.187. And these factors were applied after the mammography.

As to the MGD on the surface in mammography, that of the thyroid gland was 0.0692 mGy (ranged 0.0601~0.0921 mGy), that of the contralateral breast 0.6790 mGy (ranged 0.4062~0.8576 μ Gy), and the lower abdomen 0.0122 mGy (ranged 0.0117~0.0167 mGy), respectively, which was an extremely low level of glandular dose (Table 2). As p-values at the thyroid gland between Rt. CC and Lt. CC, breasts, and lower abdomen were insignificant and thus no statistical difference was observed. It was considered the dose to the organs near the breast during

the mammography was ignorable.

In Group B, the region likely to be exposed to a high level of glandular dose was the contralateral breast (Table 3). The dose was 0.8575 mGy before the use of an protection apron while that after the use of one decreased down to 0.0286 mGy, which indicates about 30 times greater covering effects. As to the thyroid gland, the dose decreased from 0.0922 mGy before the use of an apron down to 0.0158 mGy after the use, which indicates that the glandular dose about 6 times decreased. As p-value was under 0.05, statistically significant difference was observed between the two groups. In contrast,

p-value of the lower abdomen was 0.734, which was not statistically significant. Therefore the apron for lower abdomen was not effective for lead.

Averaging the reading which shown in the monitor during the mammography, the minimum was 2.4 mGy and the maximum was 2.6 mGy, which range meets the criteria 3 mGy of the international regulation which agreed with IAEA and six other countries.⁴⁾

Discussion and Conclusions

This study is to evaluate the effectiveness of lead apron during the mammography by measuring dose using the GD. As a result of inspecting Lt. cc of group A, in which the individuals did not wear an apron, and group B, the dose range on the surface of the thyroid glands of the volunteers was 0.0601~0.0921 mGy, that of the other breasts 0.4062~0.8576 mGy, and that of the lower abdomen 0.0117~0.0167 mGy respectively, which indicates that the level differed depending on individuals. The study result shows that when the lead apron was used, the absorbed dose of the thyroid gland surface decreased as much as 83.3% compared to when the apron was not used, and the decrease rate of the contralateral breast was 96.7%. In consideration of the fact that such other methods as lead goggle, thyroid shield, and apron-used phantom that are commonly used now and reported to decrease the dose as much as 47.72%, the method introduced in this study is more effective in reducing the exposure rate when applied to actual volunteers.⁸⁾

Lee et al. reported that thyroid exposed to 14% (0.15 mGy) of breast dose (1.09 mGy) during mammography.⁶⁾ In this study for Group A, the thyroid dose measured as 2.8% (0.07 mGy) of breast dose (2.5 mGy), which is much less than other study.⁷⁾

The results from the Monte-Carlo simulation showed that the absorbed doses to the thyroid and the contralateral breast during the mammography were 0.0036 mGy and 0.0396 mGy, respectively. Therefore, the study resulted that the apron was

not so effective to shield organs during the mammography.⁷⁾

The differences of thyroid doses seemed to be caused by the difference of measurement methods.

Use of lead apron which made with lead can effectively reduce the dose to other critical organs, but in clinics the apron is hardly used since it is heavy and uncomfortable. Hong et al. tried to overcome the limitation of conventional apron. They developed the apron made with aluminum, and it can reduce the dose up to 65.8% in CC mammography and 60.7% in MLO mammography.⁸⁾

Unlike other studies, this study shows the usefulness of lead apron by in-vivo dosimetry for real volunteers. The limitation was that only CC view was tested not MLO view, and a specific machine was used. Further study should be on various machine and techniques.

References

1. A. D. Wrixon, New ICRP recommendations. *J. Radiol. Prot.* 28, 161 (2008).
2. M. John and P. Boone, Glandular Breast Dose for Monoenergetic and High-Energy X-ray Beams: Monte Carlo Assessment. *Med. Phys.* 213, 23 (1999).
3. ICRP, Recommendations of the International Commission on Radiological Protection. Publication 60, 1991, 21.
4. IAEA, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. DS379 Paragraph Tracking from SS115, 2009:p. 209.
5. Ministry for health, w.a.f.a., Diagnostic reference level guide line for mammography. 2008. 16:p. 23.
6. M.H. Lee, K. R. Dong, S. J. Park, Y. S. Song, C. H. Cho, and M. I. Sanchez, The Effect of Scattering Dose on the Thyroid During Mammography. *Journal of the Korean Institute of Electrical and Electronic Material Engineers*, 23, 826 (2010).
7. I. Sechopoulos, S. Suryanarayanan, S. Vedantham, C. J. D'Orsi, and A. Karellas, Radiation Dose to Organs and Tissues from Mammography: Monte Carlo and Phantom Study. *Radiology* 246, 434 (2008).
8. Hong E-H, Study on the usefulness and aluminum Face Block developed for dose reduction of the lens and thyroid mammography. KOREA UNIVERSITY. (2012).

유방촬영술에서 유리선량계를 이용한 납치마의 선량차폐 효과 측정

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본 연구는 유방촬영술을 시행할 때 유방인접조직의 생체내선량 측정을 통해 방호복 착용의 유용성을 평가하고자 한다. 이를 위해 유방검진을 받는 일반 여성 중 연구의 목적과 방법을 정확히 이해하고 동의한 환자 30명을 대상으로 유방촬영시 유리선량계를 이용하여 측정을 실시 하였다. 유리선량계의 교정값을 구하기 위하여 팬텀(ACR phantom)을 이용하여 촬영 변수중 각각 관전압과 관전류의 중간값(27 kVp, 120 mAs)고정 시 mAs와 kVp를 변화시켜 장치에서 계산된 선량을 얻어 유리선량계 소자의 교정값을 구하였다. 측정 그룹은 방호복을 착용하지 않는 A 그룹과 착용하지 않은 B 그룹으로 나누었다. 생체내 선량측정 특성상 동일한 환자를 대상으로 반복 촬영을 할 수 없으므로 A 그룹은 좌 우 유방촬영에 따라 인접 정상조직의 선량이 차이가 없을 보고자 하였다. B 그룹은 한쪽 유방은 방호복으로 차폐를 하고 다른 쪽 유방은 방호복으로 차폐를 하지 않음으로 그 차이를 보고자 하였다. 인접 정상조직 측정에는 갑상선, 검사반대측 유방, 하복부로 각각의 부위에 유리선량계를 위치시켜 측정하였다. 실험 결과 유방촬영 시 입사표면선량은 A그룹의 경우, 왼쪽유방 상하방향 검사 시 갑상선은 0.0692 mGy, 오른쪽 유방은 0.6790 mGy, 하복부의 선량은 0.0122 mGy로 나타났고, 오른쪽 상하방향 검사 시에는 각각 0.0607 mGy, 0.4062 mGy 그리고 0.0166 mGy로 측정되었다. B그룹의 입사표면선량은 왼쪽유방 상하방향 검사 시 갑상선, 오른쪽 유방, 하복부의 선량이 각각 0.0922 mGy, 0.8575 mGy, 0.0150 mGy로 나타났다. 방호복을 착용한 오른쪽 상하방향 검사는 갑상선이 0.0158 mGy, 왼쪽유방은 0.0286 mGy, 하복부가 0.0173 mGy의 선량을 보여 갑상선과 유방의 선량이 대폭 감소되었고 통계적으로 유의하였다($p < 0.05$). 모니터의 유선선량을 관찰해 보면 A, B그룹 모두 권고값인 3 mGy 이하의 선량값을 보였다. 본 연구 결과 유방촬영시 환자의 결정장기가 받는 표면선량은 모두 기준치 이하의 선량을 보였으나 방호복 착용에 따른 선량 저감 효과를 볼 수 있어 방호복의 유용성을 확인할 수 있었다.

중심단어: 납치마, 유방촬영술, 유리선량계, 생체내선량 측정