Effect of filter on average glandular dose and image quality in digital mammography

C Songsaeng¹, A Krisanachinda¹ and K Theerakul²

¹Department of Radiology, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand
²King Chulalongkorn Memorial Hospital, Bangkok Thailand

E-mail: chatsuda.song@gmail.com

Abstract. To determine the average glandular dose and entrance surface air kerma in both phantoms and patients to assess image quality for different target-filters (W/Rh and W/Ag) in digital mammography system. The compressed breast thickness, compression force, average glandular dose, entrance surface air kerma, peak kilovoltage and tube current time were recorded and compared between W/Rh and W/Ag target filter. The CNR and the figure of merit were used to determine the effect of target filter on image quality. The mean AGD of the W/Rh target filter was 1.75 mGy, the mean ESAK was 6.67 mGy, the mean CBT was 54.1 mm, the mean CF was 14 lbs. The mean AGD of W/Ag target filter was 2.7 mGy, the mean ESAK was 12.6 mGy, the mean CBT was 75.5 mm, the mean CF was 15 lbs. In phantom study, the AGD was 1.2 mGy at 4 cm, 3.3 mGy at 6 cm and 3.83 mGy at 7 cm thickness. The FOM was 24.6, CNR was 9.02 at thickness 6 cm. The FOM was 18.4, CNR was 8.6 at thickness 7 cm. The AGD from Digital Mammogram system with W/Rh of thinner CBT was lower than the AGD from W/Ag target filter.

1. Introduction
Mammography is the process of using low-dose X-ray to examine the human breast. It is used as a diagnostic as well as a screening tool. The goal of mammography is early detection of breast cancer, typically through detection of characteristic of the masses and micro-calcifications. In this respect, mammography is believed to reduce mortality of breast cancer. The radiation exposure associated with mammography is a potential risk of screening which is greater in younger women. Research has shown the risk of breast cancer for asymptomatic women under 35 years is not high enough to warrant the risk of radiation exposure [4]. For this reason, and because the radiation sensitivity of breast tissue in women under 35 years is possibly greater than that of older women, screening mammography is not recommended in women under 40 years old. However, if there is high risk of cancer in patients, mammography may still be important. Digital Mammography system, in 2003, molybdenum target and molybdenum or rhodium filters were introduced. Currently, tungsten-rhodium and tungsten-silver target-filters are used in the latest development, resulting in reduction in the average glandular dose and the entrance surface air kerma [5, 7]. The spectrum was suit for various breast thicknesses. The optimal energy band and breast thickness was 14-18 keV for 2 cm, 17-21 keV for 4 cm, 19-23 keV for 6 cm and 20.5-23.5 keV for 8 cm. The K-edge Rhodium was 20.2 - 22.8 keV. The characteristics of the new digital detectors use anode filter combinations W/Rh, W/Ag which have some advantages for
imaging dense or thick breasts. Breast doses associated with these combinations (Rh/Rh, W/Rh, W/Ag, W/Al) are lower than those delivered with Mo/Mo or Mo/Rh. The threshold value for breast thickness where the spectrum changes depends on the AEC calibration. The correct selection of the X-ray beam will strongly influence the dose and image quality. Williams and colleagues [5] studied the impact of selection of exposure factors on image quality and dose for range of breast thickness and tissue type. They use the figure of merit (FOM) (contrast to noise ratio/ mean glandular dose) to compare the technique factors of all available target filter combination.

2. Material and methods

2.1. Patient group
Our retrospective study involved recruitment from 28 January to 1 September 2015 and compilation of patient data collected 400 mammograms from 200 women and included contact, automatic exposure control (AEC) mammograms of cranio-caudal and medio-lateral projections from preventive examinations, screening and after care.

2.2. Mammographic system
The study was performed using the Digital Mammography system (Hologic Selenia Dimension). This system has a dual track X-ray tube with a filter combination Tungsten (W) anode with Rhodium (Rh) filter and Tungsten (W) anode with Silver (Ag) filter. Focal spot sizes are 0.3 mm for contact examinations and 0.1 mm for magnification examinations. The 18 cm × 14 cm digital detector was used with a pixel size is 100 µm. The use of this digital detector offers the opportunity to directly acquire digital mammograms with a 14-bit resolution resulting in more than 16,000 gray levels. After exposure the images are displayed on a 2 k × 2.5 k monitor. All images were acquired with a grid. The following information was recorded for each mammogram: tube voltage (kVp); post exposure tube loading (mAs), target and filter materials, compressed breast thickness (mm), compression force (lbs.), the patient dose: AGD (mGy), ESAK (mGy) for CC and MLO projections for both breasts. The records were analyzed and AGD and ESAK between tungsten-rhodium target-filter and tungsten-silver target-filter were compared.

2.3. Determination of the image quality in phantom
The contrast to noise ratio (CNR) and the figure of merit (FOM) are estimated for the image quality using BR12 phantom and ACR phantom [2]. At 7 cm of compressed breast thickness the W/Rh filter was automatically changed to W/Ag filter. The study was performed by using ACR phantom (4 cm) and BR12 phantom was added 1.2 cm under ACR phantom. The system was operated by the automatic exposure control. The CNR for each filter were calculated by drawing the square of ROI (3×3 mm²) in object and background. The CNR and FOM were calculated according to the work of Y. Ruiz-Gonzalez et al. [2] (1), (2) and based on the definition of the European guidelines for quality assurance in mammography screening [4].

\[
\text{CNR} = \frac{I_{\text{obj}} - I_{\text{back}}}{I_{\text{back}}} \times 100
\]  

(1)

\[
I_{\text{obj}} = \text{the mean intensity values of a given ROI}
\]

\[
I_{\text{back}} = \text{the intensity values of background selected}
\]

\[
\text{FOM} = \frac{\text{CNR}^2}{\text{AGD}}
\]

(2)

CNR = Contrast to noise ratio and AGD = Average glandular dose.

3. Results
The mean and standard deviation of important parameters in the ACR and BR12 phantoms are summarized in table 1. The phantom average glandular dose (AGD) in different thickness are provided in figure 1. The figures of merit (FOM) of phantom in different breast are provided in figure 2. The mean important parameters of patient are summarized in Table 2. The patient average glandular dose (AGD) of both filters in different position (Cranio-caudal and Medio-lateral view) are provided in figures 3 and 4.

Table 1. Summary of parameters in ACR phantom and BR12 phantom

| Compressed breast thickness (cm) | Target/Filter | AGD (mGy) | ESAK (mGy) | kVp | CNR (%) | FOM (mGy⁻¹) |
|--------------------------------|---------------|-----------|------------|-----|---------|-------------|
| 4                              | W/Rh          | 1.2       | 3.7        | 28  | 9.97 ± 0.13 | 83 ± 2.5    |
| 6                              | W/Rh          | 3.3       | 10.1 ± 0.3 | 28  | 9.02 ± 0.41 | 24.6 ± 1.9  |
| 7                              | W/Ag          | 3.83 ± 0.3| 10.6 ± 2.1| 33  | 8.6 ± 0.42  | 18.4 ± 2.4  |

AGD, average glandular dose; ESAK, entrance surface air kerma; SNR, signal to noise ratio; CNR, contrast to noise ratio.

Figure 1. AGD per exposure as a function of CBT in phantom study.

Table 2. Summary of parameters of W/Rh and W/Ag in 200 patients

| W/Rh target-filter (CC view) | AGD (mGy) | ESAK (mGy) | CBT (mm) | CF (1bs.) | kVp | mAs |
|------------------------------|-----------|------------|----------|-----------|-----|-----|
| Ave                          | 1.7       | 6.67       | 54       | 14.05     | 29.5| 145.06 |
| Min                          | 0.7       | 1.8        | 32       | 4.4       | 26  | 61  |
| Max                          | 3.79      | 16.45      | 69       | 22        | 32  | 289 |

| W/Ag target-filter (CC view) | AGD (mGy) | ESAK (mGy) | CBT (mm) | CF (1bs.) | kVp | mAs |
|------------------------------|-----------|------------|----------|-----------|-----|-----|
| Ave                          | 2.6       | 12         | 75.5     | 14.9      | 31  | 196.4|
| Min                          | 1.76      | 7.86       | 64       | 4.3       | 30  | 115 |
| Max                          | 5.73      | 25.3       | 86       | 26.5      | 33  | 398 |
3.1. In phantom study
The FOM of W/Rh target filter was 24.6 ± 1.9 kVp was 28, CNR was 9.02 ± 0.41, the AGD was 3.3±0.09 mGy, and the ESAK was 10.1±0.3 mGy at phantom thickness 6 cm. The FOM of W/Ag target filter was 18.4 ± 2.4 at kVp 33, CNR was 8.6± 0.42, the AGD was 4±0.3 mGy, and the ESAK was 10.6±2.1 mGy at phantom thickness 7 cm. The relationship between CBT and patient AGD in both CC and MLO views are given in figures 3 and 4, respectively. The lines of best fit demonstrate that the AGD increases with thick breast. The AGD of W/Ag target filter is higher than W/Rh target filter as increasing the CBT, however, as a function of breast thickness. The relationship between CBT and AGD in phantom study are given in Figures 1, the AGD increases with the phantom thickness. The relationship between CBT and FOM in phantom study is given in figures 2, the FOM is affected by kVp, target filter and the phantom thickness.

4. Discussion
Our results are similar to S. Emanuelli1 et al. [6] who compared the AGD from digital mammography systems using W/Rh and W/Ag target filters. The mean AGD of W/Rh was 1.37 mGy, the mean CBT was 48.3 mm. The mean AGD of W/Ag was 2.84 mGy, the mean CBT was 75mm. In our study, the mean AGD of W/Rh was 1.7 mGy, the mean CBT was 54 mm. The mean AGD of W/Ag was 2.6 mGy, the mean CBT was 75.5 mm. Flynn’s et al. [3] studied the relationship between FOM and tube voltage of W/Rh and W/Ag. FOM is highest at kVp 28 for W/Rh target filter at 33 and 22 mGy^{-1} at kVp 26 for W/Ag target filter. Our study, the FOM decreased from 24 to 18 at thickness 6 to 7 cm for W/Rh and W/Ag target filter. The kVp was 28 for phantom thickness 4 and 6 cm of W/Rh target filter and 32 for phantom thickness 7 cm of W/Ag target filter. The AGD was 1.7 mGy for W/Rh, 2.6 mGy for W/Ag at higher CBT. All are less than the IAEA DRL of 3.0 mGy with grid for CC projection [7].

5. Conclusion
The AGD from Digital Mammogram system with W/Rh of thinner compressed breast thickness was lower than the AGD from W/Ag, although this difference may not hold for patients with similar breast thickness. The FOM and CNR decrease with the compressed breast thickness.

References
[1] Haie-Meder C et al. 2005 Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group (I): Concepts and terms in 3D image based 3D treatment planning in cervix cancer brachytherapy with emphasis on MRI assessment of GTV and CTV Radiother Oncol 74 235-245
[2] Cancer Care Ontario 2014 Imaging Strategies for Definitive Intracavitary Brachytherapy of Cervical Cancer: Recommendation Report (Ontario, Canada: Cancer Care Ontario)
[3] Pötter R 2002 Vienna method In: Gerbaulet A, Potter R, Haie-Meder C, editors. Cervix cancer. GEC ESTRO handbook of brachytherapy (Brussels: ESTRO) p. 331–8.

[4] Tanderup K 2014 Physics aspects of treatment planning intracavitary +/- interstitial techniques in cervix cancer. ESTRO Teaching Course Image Guided Radiotherapy & Chemotherapy in Gynecological Cancer (Firenze: ESTRO)

[5] Tanderup K et al. 2010 From point A to the sculpted pear: MR image guidance significantly improves tumour dose and sparing of organs at risk in brachytherapy of cervical cancer Radiother. Oncol. 94 173-180

[6] Onal C et al. 2009 Comparison of conventional and CT-based planning for intracavitary brachytherapy for cervical cancer: target volume coverage and organs at risk doses J. Exp & Clinical Cancer Research 28 95

[7] Madan R et al. 2014 Comparative evaluation of two-dimensional radiography and three dimensional computed tomography based dose-volume parameters for high-dose-rate intravitary brachytherapy of cervical cancer: A prospective study Asian Pacific J. Cancer Prevention 15 4717-21