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## The patient dose from digital mammography systems using molybdenum and tungsten targets

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**Background** : *Two digital mammographic systems of different targets and filters offer different radiation doses to patients.*

**Objective** : *To determine the average glandular dose (AGD), the entrance surface air kerma (ESAK) from cranio-caudal (CC) and medio-lateral oblique (MLO) projections and the dose reference level (DRL) from CC projection at both breasts when two digital mammogram systems of molybdenum (Mo) target and molybdenum or rhodium (Rh) filters of one system and tungsten (W) target and rhodium filter of the other system were clinically used.*

**Methods** : *Patients' data from two digital mammography systems were analyzed in terms of the compressed breast thickness (CBT), peak kilovoltage (kVp), milliampere-sec (mAs), average glandular dose (AGD, mGy), the entrance surface air kerma (ESAK, mGy) and dose reference level (DRL, mGy) to optimize the radiation dose to patient.*

**Results** : *Six hundred female patients were studied from two digital mammography systems from 2006 to 2009. Two hundred patient data for each target-filter of Mo-Mo, Mo-Rh and W-Rh were recorded for the CBT, kVp and mAs. The AGD was reduced by 41%, and the ESAK was reduced by 65% when W-Rh target-filter was used. The dose reference level is determined for the AGD and ESAK values.*

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**Conclusion** : *The radiation dose from digital mammogram system with the W-Rh target-filter systems was lower than the system with Mo-Mo and Mo-Rh target-filter. The DRL from this study is less than IAEA recommendations in Basic Safety Standards.*

**Keywords** : *Digital mammography, average glandular dose, entrance surface air kerma, tungsten target.*

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ที่มีเป้าหลอดเอกซเรย์ชนิดต่างกัน. *จุฬาลงกรณ์เวชสาร* 2554 พ.ย. - ธ.ค.; 55(6): 587 - 95

- เหตุผลของการทำวิจัย** : การถ่ายภาพรังสีเต้านมด้วยระบบดิจิตอลที่มีเป้าและตัวกรองของหลอดเอกซเรย์ต่างชนิดกัน มีผลต่อปริมาณรังสีที่ผู้ป่วยได้รับที่แตกต่างกัน
- วัตถุประสงค์** : เพื่อศึกษาปริมาณรังสีเฉลี่ยที่ต่อมน้ำนม และที่ผิวหนังเต้านมจากการถ่ายภาพรังสีเต้านมท่าตรงและท่าด้านข้างของเต้านมทั้งสองข้างและปริมาณรังสีอ้างอิงท่าตรงโดยเครื่องถ่ายภาพรังสีเต้านมระบบดิจิตอลที่ใช้เป้าหลอดและฟิลเตอร์ที่ต่างกัน ได้แก่ เป้าหลอดทำด้วยโมลิบดีนัมและฟิลเตอร์ชนิดโมลิบดีนัมหรือโรเดียมเครื่องหนึ่ง และเป้าหลอดทำด้วยทังสเตน และฟิลเตอร์ชนิดโรเดียมอีกเครื่องหนึ่ง
- วิธีการ** : เก็บข้อมูลผู้ป่วยแบบย้อนหลังจากเครื่องถ่ายภาพรังสีเต้านมระบบดิจิตอล 2 เครื่องในปัจจัยต่าง ๆ ได้แก่ ความหนาของเต้านมที่บีบอัด ค่ากิโลโวลเตจสูงสุด ค่ามิลลิแอมแปร์-วินาที ปริมาณรังสีเฉลี่ยที่ต่อมน้ำนม ปริมาณรังสีเฉลี่ยที่ผิวหนังเต้านมและปริมาณรังสีอ้างอิง เพื่อหาแนวทางในการลดปริมาณรังสีที่ผู้ป่วยได้รับ
- ผลการศึกษา** : ข้อมูลผู้ป่วยจำนวน 600 คนถูกเก็บจาก 2 เครื่องที่มีเป้าและฟิลเตอร์ 3 แบบๆ ละ 200 คน ได้แก่ โมลิบดีนัม-โมลิบดีนัม โมลิบดีนัม-โรเดียม และ ทังสเตน-โรเดียม ตั้งแต่ ปีพ.ศ. 2549 ถึงปีพ.ศ. 2552 การใช้เครื่องถ่ายภาพรังสีเต้านมระบบดิจิตอลที่มีเป้าหลอดชนิดทังสเตน และฟิลเตอร์ชนิดโรเดียมทำให้ปริมาณรังสีที่ต่อมน้ำนมลดลง 41เปอร์เซ็นต์ และปริมาณรังสีที่ผิวหนังเต้านมลดลงถึง 65 เปอร์เซ็นต์ เมื่อเทียบกับปริมาณรังสีจากเครื่องถ่ายภาพรังสีเต้านมระบบโมลิบดีนัม-โมลิบดีนัมหรือโมลิบดีนัม-โรเดียม มีการศึกษาปริมาณรังสีอ้างอิงจากปริมาณรังสีทั้งสองตำแหน่ง
- สรุป** : ปริมาณรังสีที่ผู้ป่วยได้รับจากเครื่องถ่ายภาพรังสีเต้านมระบบดิจิตอลชนิดทังสเตน -โรเดียมมีค่าต่ำกว่าปริมาณรังสีจากเครื่องชนิดโมลิบดีนัม-โมลิบดีนัมหรือโรเดียมและปริมาณรังสีอ้างอิงมีค่าต่ำกว่าค่าที่เสนอโดยทบวงการพลังงานปรมาณูระหว่างประเทศ
- คำสำคัญ** : การถ่ายภาพรังสีเต้านมระบบดิจิตอล, ปริมาณรังสีเฉลี่ยที่ต่อมน้ำนม, ปริมาณรังสีเฉลี่ยที่ผิวหนังเต้านม, เป้าหลอดเอกซเรย์ชนิดทังสเตน.

Mammography is the process of using low-dose X-rays to examine the human breast. It is used as a diagnostic as well as a screening tool. The goal of mammography is the early detection of breast cancer, typically through detection of the characteristic of the masses and/or micro calcifications. 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. The largest study of radiation risk from mammography concluded that for women at 40 years of age or older, the risk of radiation-induced breast cancer was minuscule, particularly compared with the potential benefit of mammographic screening.

The risk of breast cancer for asymptomatic women under 35 is not high enough to warrant the risk of radiation exposure. For this reason, and because the radiation sensitivity of the breast in women under 35 is possibly greater than that in older women, screening mammography is not recommended in women under 40.<sup>(1)</sup> However, if there is a significant risk of cancer in a particular patient, mammography may still be important. Often, mammography can be replaced by using ultrasound, or MRI imaging.

Digital mammography system was firstly manufactured by General Electric Company in 2000, using indirect detection of cesium iodide crystal. Direct detection using amorphous selenium was later developed by Hologic Lorad Company for better contrast, higher sensitivity and specificity. Molybdenum target and molybdenum or rhodium filters were replaced by tungsten target and rhodium or silver filters in the

latest development, resulting in reduction of average glandular dose and the entrance surface air kerma.

The purpose of this study is to determine the average glandular dose, the entrance surface air kerma and the dose reference level from the two digital mammographic systems using different target-filters of molybdenum-molybdenum or rhodium and tungsten-rhodium.

### Literature Review

Hermann KP, Obernauer S, Marten K, Kehbel S, Fischer U, Grabbe E <sup>(2)</sup> reported "Average glandular dose with amorphous silicon full-field digital mammography - Clinical results" in *Rofo Fortschr Geb Rontgenstr Neuen Bildgeb Verfahr* 174:696 – 699. The mean average glandular dose was 1.51 mGy (0.66 - 4.05 mGy) for a single view. The mean compressed breast thickness was 55.7 mm. The mean age of patients was 55 years (34 - 81 years). The full-field digital mammography with a flat-panel detector based on amorphous silicon offers about 25 % less dose in comparison with conventional screen-film mammography.

Samei E, Saunders RS Jr., Baker JA and Delong DM <sup>(3)</sup> studied the effect of reduced radiation dose on diagnostic performance and published in *Radiology* 2007, 243, 396 - 404. the mammographic dose, even for digital mammography with potentially higher detective quantum efficiency, has an effect on diagnostic accuracy. Thus, proper setup and control of radiation exposure are essential requirements for digital mammographic procedures. However, the small magnitude of the effect on diagnostic accuracy in relation to the notable reduction in dose suggests that dose may potentially

be decreased with limited effect on clinical utility. This potential is perhaps better appreciated for certain uses, such as extra views for images to confirm placement of clips or wires during or after biopsies.<sup>(4)</sup> However, the results also imply that there might be potential for modest dose reduction in screening applications. This implication should not be confirmed until future studies in which accuracy is evaluated at multiple incremental dose levels.

Both studies demonstrate the methods to optimize the mammographic dose. One simple method is the use of high atomic number target of tungsten and rhodium/silver filter materials in an x-ray tube with the advantage of short exposure time, better contrast and dose reduction.

#### Material and Method

In 2006, the full-field digital mammographic system (FFDM), manufactured by Hologic Lorad, Selenia Model with molybdenum target and molybdenum-rhodium filters was installed at King Chulalongkorn Memorial Hospital. The second system of the same manufacturer and model with tungsten target and rhodium-silver filters was installed in 2009. The acceptance test has been performed by medical physicist to assure that the system characteristics fall in the levels described in the system specification. The radiation output and the radiation quality had been verified among the measurements, the digital displayed on the monitor and the values supplied by the manufacturer.

Two hundred patients per target - filter were studied for the average glandular dose and the entrance surface exposure during 2006-2009. The patients' parameters together with the imaging

techniques of both systems were recorded. The compressed breast thickness (mm), the peak kilovoltage (kVp), the current-time (mAs), the average glandular dose (AGD) and the entrance surface air kerma (ESAK) were recorded in the unit of mGy for the cranio-caudal (CC) and medio lateral oblique (MLO) projections for both breasts. Both systems were operated using the automatic exposure control (AEC) and the tissue exposure control (TEC) systems. The dose reference level (DRL) is determined based on the third quartile value of the AGD and the ESAK. The exceed value of DRL is considered for the appropriate corrective action.

#### Results

Table 1 shows the patients' data from the first full-field digital mammography systems using Mo-Mo, Mo-Rh target filters system and W-Rh target-filter of the second system. Data of 200 patients per target-filter were recorded and displayed in average, minimum and maximum values for the compressed breast thickness, peak kilovoltage, milliAmpere-sec, average glandular dose and entrance surface air kerma. The automatic exposure control was selected for different breast thickness to optimize the image quality and the patient dose. Mo/Mo target filter was automatically selected for breast thickness from 22 - 64 mm. Mo-Rh target-filter was automatically selected for the breast thickness from 65 - 111 mm. As for the second system, W-Rh target was selected for the breast thickness from 16 - 69 mm and the number of patients was 200 while the number of patient with the compressed breast thickness of 70 mm and thicker was very limited. Therefore, the W-Ag target-filter has not been used during that period. The

range of peak kilovoltage was 24 - 31 for Mo-Mo, 32-37 for Mo-Rh and 24-32 for W-Rh. The mAs ranged from 37 - 170 for Mo-Mo, 49 - 260 for Mo-Rh and 38 - 251 for W- Rh systems. The range of AGD was 0.73 - 4.02 mGy for Mo-Mo, 1.13 - 5.59 mGy for Mo-Rh and 0.46 - 3.89 mGy for W-Rh systems. The entrance surface air kerma ranged from 1.4 - 26.4 mGy for Mo-Mo, 7.36 - 53.0 for Mo-Rh and 0.89 - 15.7 mGy for W-Rh system.

**Table 1.** The data recorded from two digital mammographic systems of Mo/Mo, 200 patients, Mo/Rh, 200 patients and W/Rh, 200 patients, in terms of: a) CBT in mm; b) kVp; c) mAs; d) AGD, mGy; e) ESAK, mGy for RCC, LCC, RMLO and LMLO views.

Target/Filter Mo/Mo 200 patients										
	(RCC)					(LCC)				
	CBT (mm)	kVp	mAs	AGD(mGy)	ESAK	CBT(mm)	kVp	mAs	AGD(mGy)	ESAK
Ave	53.7	29.4	83.5	2.15	14.49	53.3	29.2	84.5	2.2	14.37
Min	23	24	43.7	0.81	3.67	24	24	37	0.73	1.88
Max	64	31	149	3.6	26	64	31	170	4.02	26.4
	(RMLO)					(LMLO)				
	CBT (mm)	kVp	mAs	AGD(mGy)	ESAK	CBT(mm)	kVp	mAs	AGD(mGy)	ESAK
Ave	53.7	29.4	85.9	2.2	14.68	53	29.2	83.8	2.21	14.21
Min	23	24	47.9	1.1	1.4	22	24	44	1.09	2.33
Max	64	31	141	3.44	24.1	64	31	155	3.68	23.4
Target/Filter Mo/Rh 200 patients										
	(RCC)					(LCC)				
	CBT (mm)	kVp	mAs	AGD(mGy)	ESAK	CBT(mm)	kVp	mAs	AGD(mGy)	ESAK
Ave	73.5	32.3	106.3	2.36	16.96	72.6	32.2	100.3	2.23	15.64
Min	65	32	53	1.19	7.85	65	32	49	1.16	7.36
Max	111	37	244	5.59	53	97	34	216	4.74	42.20
	(RMLO)					(LMLO)				
	CBT (mm)	kVp	mAs	AGD(mGy)	ESAK	CBT(mm)	kVp	mAs	AGD(mGy)	ESAK
Ave	72.82	32.2	110.6	2.45	17.32	71.8	32.1	105.9	2.37	16.52
Min	65	32	55	1.29	7.99	65	32	52	1.13	7.74
Max	101	35	260	5.59	51.40	98	34	214	4.58	37.30
Target/Filter W/Rh 200 patients										
	(RCC)					(LCC)				
	CBT (mm)	kVp	mAs	AGD(mGy)	ESAK	CBT(mm)	kVp	mAs	AGD(mGy)	ESAK
Ave	52.9	28.8	110.5	1.35	5.08	52.4	28.9	104.2	1.29	4.89
Min	16	25	39	0.48	0.91	25	25	41	0.53	1.21
Max	69	32	251	3.13	13.3	69	32	237	2.87	15.7
	(RMLO)					(LMLO)				
	CBT (mm)	kVp	mAs	AGD(mGy)	ESAK	CBT(mm)	kVp	mAs	AGD(mGy)	ESAK
Ave	52.0	28.7	106.3	1.29	4.84	52.8	28.9	103.9	1.28	4.71
Min	16	24	38	0.47	0.89	26	25	41	0.46	0.95
Max	69	32	227	2.8	12.3	69	32	218.4	3.89	10.4

The average compressed breast thickness at four views was 53.4 mm for Mo/Mo target filter, 72.7 mm for Mo/Rh target filter and 52.5 mm for W/Rh target filter system. The average kVp was 29.3 for Mo/Mo, 32.19 for Mo/Rh, and 28.82 for W/Rh. The average mAs was 84.4 for Mo/Mo, 105.8 for Mo/Rh, 106.2 for W/Rh.

The average glandular dose was 2.2 mGy for Mo/Mo, 2.35 mGy for Mo/Rh and 1.3 mGy for W/Rh target filter. The average entrance surface air kerma was 14.44 mGy for Mo/Mo, 16.61 mGy for Mo/Rh and 4.88 mGy for W/Rh target filter system. The average glandular dose was reduced by 41 % when changed from Mo/Mo to W/Rh target/filter of similar CBT. The average entrance surface air kerma was reduced to 65 % when changed from Mo/Mo to W/Rh target/filter systems for the similar CBT.

### Conclusion and Discussion

The radiation dose from mammographic procedure has been a common concern to the radiology community. The US government regulated mammographic examinations with the Mammography Quality Standards Act (MQSA)<sup>(5-7)</sup> of 1992. The mammographic dose reduction was reported from the transition of analog to digital systems.<sup>(8)</sup> Such reductions have been explored in a few studies.<sup>(9-11)</sup> However, concerns about the potential loss of image quality and the resultant effect on diagnostic accuracy have prevented any dose reduction in clinical procedures, with clinical implementations still aiming to mostly maintain the dose used with digital systems at a level similar to that used with analog systems.

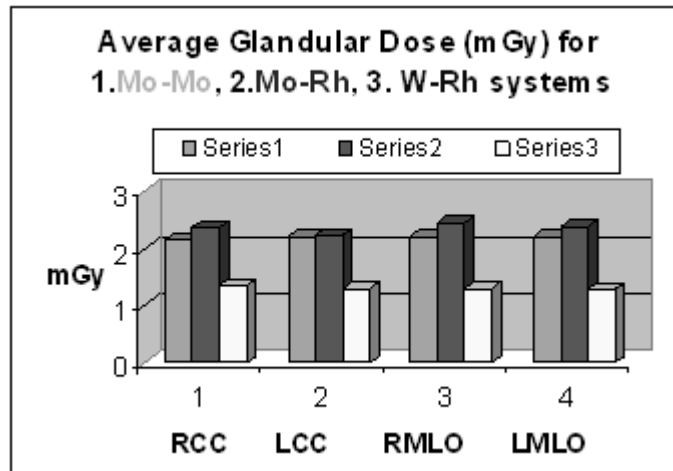
Digital mammography, Hologic system

with tungsten anode, dose savings between 9 and 52 percent were achieved, for polymethylmethacrylate (PMMA) phantom thickness ranging from 20 to 70mm.<sup>(12)</sup> As for the Siemens Novation, for the same range of PMMA thicknesses simulating breasts, the dose saving was 10 to 50 percent when using a W/Rh rather than Mo/Mo target-filter combination. Comparing W/Rh with Mo/Rh for the Novation, a more modest dose reduction ranging from 4% to 18% was achieved.

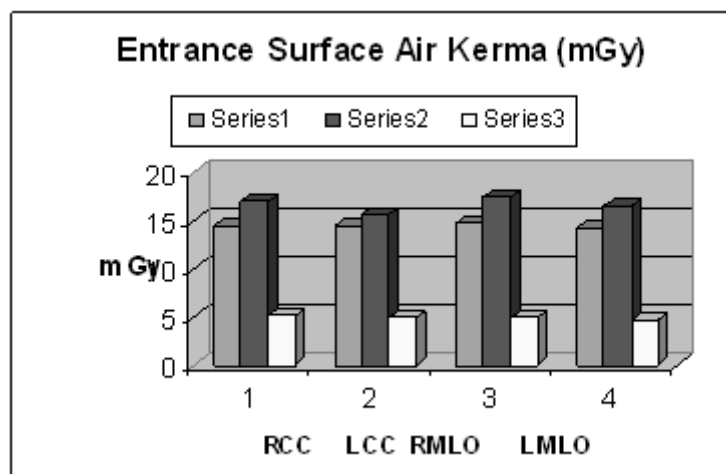
The result from this study of FFDM of W-Rh target-filter shows the optimization for the patient dose<sup>(13)</sup> of 41 percent lower in AGD when compared with the Mo-Mo at the average CBT of about 52 mm, as displayed in Figure 1. The ESAK is reduced<sup>(14)</sup> to 65% as in figure 2 when compared with Mo-Mo while keeping the image quality at the diagnostic requirement. The result was comparable to that of Hermann KP<sup>(2)</sup> *et al.* who had compared the average glandular dose from the digital mammography to the conventional mammography. The mean average glandular dose was 1.51 mGy (0.66 - 4.05) for a single view. The FFDM with a flat-panel detector based on amorphous silicon offered about 25 % less dose in comparison with conventional screen-film mammography.

The International Atomic Energy Agency, IAEA, has recommended in the International Basic Safety Standard (BSS)<sup>(15)</sup> the Dose Reference Levels DRL, for mammography of a typical adult patient of 3.0 mGy with grid for the single view of CC. The result of this study could be used as a baseline of the DRL of Thai women for the digital mammography. The third quartile of the AGD was 2.56 mGy for Mo-Mo, 2.73 mGy for Mo-Rh and 1.57 mGy for W-Rh. All are





**Figure 1.** The average glandular dose, mGy for RCC, LCC, RMLO and LMLO Projections of Mo-Mo (Series 1), Mo-Rh (Series 2), and W-Rh (Series 3), target filter systems.



**Figure 2.** Entrance Surface Air Kerma (mGy) for RCC, LCC, RMLO and LMLO Projections of Mo-Mo (Series 1), Mo-Rh (Series 2), and W-Rh (Series 3) target filter systems.

less than the IAEA DRL of 3.0 mGy for CC projection. The third quartile for ESAK was 17.35 mGy for Mo-Mo, 19.70 mGy for Mo-Rh and 7.14 mGy for W/Rh. The awareness of radiation dose to the patient can be fulfilling when the DRL is available and the factors affecting the radiation dose should be used to optimize the patient radiation dose.

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