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ONLINE BRIEF COMMUNICATION

Estimates of Average Glandular Dose with Auto-modes of X-ray Exposures in Digital Breast Tomosynthesis

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تقدير الجرعة الغدية المتوسطة بواسطة طرز ذاتية للتعرض للأشعة السينية في التركيب المقطعي الرقمي للثدي

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abstract: ***Objectives:*** The aim of this research was to examine the average glandular dose (AGD) of radiation among different breast compositions of glandular and adipose tissue with auto-modes of exposure factor selection in digital breast tomosynthesis. ***Methods:*** This experimental study was carried out in the National Cancer Society, Kuala Lumpur, Malaysia, between February 2012 and February 2013 using a tomosynthesis digital mammography X-ray machine. The entrance surface air kerma and the half-value layer were determined using a 100H thermoluminescent dosimeter on 50% glandular and 50% adipose tissue (50/50) and 20% glandular and 80% adipose tissue (20/80) commercially available breast phantoms (Computerized Imaging Reference Systems, Inc., Norfolk, Virginia, USA) with auto-time, auto-filter and auto-kilovolt modes. ***Results:*** The lowest AGD for the 20/80 phantom with auto-time was 2.28 milliGray (mGy) for two dimension (2D) and 2.48 mGy for three dimensional (3D) images. The lowest AGD for the 50/50 phantom with auto-time was 0.97 mGy for 2D and 1.0 mGy for 3D. ***Conclusion:*** The AGD values for both phantoms were lower against a high kilovolt peak and the use of auto-filter mode was more practical for quick acquisition while limiting the probability of operator error.

Keywords: Thermoluminescent Dosimetry; Breast; Mammography; Radiation Dosage.

الملخص: الهدف: يهدف هذا البحث لدراسة الجرعة الغدية المتوسطة (ج غ م) في مختلف مكونات الثدي بواسطة اختيار عامل الطرز الذاتية للتعرض. وأجريت هذه الدراسة بجمعية السرطان القومية في كوالا لامبور بماليزيا بين فبراير 2012م وفبراير 2013م، وذلك باستخدام جهاز تصوير الثدي الاشعاعي الرقمي. وتم تحديد كيرما (وحدة الطاقة المنطلقة في المادة) مدخل سطح الهواء وطبقة قيمة النصف باستعمال المقياس اللمعي الحراري للجرعات الشعاعية (H 100) في ثدي شبحي (50/50 و20/80) متوفر تجاريا بشركة أنظمة التصوير المحوسب–نورفولك–فيرجينا–الولايات المتحدة الأمريكية، والذي يعمل بطراز ذاتي بالنسبة للتوقيت والترشيح ونظام K-V. وتوصلت الدراسة إلى أن أقل ج غ م للشبح 20/80 ذاتي التوقيت كان 2.28 ميلي قري لبعدين و2.48 ميلي قري لثلاثة أبعاد. بينما كان أقل ج غ م للشبح 50/50 ذاتي التوقيت هو 0.97 ميلي قري لبعدين و1.0 ميلي قري لثلاثة أبعاد. ووجد أن قيم ج غ م للشبحين كانت أقل على خلفية ذروة كيلو فولت، وأن استخدام طراز المرشح الذاتي كان أكثر عملية في عملية الاكتساب، وأقل احتمالا لحدوث خطأ من قبل مشغل الجهاز.

مفتاح الكلمات: مقياس الجرعات الاشعاعية اللمعي الحراري؛ ثدي؛ تصوير الثدي الشعاعي؛ الجرعة الاشعاعية.

It is generally assumed that the glandular tissue of the breast is most vulnerable to the induction of cancer by ionisation radiation.[1] In order to calculate the average glandular dose (AGD) of radiation in different breast compositions, parameters such as the half-value layer (HVL) and entrance surface air kerma (ESAK) have to be measured.[2] The average glandular tissue dose in mammography is generally determined from published tables with knowledge of the breast entrance skin exposure, X-ray tube target material, beam quality (HVL), breast thickness and breast composition.[3] In addition, the beam spectral quality, scatter control with compression and grid, detector characteristics, image processing and radiation dosage must be taken into consideration in order to optimise the AGD.[4]

Clinical trials and scientific investigations have found that, in digital mammography, a tungsten X-ray tube with rhodium (Rh) and argentum (Ag) filters is optimal for measuring all breast thicknesses, and will allow for important dosage reductions by approximately 30% while still maintaining excellent image quality.[5]

In February 2011, the Food and Drug Administration (FDA) approved tomosynthesis machines as safe for usage in the screening and diagnosis of breast cancer, as their two dimensional (2D) and three dimensional (3D) tomosynthesis images can reveal the

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Table 1: Parameters used for the assessment of the 6 cm thick 20% glandular and 80% adipose tissue (20/80) breast phantom

Mode of exposure	HVL	Projection	kVp	mAs	Target/ filter	ESAK in mGy	AGD ± SD in mGy
Auto-time†	0.550	CC/2D	28	163	W/Ag	5.62	2.62 ± 0.10
	0.580	CC/2D	30	114	W/Ag	5.48	2.60 ± 0.19
	0.610	CC/2D	32	78	W/Ag	4.76	2.30 ± 0.06
	0.520	CC/2D	28	228	W/Rh	9.16	2.82 ± 0.01
	0.530	CC/2D	30	199	W/Rh	7.94	2.67 ± 0.14
	0.540	CC/2D	32	142	W/Rh	6.83	2.28 ± 0.01*
	0.580	CC/3D	32	59	W/Al	6.93	2.48 ± 0.11*
Auto-filter	0.535	CC/2D	31	171	W/Rh	7.01	2.44 ± 0.13
	0.590	CC/3D	33	62	W/Al	7.47	2.5 ± 0.16
Auto-kV	0.535	CC/2D	31	150	W/Rh	7.12	2.31 ± 0.40
	0.580	CC/3D	32	62	W/Al	7.34	2.61 ± 0.12

HVL = half-value layer; kVp = kilovolt peak; mAs = milliampere per second; ESAK = entrance surface air kerma; mGy = milliGray; AGD = average glandular dose; SD = standard deviation; CC = craniocaudal; 2D = two dimensional; W = tungsten; Ag = argentum; Rh = rhodium; 3D = three dimensional; Al = aluminium; auto-kV = auto-kilovolt.

**Lowest AGD values for 2D and 3D images, respectively. †Only 32 kVp available for the auto-time 3D image.*

internal breast architecture without distortion from tissue overlapping.[6,7] In current clinical practice, auto-filter is often used rather than the auto-time and auto-kilovolt (kV) modes as the latter require manual set-up by the operator.[8] However, there has been a need for further study to determine the best practice for screening mammography.

The aim of this study was to assess the AGD of radiation in two different breast compositions (50% glandular and 50% adipose [50/50] and 20% glandular and 80% adipose [20/80]) with auto-modes (auto-time, auto-filter and auto-kV) of exposure factor selection.

Table 2: Parameters used for the assessment of the 4 cm thick 50% glandular and 50% adipose tissue (50/50) breast phantom

Mode of exposure	HVL	Projection	kVp	mAs	Target/ filter	ESAK in mGy	AGD ± SD in mGy
Auto-time	0.550	CC/2D	28	55	W/Ag	2.26	1.20 ± 0.20
	0.580	CC/2D	30	65	W/Ag	1.88	1.12 ± 0.04
	0.610	CC/2D	32	33	W/Ag	1.91	1.01 ± 0.15
	0.520	CC/2D	28	96	W/Rh	2.98	1.16 ± 0.03
	0.530	CC/2D	30	45	W/Rh	2.84	1.10 ± 0.03
	0.540	CC/2D	32	33	W/Rh	2.31	0.97 ± 0.32*
	0.510	CC/3D	28	60	W/Al	4.37	1.80 ± 0.136
	0.550	CC/3D	30	38	W/Al	3.32	1.28 ± 0.15
	0.580	CC/3D	32	27	W/Al	2.73	1.00 ± 0.01*
Auto-filter	0.520	CC/2D	28	91	W/Rh	3.16	1.17 ± 0.01
	0.522	CC/3D	29	58	W/Al	3.74	1.33 ± 0.32
Auto-kV	0.520	CC/2D	28	46	W/Rh	3.21	1.32 ± 0.14
	0.530	CC/3D	29	48	W/Al	3.76	1.68 ± 0.17

HVL = half-value layer; kVp = kilovolt peak; mAs = milliampere per second; ESAK = entrance surface air kerma; mGy = milliGray; AGD = average glandular dose; SD = standard deviation; CC = craniocaudal; 2D = two dimensional; W = tungsten; Ag = argentum; Rh = rhodium; 3D = three dimensional; Al = aluminium; auto-kV = auto-kilovolt.

**Lowest AGD values for 2D and 3D images, respectively.*

Methods

Between February 2012 and February 2013 a phantom study was conducted using a tomosynthesis digital mammography X-ray machine, the Hologic® Selenia® AWS 5000 (Hologic, Bedford, Massachusetts, USA). Two types of commercially available breast phantoms (Computerized Imaging Reference Systems, Inc., Norfolk, Virginia, USA) were used. The first tissue equivalent breast phantom was composed of 50/50 tissue with a thickness of 4 cm, while the second phantom was composed of 20/80 tissue with a thickness of 6 cm.

A 100H thermoluminescent dosimeter (TLD) was used to obtain the ESAK value. The experiment was repeated three times for each parameter in order to reduce any errors in measurement. The first experiment was conducted using the auto-filter mode to enable the automatic choice of the target, filter, kV peak (kVp) and milliampere per second (mAs). For auto-time, the system automatically selected the mAs but the operator manually selected the filter and kVp. For 2D images, two types of filter were used, Ag and Rh, while for 3D images only one filter was used, aluminium (Al). Each filter was used with 28, 30 and 32 kVp, respectively. Finally, for auto-kV, the system automatically selected the kVp and mAs while the operator selected the filter.

A sachet containing three TLDs was placed on the surface of the phantom, with the centre of the sachet 40 mm from the chest wall edge and centred with regards to the lateral direction. A further sachet of unexposed TLDs was retained for background reading.[9] TLDs were calibrated in terms of air kerma at mammographic energies, using all anode/filter combinations as used in normal practice. In this study, an ionisation chamber was used to calibrate the TLDs. The ionisation chamber was placed at the same effective point of the measurements and exposed to the same dose as the TLDs. Thus, the energy responses were consistent because they were calibrated at the same energies where the measurements were taken.[10] In order to calculate the AGD, the HVL for each kVp was also measured.

The experimentally estimated AGDs were compared with theoretically calculated values based on methods indicated in earlier studies.[11–13] According to methods proposed by Dance *et al.* the AGDs in the current study were calculated using this equation: AGD = K x G x C x S x T.[11–13] In this equation, K is the ESAK value from the TLD reading; factor G is the conversion factor of ESAK to AGD; factor C corrects any differences in breast composition from 50% glandularity, and factor S corrects any differences from the original tabulation due to the use of a different X-ray spectrum. Furthermore, in order to estimate the AGD for breast tomosynthesis, Dance *et al*. introduced T-factors for the calculation of breast dose from a single projection and T-factors for a complete exposure series from -7.5–7.5 degrees for 15 projection in less than four seconds of scanning time.[13] The T-factor value for this study was between 0.93 and 1.0.

The statistical analysis of the data was performed with Statistical Package for the Social Sciences (SPSS) Version 18.0 (IBM Corp., Chicago, Illinois, USA). The statistical significance of the overall differences between auto-modes was analysed using the one-way analysis of variance.

Results

Table 1 and Table 2 show the parameters used in the experiment. The results were divided according to composition and thickness (6 cm 20/80 and 4 cm 50/50). AGD values obtained from the experiment increased with the thickness of the phantom. The lowest AGD for the fatty breast tissue (20/80) on auto-time was 2.28 mGy with tungsten (W)/Rh anode/filter for 2D images and 2.48 mGy for 3D images [Table 1]. Meanwhile, for normal breast tissue (50/50), the lowest AGD for the 2D images on auto-time was 0.97 mGy with W/Rh anode/filter and 1.0 mGy for 3D images [Table 2].

With auto-time mode, the dosage was minimal compared with the two other modes (auto-filter and auto-kV). However for the 3D image, a tube voltage of 28 kVp and 30 kVp was insufficient to penetrate the 20/80 phantom due to the existence of a backup timer, which automatically stops the exposure when the time ends. Therefore only the 32 kVp was able to penetrate the phantom.[14]

Analysis of the 50/50 phantom was statistically significant, indicating that the AGD value was influenced by different types of auto-modes (auto-filter, auto-time and auto-kV) ($F [2, 15] = 6.918$; $P < 0.05$). However, for the phantom 20/80, the analysis was not statistically significant, indicating that the AGD values were not influenced by the different types of auto-modes ($F [2, 15] = 0.495$; $P > 0.05$).

Discussion

For the 20/80 breast phantom, the AGD with auto-time produced a lower dose with the Rh filter, correlating with the manufacturer's suggestion to use the W/Rh combination for a breast phantom thickness between 4 and 7 cm.[15] The Ag filter should be considered for use on patients with fatty tissue and a thickness greater than 6 cm for dose reduction purposes. It is recommended that, for fatty tissue, all factors such as kVp, filter and compression should be optimised in order to obtain the lowest dose possible without compromising the image quality.[16] With the breast phantom 50/50, the pattern was similar as the lowest AGD was obtained using auto-time, followed by auto-filter and auto-kV.

When the efficacy of different exposure modes are compared, the following factors should be considered: the radiation dose received by the patient, the image quality and the ease of use of the modes for the operator.[17] In this study there was a significant dose change between the different modes of exposure, particularly for the 50/50 breast phantom. For 2D and 3D images, the 32 kVp with auto-time mode produced a low radiation dose, but when the kVp was high, the scatter radiation increased and therefore reduced the image contrast.[18] Therefore, unnecessary changes to the kVp should be avoided, especially for breasts with reduced thicknesses. Furthermore, several research studies have shown that 28 kVp is the optimum kVp for the 50/50 breast phantom since it produces a high-quality image.[4,19] In the current study, the auto-filter mode automatically calculated 28 kVp as the tube output. The results of this study indicate that the auto-filter mode is preferable for normal breast tissue (50/50) since this mode is automatic, fast and easy to operate.

The 20/80 AGD value showed no significant difference between the exposure modes. The difference between the kVp values was minimal for the 2D images. The auto-time used 32 kVp, the auto-filter used 31 kVp and the auto-kV used 31 kVp, meaning that the difference was only 1 kVp. Therefore, there was no significant difference in the AGD values when the exposure modes used were different. This finding was also found to be consistent with the 3D imaging. Therefore the auto-mode did not have an obvious role in reducing the dose for fattier breast tissue. This is contrary to the findings of Myung *et al.*, which found differences in the AGD values.[17] However, their findings may have been due to the mammography system used, which could operate in three different modes of automatic optimisation of parameter: contrast (CNT), standard (STD) and dose modes, which vary between low dose and high image quality.[17] The CNT mode emphasised higher contrast and, therefore, higher image quality. The dose mode focused on dose reduction with acceptable image quality. The STD mode was balanced between good contrast and dose reduction.[17] The AGD, ESAK, and mAs were ordered as CNT mode had a higher AGD than STD mode and dose mode produced the lowest AGD.

For the phantom 50/50, the total AGD value for the 2D and 3D combination mode was below the recommended dose limit of 3 mGy per projection. In order to ease the operator's task, the auto-filter is the recommended mode for 50/50 breast types for both 2D and 3D images.[20] On the other hand, the results obtained in the current study showed that the auto-kV mode produced the highest AGD and, therefore, was not advisable for use with this type of breast. Similarly, for the fatty type of breast tissue (20/80), auto-filter could be considered the mode of choice for both a 2D and 3D image as the kVp is high enough to penetrate thicker breast tissue and the mode is automatic.

A limitation to this study was that the findings focused only on the dosage of radiation. Further research on auto-modes of exposure and image quality is therefore required.

Conclusion

This study demonstrated that the AGD values for 50/50 and 20/80 breast phantoms for both 2D and 3D imaging were lower with a high kVp while using auto-time mode. However, the use of auto-filter mode was found to be more practical as it was fast to use and reduced the risk of operator error. Alternatively, for 20/80 breast types, it would be more suitable to choose either auto-time or auto-filter modes interchangeably since the dose does not change. However, this can be risky if the operator has insufficient training or knowledge of utilising different modes.

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