應用對比細微度假體評估台灣女性乳房攝影之影像品質
Evaluation of Mammographic Image Quality for Taiwanese Women Using Contrast-Detail Phantom

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摘要

在乳房攝影中許多國家採用 CDMAM 假體加上 4 公分厚的 PMMA 來模擬中等大小乳房以評估影像品質，此一 CDMAM 組成約等效於 5 公分厚之 PMMA。由我們先前的研究顯示，台灣女性乳房的平均厚度比西方女性薄，因此，本研究的目的為比較 CDMAM 假體加上 4 公分 PMMA 與加上台灣女性乳房平均等效厚度的 PMMA 之影像品質差異。本研究共收集 3910 頭腳方向（CC views）乳房影像之攝影參數，同時對每個乳房評估 PMMA 的等效厚度，並評估三種乳房攝影系統攝影－底片式（SF）、電腦放射影像式（CR）與數位全景式（FFD）系統。本研究的結果顯示，台灣女性乳房平均等效厚度為 4 公分 PMMA，相當於 CDMAM 假體加上 3 公分厚 PMMA，本實驗中含 4 公分 PMMA 的 CDMAM 假體之影像品質係數（IQFinv）為 66 到 83 $(\mu m \times mm)^{-1}$，含 3 公分 PMMA 的 CDMAM 假體之影像品質係數（IQFinv）為 80 到 102 $(\mu m \times mm)^{-1}$。就結論而言，以 CDMAM 假體加上 3 公分 PMMA 所測量之每一細微直徑的可辨認閾值厚度比加上 4 公分 PMMA 時薄，因此影像品質較佳。

關鍵詞：乳房攝影，乳房厚度，假體

Abstract

The contrast-detail mammography phantom (CDMAM) with 4-cm PMMA slabs is frequently used for estimation of the image quality of a medium-sized breast in many countries. This CDMAM configuration is equivalent to 5-cm PMMA slabs. In our previous studies, the average equivalent thickness of PMMA to breasts of Taiwanese women is thinner than that of western female. The purpose of this study is to compare the differences of image quality acquired between the CDMAM phantom with 4-cm PMMA slabs and the average equivalent thickness of PMMA to breasts of Taiwanese women. The imaging parameters from 3910 craniocaudal screen/film mammograms are collected and the equivalent thickness of PMMA is determined for each breast image. Three types of mammography imaging systems – screen/film (SF), computed radiography (CR) and full-field digital (FFD), were evaluated. Results from this study show that the average thickness of PMMA to the studied breasts is 4 cm which equivalent to the CDMAM phantom with 3-cm PMMA slabs. The inverse image quality factors (IQFinv) are ranged from 66 to 83 $(\mu m \times mm)^{-1}$ for the CDMAM phantom with 4-cm PMMA slabs and ranged from 80 to 102 $(\mu m \times mm)^{-1}$ for the CDMAM phantom with 3-cm PMMA slabs respectively. In conclusion, the threshold thickness of each detail diameter measured from the CDMAM phantom with 3-cm PMMA slabs is thinner than that of acquired from the CDMAM phantom with 4-cm PMMA slabs, which makes better image quality in mammography.

Keywords: mammography, breast thickness, phantom

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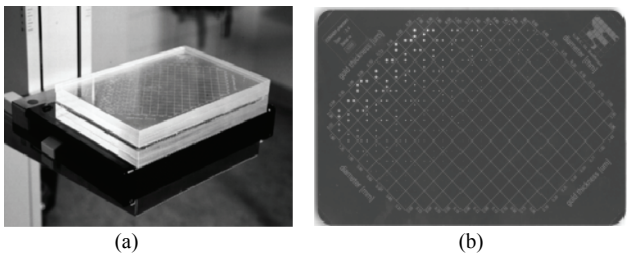
I. INTRODUCTION

The assessment of the image quality is an important part of routine quality control (QC) procedures in mammography [1]. To quantify image quality in mammography, several approaches have been developed for image quality assessment using breast phantoms. One of the commonly used breast equivalent phantoms is the contrast-detail mammographic (CDMAM) phantom (see Fig. 1) [1, 2].

The CDMAM consists of a matrix of gold discs of thicknesses from 2 to 0.03 μm and diameters from 2 to 0.06 mm on a 2 mm aluminum base encased in polymethylmethacrylate (PMMA) slab. In each square of the matrix were two identical gold discs. One was in the center and the other in one of the four corners. To quantify the image quality of an image, each observer was required to identify the location of the corner discs in each square cell. The results of CD assessments were compared to the manufacturer's correction scheme to determine threshold thickness (C_i), that is the minimum visible thickness, for each detail diameter (D_i).

It is clear that the image quality of a mammogram is depended on the compressed breast thickness (CBT) [3, 4]. In general, each local quality assurance (QA) program defines an adequate thickness of breast phantom for QC testing in mammography [1]. At recent years, the European protocol defined limiting threshold values for image quality assessment using the CDMAM phantom with 4-cm PMMA slabs for assessment of image quality in mammography. It is unclear that these limiting threshold values can be applied to assessment of image quality of the CDMAM phantom with other thickness of PMMA slabs.

Results from our previous investigation show that the average compressed breast thickness (CBT) of Taiwanese women is smaller than that of the Western women reported [2]. This indicates that the CDMAM phantom with 4-cm PMMA slabs would not be the optimal thickness for the assessment of mammographic image quality for Taiwanese women. To our knowledge, very few attempts have been made to investigate the optimal thickness of CDMAM for the assessment of image quality for Asian women in mammography. The purpose of this study is to investigate the average image quality for screening-age Taiwanese women using the equivalent CDMAM phantom.



(a) (b)

Fig. 1 (a) The CDMAM phantom with 4-cm PMMA slabs, (b) the detail structure of the CDMAM phantom

II. MATERIALS AND METHOD

Three types of mammography imaging systems were used in this study – screen/film (SF), computed radiography (CR) and full-field digital (FFD). Both SF (SIEMENS, Mammomat 3000) and FFD (Selenia, Hologic) mammography X-ray units were used. For SF mammography, Fuji screen/film cassettes (ADM film, AD Mammo Screen-Fine and UM-Mammo cassette) and an image processor (FPM2100, Fuji) were employed. For CR mammography, a CR imaging system (FCR PROFECT CS, Fuji) was used for imaging various phantoms.

A total of 3910 craniocaudal views were collected from the Mammomat 3000 X-ray unit. The age of the women ranged from 30 to 69 years. The tube loadings, CBT, tube voltage, and target/filter combination of each mammogram were collected.

The equivalent PMMA thickness that would require the same *mAs* as the breast was calculated for each exposure. The PMMA slabs at four thicknesses (2, 4, 6 and 8 cm) were exposed at various target/filter-kV combinations [5]. The relationship between the equivalent phantom thickness (T) and exposure parameters can be expressed as

$$T = C_1 \times ln(mAs) + C_2 \times ln(kV) + b \quad (1)$$

where C_1, C_2 and b are fitted coefficients, and *mAs* and *kV* are the tube loading and the tube voltage of each phantom exposure, respectively. A least-squares fit was applied to determine the coefficients (C_1, C_2, and b) for each calibration data set. These fitted functions were used to calculate the equivalent PMMA thickness of each patient exposure.

A set of CDMAM phantom (version 3.4) was used for image quality assessments. The difference in contrast-detail (CD) visibility between measurements taken using the optimal PMMA obtained in this study and measurements made using a total attenuation equivalent to 5 cm PMMA as recommended in the European protocol were compared. Various thicknesses of CDMAM phantoms were exposed with Mammomat 3000 and Selenia mammography units.

The CD assessments for SF, CR and FFD mammograms were carried out by three observers following the European guidelines. The CR and FFD images were displayed on a 5 megapixel (MP) LCD monitor (MFGD 5421, BARCO) in full-resolution mode. An image presentation tool (SmartRIS, v1.1.6.52), which was built into our radiology information system (RIS), was used where required, including window, level and magnification.

The results of CD observations were compared to the manufacturer's correction scheme to determine C_i, which is the minimum visible thickness, for each D_i. The inverse image quality factor (IQFinv) for each mammogram was determined using the minimum visible thicknesses for 0.1, 0.25, 0.5, 1, and 2 mm detail diameters, defined as

$$IQF_{inv} = \frac{100}{\sum_{i=1}^{n} C_i \times D_i}.$$

III. RESULTS

Fig. 2 shows the distribution of equivalent PMMA thickness of breasts in this study. The range and average (± standard deviation) equivalent PMMA thickness were 1.7-6.4 cm and 4.0 ± 0.7 cm, respectively. The average thickness of PMMA slabs producing the same exposure factors as observed in a large group of Taiwanese women is less than that reported for American women (4.5 cm). The results from this study may provide useful information for adjusting the suitable thickness ranges of PMMA for some of the quality assurance testing procedures.

Fig. 3 shows the results of CD curves of CDMAM phantom with 3-cm and 4-cm PMMA slabs for different imaging systems. For the same phantom configuration, the threshold thickness is decreased with increasing detail diameter.

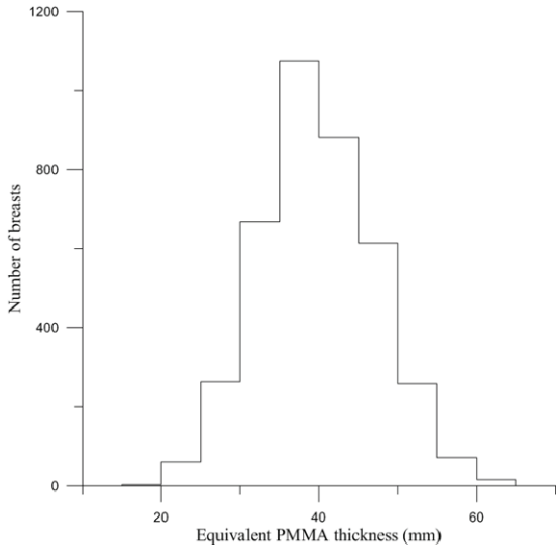


Fig. 2 The distribution of CBTs in this study

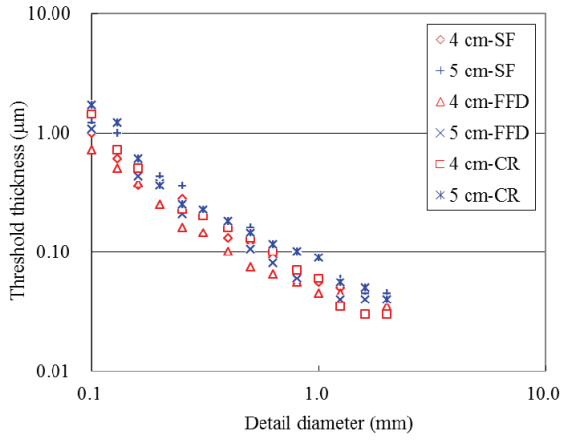


Fig. 3 The distributions of contrast-detail measurements of the CDMAM phantom with 3-cm and 4-cm PMMA slabs for different imaging systems

To further comparison of the CD curves obtained above, the threshold thickness of the 0.1-mm detail diameter for each phantom exposure was evaluated and depicted in Fig. 4. The acceptable limit value which defined at the CDMAM phantom with 4-cm PMMA slabs (the total equivalent PMMA thickness is 5 cm) recommended from European protocol is 1.68 m. All the threshold thicknesses of the 0.1-mm detail diameter measured in this study were thinner than this limiting value, except for the CR image of the CDMAM phantom with 4-cm PMMA slabs (threshold thicknesses = 1.71 μm). For the same imaging system, the threshold thickness of the CDMAM phantom with 3-cm PMMA slabs was lower than that with 4-cm PMMA slabs. This result is agreement with the clinical experience in mammography that thinner lessons can be detected in a thinner breast.

Fig. 5 shows the IQFinvs for each imaging system. The IQFinvs were ranged from 66 to 83 $(\mu m \times mm)^{-1}$ for the CDMAM phantom with 4-cm PMMA slabs and ranged

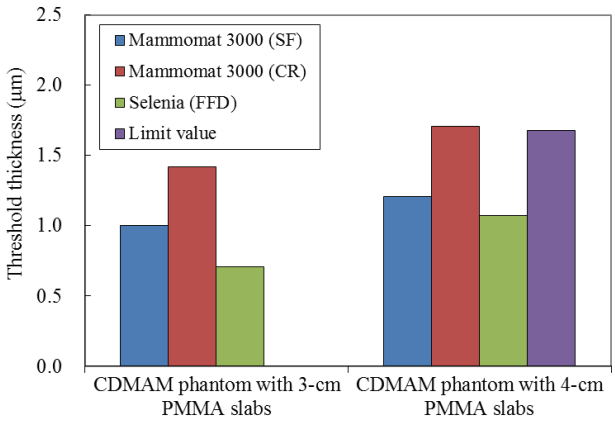


Fig. 4 The threshold thicknesses of 0.1-mm detail diameter for different imaging system. The limiting threshold thickness recommended in European protocol for the CDMAM phantom with 4-cm PMMA slabs was also plotted

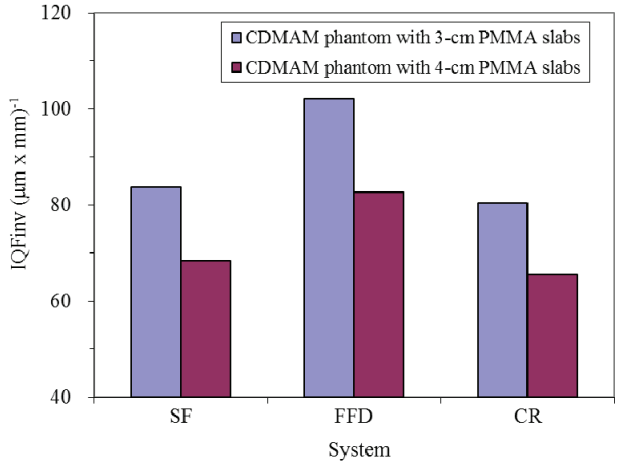


Fig. 5 The IQFinv values for various mammographic systems

from 80 to 102 $(\mu m \times mm)^{-1}$ for the CDMAM phantom with 3-cm PMMA slabs. For the same imaging system, the IQFinv acquired from the CDMAM phantom with 3-cm PMMA slabs is higher than that from the CDMAM phantom with 4-cm PMMA slabs, i.e., a better image quality can be acquired for thin breasts. The image quality of the digital mammography system Selenia is significantly higher than those acquired from the Mammomat 3000 system (SF and CR).

Fig. 6 shows the relative IQFinvs of the CDMAM phantom with 3-cm and 4-cm PMMA slabs for each imaging system. The relative IQFinv is defined as the ratio between the IQFinv measured using each CDMAM configuration and the IQFinv estimated using the limit threshold thicknesses that recommended in the European guidelines. All relative IQFinvs measured in this study is >1, i.e., the image qualities of these images are superior to that recommended in the European guidelines.

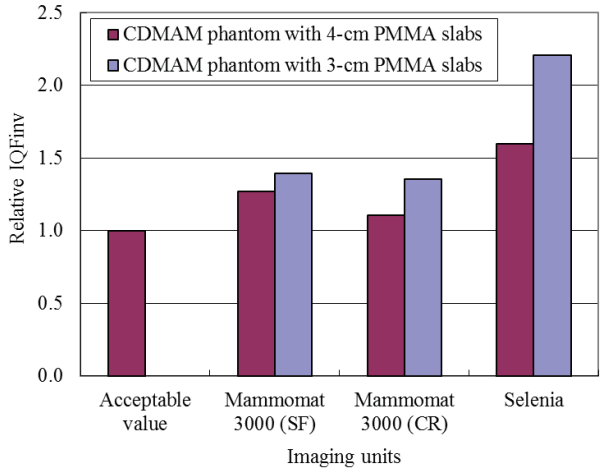


Fig. 6 The relative IQFinv values for various mammographic systems. The IQFinv of limiting threshold thickness recommended in European protocol for the CDMAM phantom with 4-cm PMMA slabs was also plotted

IV. CONCLUSION

Results from this study demonstrate that the image quality acquired from the CDMAM phantom with 3-cm PMMA slabs is higher than that from the CDMAM phantom with 4-cm PMMA slabs. The acceptable limiting values of threshold thickness for each detail diameter recommended in the European guidelines may not suitable for applying to the CDMAM phantom with 3-cm PMMA slabs. This study can provide useful information for estimation of mammographic image quality of Taiwanese women.

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