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Effect of exposure factors on image quality in screening mammography

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ABSTRACT

Introduction: The aim of this research was to study the effect of exposure factors on image quality for digital screening mammography units in Kuwait which use Tungsten (W) targets with Rhodium (Rh) and Silver (Ag) as filters.

Methods: Mammography Accreditation Phantom Model 015 was imaged using a Hologic Selenia Digital mammography unit with W targets and Rh and Ag filters. Four images, each at 26, 28, 30, and 32 kVp, were obtained using each target-filter combination (W/Rh and W/Ag). The images were evaluated by five senior technologists for the number of specks, fibers and masses visible on each image. Statistical analysis was carried out using non-parametric tests at $p = 0.05$ level.

Results: There were significant changes in the visibility of fibers and specks between different kVp values with W/Rh ($p < 0.001$). However, with W/Ag combination, significant differences were observed in the fibers only ($p < 0.001$). Among the kVp values used, 28 kV emerged as the optimal value. Comparison of images obtained with the two filter materials, led to significant differences in the visibility of fibers and specks ($p < 0.008$). At 32 kVp, there were significant differences in the visibility of specks only ($p < 0.008$).

Conclusion: A W/Rh target-filter combination provides better image quality than that provided by W/Ag. In particular, 30 and 32 kVp X-ray beams produce higher quality images than the lower kV values.

Introduction

Breast cancer is considered to be the most frequent malignancy in women worldwide and is the leading cause of cancer-related disability and mortality in females. Over the last 30 years, the incidence of breast cancer among the Kuwait population has increased threefold (from 15 to 50 cases/100,000 population).[1] In 2014, the Kuwait Ministry of Health started a screening mammography program, for women over the age of 40 years, at five imaging centers using 10 digital mammographic units. Screening mammography is known to detect breast cancer at an early stage and reduce mortality. However, inadequate image quality in mammograms may lead to nondetection of breast cancer or misdiagnosis.[2] Hence, high quality mammograms are crucial for successful breast cancer detection and adequate education of personnel is essential to achieve high quality mammographic images.[3]

Currently, Tungsten-Rhodium (W/Rh) and Tungsten-Silver (W/Ag) target-filter combinations are being used in Digital Mammography (DM) units, which result in the reduction of entrance surface air kerma and average glandular dose.[4] The correct selection of the X-ray beam quality and quantity will strongly influence the image quality and the radiation dose used to acquire the image. Several studies have reached various conclusions regarding the effects of target-filter combinations on mammographic image quality. Williams[5] studied the impact of the selection of exposure factors on image quality and dose for a range of breast thicknesses and tissue types. Dance et al.,[6] in their Monte Carlo study, concluded that for compressed breast thicknesses of 4 cm–6 cm, W/Rh is recommended as a more suitable target-filter combination. Andre and Spivey[7] computed the spectra and average glandular doses (AGD) for a W target and various filters (Al, Sn, Rh, Mo, and Ag), for different kVp values and breast types and thicknesses. They suggested the use of Mo filter for 30 mm, Ag filter for 45 mm, Sn filter for 60 mm, and Al filter for 75 mm breast thicknesses. Simulation studies demonstrated that using a W target is preferable to a Mo target for the detection of infiltrating ductal carcinoma and

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calcifications.[8,9] Using a W target with a Tin (Sn) filter resulted in a 34% improvement in Contrast to Noise Ratio (CNR) for the same dose to the breast compared with the use of a Mo target with a Mo filter.[10] However, for an amorphous-selenium (a-Se) detector, the W/Rh target-filter combination is deemed as the most appropriate choice for all breast thicknesses and compositions and for the detection of both micro-calcifications and tumors.[11,12] Toroi[13] investigated the suitability of W/Rh combination for digital mammography systems using a-Se image receptors using polymethylmethacrylate (PMMA) and aluminium sheets to simulate different thickness breasts. Based on Contrast-to-Noise Ratio (CNR) measurements with radiation dose, the study recommends the use of W/Rh.

Most of these studies have evaluated image quality using objective image quality parameters such as CNR. Although these parameters indicate a system's ability to produce quality images, subjective image quality analysis closely represent clinical diagnosis from images. The accuracy of diagnosis depends on how small or how well small calcifications and masses can be visually identified by human observers. Hence, it is more appropriate to investigate the changes in visibility of breast abnormalities with different exposure factors. This is important in the management of image quality and patient dose as per the optimisation principle of radiation protection. The aim of our study was to examine the effect of exposure factors on image quality for digital screening mammography units in Kuwait which use W target with Rh and Ag as filters using human observer based image quality analysis.

Method

A Hologic Selenia (Hologic, Inc. Marlborough, USA) DM unit, using a W target, Rh and Ag as possible filter materials, was used. The unit is equipped with Amorphous Selenium (a-Se) detectors with 70-μm pixel size. The Mammography Accreditation Phantom Model 015 (CIRS, Norfolk VA, USA), designed to test the performance of the mammographic systems, was used to simulate compressed breast. The objects within the phantom simulate calcifications, including fibrous calcification in the ducts, and tumor masses. The phantom is 4.5-cm thick and consisted of a 7 mm wax block insert containing 16 sets of test objects imbedded in a 3.4 cm thick Polymethylmethacrylate (PMMA) and 3 mm cover. All of this together simulated approximately 4.2 cm of compressed breast tissue with average glandular/adipose composition. It contains six nylon fibers of diameters 1.56, 1.12, 0.89, 0.75, 0.54, and 0.40 mm respectively; five simulated spherical tumor masses of diameter 2.00, l.00, 0.75, 0.50, and 0.25 mm respectively; and five groups of calcification specks, each group containing 6 specks of diameters 0.54, 0.40, 0.32, 0.24, and 0.16 mm respectively (Fig. 1).

Four images were obtained using each target-filter combination (W/Rh and W/Ag), one each at 26, 28, 30, and 32 kVp respectively. These kVp values represent the range used in clinical studies with patients. The Automatic Exposure Control (AEC) unit of the system was used to determine the appropriate mAs for all images. The entrance surface dose (ESD) and mean glandular dose (MGD) were recorded from the Hologic Selenia DM unit for each exposure. The images were processed according to the manufacturer recommended methods. Images were evaluated using Barco's (Barco Inc., Zug, Switzerland) 5 mega pixel display systems for digital breast imaging. All images were evaluated by five senior technologists who work in the screening mammography centers. The reviewers were prohibited from making any further enhancements during their review. They were requested to write down the number of groups of specks, number of fibers, and number of masses that were visible. Image scores were assigned, for each type of feature present in the phantom, equal to the number of features visible to the observers. An overall score for each image was calculated as the percentage of the total number of features that were visible to the observers. Statistical analysis was performed using Mann–Whitney test for comparing two sets of scores and Kruskal–Wallis test to compare more than two sets of scores at $p = 0.05$ level.

Result

In this study, images of a phantom were used to compare the effect of different exposures using two different target-filter combinations (W/Ag vs. W/Rh) at four different kVp values (26, 28, 30, and 32 kVp). Table 1 illustrates the ESD and MGD recorded by the DM unit for each exposure. Comparison of the image quality between W/Rh and W/Ag for the visibility of fibers, specks, and masses against the tube potential for each target-filter combination, are shown in Figs. 2–4, respectively. The visibility of fibers was better with W/Rh than with W/Ag at kVp higher than 28. However, the visibility of fibers was better with W/Ag at lower kVp. For both target-filter combinations, the smallest size fiber that was visible measured was 0.54 mm, at 28 kVp.

In terms of the visibility of specks, a significant increase was observed with W/Rh at 30 and 32 kVp compared to W/Ag all the tested kVp values. Four out of the five groups of specks were visible at these exposure parameters, making the smallest size speck detectable to be 0.24 mm. The average score for the visibility of simulated masses similar for both target/filter combinations for kVp below 30. A significant increase in the visibility of masses was observed when W/Rh is used with 32 kVp, making the smallest size mass detectable between 0.5 and 0.25 mm. Fig. 5 displays the overall image score calculated as a percentage of features visible for both target/filter combinations. A significant increase in the percentage of features visible was observed with W/Rh combination at 30 and 32 kVp.

Table illustrates the ESD and for the different target/filter combinations at different kVp values. As the kVp is increased from 28 to 32, the ESD and MGD increased for the W/Rh combination but decreased for the W/Ag combination. For 26 and 28 kVp exposures, W/Rh registered slightly lower MGD and significantly lower ESD than W/Ag. However, the reverse was observed at 30 and 32 kVp.

Discussion

The purpose of optimizing radiographic techniques is to establish standardized imaging protocols balancing image quality with patient radiation dose. This is particularly important for screening mammography as asymptomatic patients are exposed to radiation. Higher image quality obtained at higher doses would guarantee a clinically significant increase in the diagnostic performance. However, the more conservative approach of favoring dose reduction while maintaining acceptable image quality should be followed.[14] For this reason, the primary objective of our study was to evaluate the difference of image quality between the two target-filter combinations used in screening mammography. The results of this study will provide useful information for the proper selection of optimal exposure techniques to specific digital mammography units.

This study found significant changes in the visibility of fibers and specks between different kVp values with a W/Rh target-filter combination ($p < 0.001$). The fibers were optimally visible when the kVp was 28 or above, while the specks were optimally visible at kVp 30 and above. There were no significant differences in the visibility of masses when the kVp was changed with the W/Rh combination. With W/Ag, there were significant differences between kVps and fibers and in overall image score as well ($p < 0.001$). Comparing between the two target/filter combinations

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