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Use of Processed Mammography Images as a Quality Control Tool

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Abstract

Introduction: According to international quality control testing standards, image quality determination in mammography systems is based on measuring contrast-detail measurements with contrast-detail for mammography (CDMAM) phantom. It is therefore important to evaluate the CDMAM phantom images correctly. The purpose of this study is to compare the inverse image quality figure index (IQF_{inv}) obtained by automatically evaluating digital CDMAM phantom images with Artinis software (version 2.2, CDCOM) for raw and processed images.

Methods: Digital phantom images were acquired in three different full-field digital mammography systems by using automatic exposure conditions (AEC). Five different phantom images were obtained from each mammography system as raw and processed as well as evaluated by the software. In addition, the IQF_{inv} values of the systems were compared for mammography systems and the difference in between values was observed.

Results: The differences between the IQF_{inv} values of raw and processed images were found to be 1.34%, 5.62%, and 6.7% for System A, B, and C, respectively.

Discussion and Conclusion: It was observed that the differences between the IQF_{inv} values of raw and processed images were almost negligible and the IQF_{inv} values obtained from the raw images were slightly higher than the values obtained from the processed images.

Keywords: CDMAM; contrast-detail; digital mammography; image quality.

Mammography systems are the preferred method for early detection of breast cancer not only because they are able to detect intensity changes in the breast tissue but also because they are the most cost effective and pratical methods [1]. Microcalcifications in breast tissue, depending on their size and shape, are considered to be the earliest indications of breast cancer. It is, therefore, important to obtain maximum image quality with minimal radiation dose in mammography systems (ALARA-principle). The performance of digital mammography systems can be evaluated by using different methods [2]. The image quality of a mammography system can be assessed objectively by contrast-detail analysis and modulation transfer function (MTF) which indicates the resolution power of the system in frequency domain [2].

The information content of a mammographic image should

be best defined in terms of visible contrast as well as details and is characterized by a contrast-detail curve [3, 4]. In this case, the minimum observable threshold contrast-detail detection is an important quality parameter for imaging systems. The contrast-detail analysis is a parameter that contains the noise, contrast, and resolution of an image as a whole. Hence, it provides a simple measurement for overall performance of the system [5]. The observable minimum distinguishable contrast detection is carried out with a low contrast test phantom that includes test objects in different sizes and contrasts.

According to European quality control testing standards and IEC 61223-3-2 (International Electrotechnical Commission), image quality measurements for digital systems are based on contrast-detail measurements with contrast-detail for mammography (CDMAM) phantom [3, 4, 6]. CDMAM phantom (version 3.4) is an image quality phantom designed specifically for mammography systems. CDMAM 3.4 is composed of gold disks of different thicknesses and diameters placed on an aluminum substrate. The aluminum substrate are added on a polymethyl-methacrylate (PMMA) layer. Aluminum layer and PMMA layer together are equivalent to 10 mm PMMA thickness. The gold disks are placed in 205 square cells in a raster fashion as 16 rows and 16 columns. The gold disks' thicknesses vary between 0.03 mm and 2 mm and their diameters vary between 0.06 mm and 2 mm as they are also logarithmically scaled. Each square is rotated by forty-five degrees to minimize the intensity difference caused by the heel effect [7]. There are two identical gold disks in each square, one at the center and one at a randomly chosen corner (of the same thickness and same diameter). The detail in the center is the reference signal and the detail in the randomly selected corner is the test signal that should be detected correctly. The ratio of correctly identified disk-positions to total number of squares, image quality figure (IQF), and inverse image quality figure (IQF$_{inv}$) are used in evaluating the image quality of CDMAM phantom images. IQF can be defined as the contrast-detail resolution of the image analysis.

In addition, IQF is considered as an adequate parameter to detect abnormal functioning of the equipment and defined in Equation 1 [1, 7].

$$IQF = \sum_{i=1}^{16} C_i \times D_{i,min} \quad (1)$$

Where Ci is the threshold thickness of diameter $D_{i,min}$.

Image quality increases with an increasing number of correctly identified disk-positions. In this case, the IQF will become smaller because the values of diameter and thickness of the threshold-disks are smaller. The current evaluation method is to determine the threshold thickness per diameter, which is defined in Equation 2 [7].

In this method, only the number of partly visible columns of the phantom are measured and higher IQF$_{inv}$ expresses better image quality [7].

$$IQF_{inv} = \frac{100}{IQF} \quad (2)$$

There is a linear relationship between the IQF$_{inv}$ value and the contrast-to-noise ratio (CNR) which is a preferred parameter for finding the optimal dose value. IQF$_{inv}$ has a better correlation with threshold contrast than CNR, hence IQF$_{inv}$ is considered as a more reliable and objective parameter for image quality assessment [1, 8]. European protocol suggests using of raw phantom images as long as they are accessible in threshold contrast detection. This is because processed images are useful for clinical diagnosis, but are useless for numerical tests, and the values obtained from raw images reflect the detector's response considerably better. There is no general standard for the definition of raw data, but in the European protocol, raw data is defined as "for processing" version of the images. However, each manufacturer applies its own device-specific "corrections" to obtain a raw image [3, 9]. Moreover, raw data is not accessible for some systems, in which case, the protocol suggests that processed data can be used.

The purpose of this study is to compare the IQF$_{inv}$ values of raw and processed digital phantom images.

Materials and Methods

Digital CDMAM 3.4 phantom images were taken from three different full digital mammography systems (System A, System B, and System C) with selenium (a-Se) flat-panel direct system detector technology. The detector for system A had a pixel pitch of 70µm and the pixel pitch for systems B and C was 80µm, manufactured in 2010, 2015, and 2010, respectively. Measurements were carried out in digital mammography systems using similar anode material. The use of a tungsten-anode tube instead of molybdenum-anode tube reduced the breast dose in the same image quality [10]. Images were obtained while System A and C were in Tungsten/Rhodium (W/Rh) anode/filter combination and System B in Tungsten/Silver (W/Ag) combination.

The CDMAM phantom is equivalent to 10mm PMMA thickness and was placed between 4 PMMA plates of 1cm, with the smallest disk-diameters on the thoracic side. In order to simulate a total 60mm breast thickness, images were taken using 1 cm spacer on the sides of 50 mm phantom.

The 1 cm spacer was used in the test set-up because the choice of x-ray spectrum in many mammography systems depends on the breast thickness or the height of the compression pedal. Five different images were obtained in the automatic exposure mode (AEC) with the exposure parameters used in the clinic. The IQF_{inv} value is different for each image and is affected by the working conditions of the mammography system. For this reason, 5 different phantom images were acquired to obtain statistically reliable results from each system. After each image, the phantom was moved by 1 mm to avoid any local problem that may be present in the detector structure. Each image was recorded in DICOM format in a way that the user can access the processed data and its corresponding raw data (without pre-processing) for three systems. Artinis software (version 2.2, CDCOM) was used for the automatic evaluation of digital CDMAM phantom images. The program is able to evaluate and analyze the digital CDMAM 3.4 phantom images fast and automatically detects the location of the gold disks in the phantom image. CDCOM software is available on the EUREF website [www.euref.org].

Studies comparing IQF_{inv} results from raw and processed images are available in the literature [11-14], but it is recommended that 1 cm spacer should be used on phantom edges to better simulate breast thickness with respect to European standards. For this reason, in our study, 60 mm breast thickness was simulated by using 1cm thick spacer.

Results

Raw and processed phantom images were acquired from three different digital mammography systems and then IQF_{inv} values were obtained by evaluating with the Artinis software (V.2.2).

IQF_{inv} values for System A, B, and C are shown for raw and processed images and the difference between them is expressed as percentage (%) in Table 1.

The difference between the IQF_{inv} values were 1.34%, 5.62%, and 6.7% for System A, B, and C, respectively. The difference of IQF_{inv} values between raw and processed im-
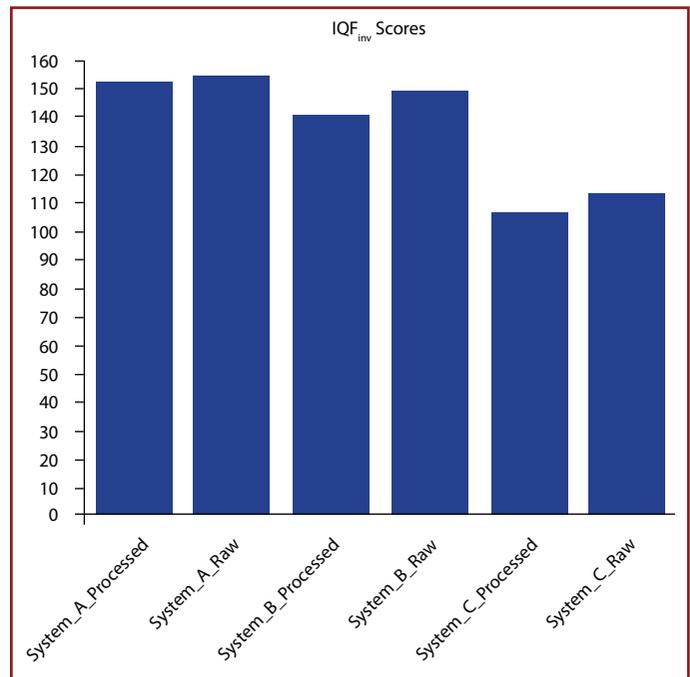

Figure 1. Comparison of Inverse image quality figure index (IQF_{inv}) values of systems for raw and processed images.

ages differs from system to system as manufacturers employ different image processing algorithms such as Musica 1, IMS Raffaello, OpView v1, OpView v2, and Sigmoid in the processing of images. The IQF_{inv} values of the raw and processed images for System A, B, and C are shown graphically in Figure 1.

Conclusions

European standards recommend the use of raw images for the detection of the contrast-detail curve in previous studies. However, it has been observed that there is no significant difference between the IQF_{inv} values of raw and processed images calculated by the software. The difference between the IQF_{inv} values obtained from raw and processed images differs from system to system, so it is not possible to generalize this conclusion for all digital mammography systems. In addition, when IQF_{inv} values are used to compare different systems, similar results are observed for raw and processed images.

Table 1. Inverse image quality figure index (IQF_{inv})values of raw and processed images

Mammography systems	Raw_IQF_{inv}	Processed_IQF_{inv}	% Difference two groups between
A	154.38	152.33	1.34
B	148.61	140.69	5.62
C	113.05	105.95	6.7

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