Radiation Physics and Chemistry 116 (2015) 292–299

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

Dosimetry and image quality in digital mammography facilities in the State of Minas Gerais, Brazil

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HIGHLIGHTS

- Mean glandular dose and image quality in digital mammography systems.
- Linearity of the detector response to the system computed radiography.
- Dosimetry and image quality on digital mammography in Minas Gerais, Brazil.
- 44% Of CR and DR mammography systems passed in the evaluation of mean glandular dose.
- The overall uncertainty for mean glandular dose measurement was 5.2%.

ARTICLE INFO

Article history:
Received 8 October 2014
Received in revised form
9 May 2015
Accepted 12 May 2015
Available online 1 June 2015

Keywords:
Mammography
Mean glandular dose
Quality control
Contrast-to-noise ratio

ABSTRACT

According to the National Register of Health Care Facilities (CNES), there are approximately 477 mammography systems operating in the state of Minas Gerais, Brazil, of which an estimated 200 are digital apparatus using mainly computerized radiography (CR) or direct radiography (DR) systems. Mammography is irreplaceable in the diagnosis and early detection of breast cancer, the leading cause of cancer death among women worldwide. A high standard of image quality alongside smaller doses and optimization of procedures are essential if early detection is to occur. This study aimed to determine dosimetry and image quality in 68 mammography services in Minas Gerais using CR or DR systems. The data of this study were collected between the years of 2011 and 2013. The contrast-to-noise ratio proved to be a critical point in the image production chain in digital systems, since 90% of services were not compliant in this regard, mainly for larger PMMA thicknesses (60 and 70 mm).

Regarding the image noise, only 31% of these were compliant. The average glandular dose found is of concern, since more than half of the services presented doses above acceptable limits. Therefore, despite the potential benefits of using CR and DR systems, the employment of this technology has to be revised and optimized to achieve better quality image and reduce radiation dose as much as possible.

1. Introduction

In recent decades cancer has gained greater prominence, becoming a global public health problem. According to the World Health Organization, in the year 2030 one can expect 27 million incident cases of cancer, with 17 million deaths and 75 million people living with the disease (INCA, 2014). Among the types of cancer, breast cancer is the second most common type in the world and the most common among women, accounting for 22% of new cases each year. Data from the National Cancer Institute reveal that 57,120 new cases of breast cancer are expected in Brazil for the year 2014. In the state of Minas Gerais, Brazil, the estimate is 5210 new cases each year (INCA, 2014).

Mammography is irreplaceable in the diagnosis and early

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http://dx.doi.org/10.1016/j.radphyschem.2015.05.024
0969-806X/

detection of breast cancer. The introduction of digital technologies in mammography, through the computed radiography (CR) and direct digital radiology (DR), has created new expectations for this technique, based on its potential benefits in the early detection of breast cancer. CR systems use phosphor plates and a separate reader. DR systems have an integrated x-ray system and detector. The image is available on the computer immediately after the x-ray exposure (Bick and Diekmann (2009).

There is a small but significant risk of carcinogenesis induced by x-rays in performing a mammogram. However, testing the quality of the technical aspects of mammography equipment at regular time-intervals can minimize this risk. Determination of mean glandular dose (D_G) is an important factor in quality control of mammography systems, since this is the dosimetric quantity that best defines this risk (Dance et al., 1999).

In the European Guidelines (Perry et al., 2006) the image quality is expressed via contrast thresholds. This criterion is evaluated with the Contrast Detail for Mammography (CDMAM) test object (Artinis, the Netherlands). The Artinis CDMAM phantom consists of an aluminum base with gold disks of different thicknesses and diameters, and aims at testing the ability of detecting objects with very small contrast and diameter in mammography. The results of an analysis with the CDMAM phantom are threshold levels expressed as x-ray contrast or in terms of the thickness of gold disks. This analysis is featured by the relationship between the thresholds of visualization of disks and dose values related to that image. This research aimed at evaluating the mean glandular dose to which patients are exposed while undergoing a mammogram using CR or DR systems; image quality was evaluated using images of the CDMAM phantom. The overall uncertainty for mean glandular dose measurement with solid-state dosimeter (Unfors Xi) was estimated at 5.2%.

2. Material and methods

In this study 68 digital processing systems were assessed, including 65 CR systems and 3 DR systems, for a total of 72 combinations of mammography-CR or DR. This corresponds to approximately 14% of mammography units currently in use throughout Minas Gerais and about 34% of digital mammography systems. (Tables 1 and 2). According to the (CNES (2014), there are approximately 477 mammography services operating in Minas Gerais, of which about 200 are digital apparatus using CR or DR systems.

2.1. Image quality for CR or DR systems

It is recognized that high-quality images are essential for the reliable detection in the breast mammography. There is no clear pattern for specifying mammographic image quality (ICRU, 2009). However, knowing to quality of the images depends of several factors like the performance of x-ray unit and image detector (NHSBSP, 2009). Taking into account such allegations, in order to assess the quality of mammographic images and the integration between mammography unit and digital image processing system, besides the analysis of image quality parameters like contrast and definition by means of a breast phantom, the linearity of the detector response, the contrast-to-noise ratio, noise and average glandular dose were evaluated.

Table 1
Mammography systems and mammography DR studied.

Manufacturer of the mammography unit	Percentage of systems assessed
GE	65
Hologic[a]	10
Siemens	13
VMI[b]	7
Other (Philips, Elscint)	5

[a] Three of them were DR systems.
[b] VMI is a mammography unit made in Brazil.

Table 2
CR modalities studied.

Manufacturer of the CR reader	Percentage of systems assessed
KODAK	43
FUJI	39
AGFA	18

2.1.1. Linearity of the detector response

The exposure range over which the detector response is linear could be specified by the manufacturer. In the DR system the mean pixel value (MPV), depending on the values of the incident air kerma (K_i), has a linear response. For CR systems this relation is logarithmic.

In this test, four polymethyl methacrylate (PMMA) plates measuring $18 \times 24\ \text{cm}^2$ with the thickness of 1 cm each were positioned near the output of the x-ray tube to provide the image, and measure the incident air kerma, K_i. The K_i value was measured with a solid-state detector (Unfors Xi R/F & MAM platinum detector, serial number 181096). The generated and used images in the analysis were saved without processing (raw data). These measurements were performed with a x-ray tube voltage of 28 kV, alongside with an anode-filter combination Mo/Mo, and a wide interval of current exposure time product values: 4, 8, 16, 25, 32, 45, 63, 100 and 140 mAs. According to SEFM (2007) the tube voltage of 28 kV and the anode-filter combination Mo/Mo are standard conditions for performing this test. Besides, the response function of the detector is assessed in the manual mode with the range of mAs that cover 1/10 or five times the value of mAs used for radiographing a standard simulator, in this case, we used one with 45 mm of PMMA. In this research the devices tested were very old, and for safety issues it was not spent the given amount of 140 mAs during quality control assessments. For the CR systems, MPV is represented in the function of the logarithm of K_i and is provided by (SEFM, 2012):

$$\text{MPV} = a\ln(K_i) + b \tag{1}$$

where MPV is the mean pixel value, $\ln(K_i)$ is the value of the logarithm of the air kerma and $\boldsymbol{a}$ and $\boldsymbol{b}$ are fitted coefficients of the linear equation. In each image, a region of interest (ROI) of $4\ \text{cm}^2$ was selected at 6 cm from the thorax wall in order to provide the MPVs and standard deviations (SD) of the image.

With the coefficients $\boldsymbol{a}$ and $\boldsymbol{b}$ of the linear equation (Eq. (1)), the MPVs and SDs were linearized through Eqs. (2) and (3) respectively (SEFM, 2012):

$$\text{MPV}' = e^{\left(\frac{\text{MPV}-b}{a}\right)} \tag{2}$$

$$\text{SD}' = \frac{\text{SD}}{a} e^{\left(\frac{\text{MPV}-b}{a}\right)} \tag{3}$$

where MPV′ is the linearized mean pixel value, MPV is the mean pixel value, and $\boldsymbol{a}$ and $\boldsymbol{b}$ are the fitted coefficients of Eq. (1) (SEFM, 2012). In addition to that, SD′ and SD are the values of linearized standard deviation and standard deviation associated with the image background, respectively. For DR systems, the linearization of SD and MPV was not necessary because the system already presents a linear response. If the coefficient of