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QUALITY CONTROL IN DIGITAL MAMMOGRAPHY: THE NOISE COMPONENTS

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ABSTRACT

To measure the linearity of the detector and determine the noise components (quantum, electronic and structural noise) that contributed to losing image quality and to determine the signal noise ratio (SNR) and contrast noise ratio (CNR).
This paper describes the results of the implementation of a protocol for quality control in digital mammography performed in two direct digital mammography equipment (Hologic, Selenia) in Santiago of Chile. Shows the results of linearity and noise analysis of the images which establishes the main cause of noise in the image of the mammogram to ensure the quality and optimize procedures.
The study evaluated two digitals mammography's Selenia, Hologic (DR) from Santiago, Chile. We conducted the assessment of linearity of the detector, the signal noise ratio, contrast noise ratio and was determined the contribution of different noise components (quantum, electronics and structural noise). Used different thicknesses used in clinical practice according to the protocol for quality control in digital mammography of Spanish society of medical physics and NHSBSP Equipment Report 0604 Versión 3. The Selenia mammography software was used for the analysis of images and Unfors Xi detector for measuring doses.
The mammography detector has a linear performance, the CNR and SNR did not comply with the Protocol for the thicknesses of 60 and 70 mm. The main contribution of the noise corresponds to the quantum noise, therefore it is necessary to adjust and optimize the mammography system.

1. INTRODUCTION

According to the National Cancer Institute (INCA), breast cancer is the leading cause of death among women in Brazil, with an incidence of 49,240 cases for 2010. With this estimate, only the state of Minas Gerais will be 4,250 new cases [1].

The mammography for early cancer detection requires quality standards to ensure the effectiveness of the procedure, which depends significantly on a diagnostic quality image. Therefore, it is essential for efficiency and safety of this technique implementing a Quality Assurance program. [2.3]

At present there is a change in technology to perform mammography, where the direct digital mammography systems (DR) and computed radiography (CR) have been rapidly replacing traditional film-screen system. It is accepted the fact that digital systems provide a greater dynamic range, the contrast manipulation and the availability of new tools that help the diagnosis. [4]

However, this technological change has brought impact on image quality, so the implementations of quality assurance protocols are a tool for diagnostic quality images with a reasonable dose (ALARA concept) [3].One such test is the image quality which analyzes the image noise, fundamental parameter to obtain images of diagnostic quality and a parameter for optimizing practice [5].

This paper describes the results of the implementation of a protocol for quality control in digital mammography performed in two direct digital mammography equipment (Hologic, Selenia) in Santiago of Chile. It shows the results of linearity and noise analysis of the images which establishes the main cause of noise in the image of the mammogram to ensure the quality and optimize procedures.

2. MATERIAL AND METHOD

The study evaluated two digitals mammography's (DR) Selenia (Hologic, USA) from Santiago of Chile. The digital system has an amorphous selenium detector 24x29 cm2, with a pixel size of 70 µm. The equipment has two anode (Mo and Rh) and two filters (Mo and Rh).

On the measurement an Unfors dosimetry system [6] MAM Xi with a specific solid state detector for mammography (Xi mam detectorplatinum) was used and different thicknesses of polymethyl methacrylate (PMMA) 18x24 cm. The exposure technique was recorded according to the clinical conditions of each institution. These were obtained with automatic exposure control (AEC) for the different PMMA thicknesses. Used different thicknesses used in clinical practice according to the protocol for quality control in digital mammography of Spanish society of medical physics and NHSBSP Equipment Report 0604 Versión 3.

The detector was positioned and centered on the bucky (support of the breast), the detector's sensitive volume was positioned at 4 cm from the chest wall. Then it was manually selected the technique obtained with the AEC for each PMMA thickness and measured the incident air kerma.

Then, in order to obtain the air kerma at the entrance surface (ESAK) [7-11] the following expression was used:

$$ESAK = \frac{K_i}{P_{it}} \cdot P_{it,auto} \cdot \left(\frac{d_1}{d_2}\right)^2 \qquad (1)$$

Where K_i is the incident air kerma, $P_{it,auto}$ and P_{it} are the product of the current by the time obtained with the automatic exposure control for PMMA thicknesses and tube charge at the time of the measurement with the detector, respectively. The distances from the focus to the detector and the surface of PMMA are d_1 and d_2, respectively.

For DR systems used the auto-filter mode and auto-time for thicknesses from 60 and 70 mm to be compared to the studies conducted in Brazil by Dantas and Nogueira [12]. All the measurements were made with compressor, grill and the combination of target/Molybdenum filter/Molybdenum (Mo) with Mo filter of 30 µm.

We conducted the assessment of linearity of the detector with a thickness of 50mm of PMMA for different currents used in clinical practice and was determined the contribution of different noise components (quantum, electronics and structural noise) according to Young et. al, the signal noise ratio (SNR), contrast noise ratio (CNR) the following expression was used according to the protocol used [4,10].

$$SNR = \frac{MPV - offset}{sd} \qquad (2)$$

Where
MPV is the mean value of the pixel in the region of interest
sd is the value of the standard deviation of the region of interest

$$CNR = \frac{MPV_1 - MPV_2}{\sqrt{\frac{sd_1^2 + sd_2^2}{2}}} \quad (3)$$

Where
MPV is the mean value of the pixel in the region of interest 1 or 2
sd is the standard deviation value in the region of interest 1 or 2

The MPV and sd measure were performed with an ROI of 100 cm^2 using Selenia mammography software.

3. RESULTS

It has been verified that for both mammography equipment, exists a linear correlation between the signal and ESAK with a coefficient of determination $R^2 = 0.9999$, higher than 0.99 recommended by the Spanish protocol.

Tables 1 and 2 show the values obtained for the signal to noise ratio (SNR) according to equation 2, for each of mammograph. In both cases differences were greater than 10% from the average value 52.2 and 50.2 for mammograph DR1 and DR2, respectively.

Table 1: Noise signal ratio for different thickness, DR1

SNR DR1					
Thickness (cm)	kV	mAs	SNR	mean	Variation %
2	26	31.2	56.3	52.2	7.8
3	27	55.2	56.9		8.9
4	28	84.6	54.7		4.7
5	30	100.3	50.9		-2.5
6	32	109.7	48.6		-7.0
7	32	172.0	45.9		-12.0

Table 2: Noise signal ratio for different thickness, DR1

SNR DR2					
Thickness (cm)	kV	mAs	SNR	mean	Variation %
2	26	30.5	55.8	50.2	11.0
3	27	51.0	54.8		9.1
4	28	80.1	52.0		3.6
5	30	100.0	49.0		-2.5
6	32	108.4	45.8		-8.8
7	32	174.1	44.0		-12.3

Measurements of noise contrast ratio CNR are seen in Tables 3 and 4, which were obtained from equation 3 for each mammography equipment.

Table 3: Contrast noise ratio for different thickness, DR1

CNR DR1				
PMMA Thickness (cm)	kV	mAs	CNR calculated	Limiting value for relative CNR %
20	26	35.0	13.6	>115
30	27	60.1	12.1	>110
40	28	90.5	10.4	>105
50	30	108.7	8.0	>100
60	32	109.9	5.8	>95
70	32	172.5	5.1	>90

In both cases, the CNR measured for thicknesses of 60 to 70 mm CNR did not comply with the limits of 95 and 90% established in the protocol.

Table 4: Contrast noise ratio for different thickness, DR2

CNR DR2				
PMMA Thickness (cm)	kV	mAs	CNR calculated	Limiting value for relative CNR %
20	26	38.5	14.3	>115
30	27	64.2	12.8	>110
40	28	98.8	10.8	>105
50	30	118.9	8.4	>100
60	32	110.3	5.8	>95
70	32	175.9	5.0	>90

The relative noise and components are shown in figure 1, the quantum noise is the main cause of noise, electronic noise has more influence at low currents.

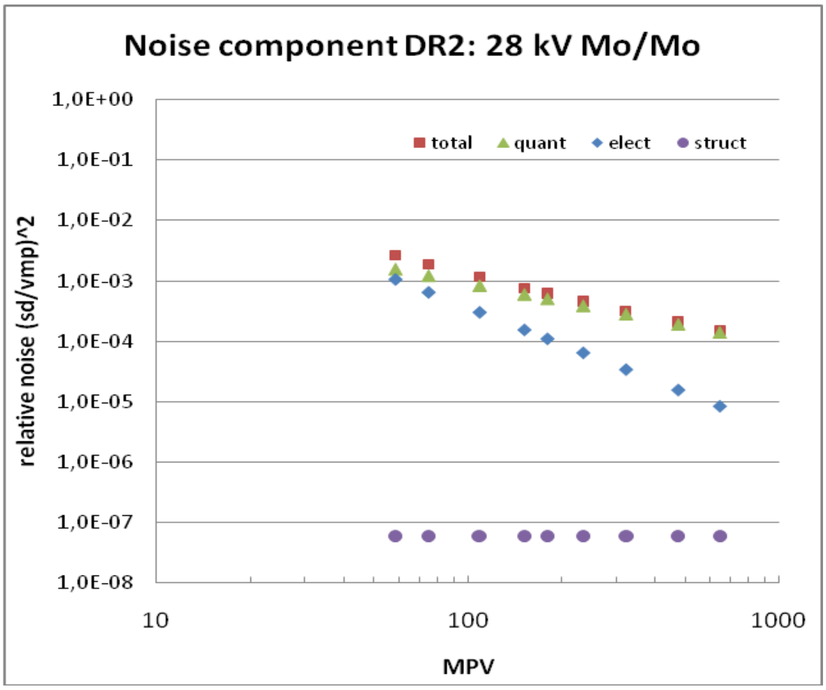

Figure 1. Noise component for DR2, 28 kV with Mo/Mo.

4. DISCUSSION

The detector response was linear for both cases. The noise analysis confirmed that the quantum noise is the main source of noise. However, the contribution of electronic noise is higher for lower currents [13,14] as shown in Figure 1. This may show increased noise in the images for thin breasts hampering proper diagnosis.

CNR values were higher for smaller thicknesses. The CNR value decreased with increasing thickness of PMMA. The thicknesses of 60 and 70 mm did not meet the requirements of the protocol applied [2.4], but agrees with the results of Dante and Nogueira [12] carried out in CR system and Chevalier et. al. [14] carried out in a DR; which also did not meet the criteria of the protocol for thicknesses of 60 and 70 mm.

SNR values for larger and smaller thicknesses have a deviation greater than 10%. This difference confirms the founding in Figure 1 which shows that there is the presence of additional noise to quantum noise that contributes to the loss of image quality diagnosis.

Figure 1 shows clearly the contribution of each component of the noise, the quantum, electronic and structural noise. Which shows that the main contribution is due to quantum noise, however, the contribution of electronic noise is higher for low currents, which could deteriorate the image quality for thin breasts.

5. CONCLUSIONS

It was verified that the mammography detector has a linear performance, the CNR and SNR did not comply with the Protocol for the thicknesses of 60 and 70 mm. The main contribution of the noise corresponds to the quantum noise, therefore, it is necessary to adjust and optimize the mammography system.

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REFERENCES

1. Ministério da Saúde. Secretaria de Atenção à Saúde. Instituto Nacional do Câncer. *Estimativa 2010: Incidência de câncer no Brasil*, Instituto Nacional do Câncer, Rio de Janeiro, Brasil (2009).
2. Comimission of the European Communities (CEC). *European guidelines for quality assurance in breast cancer screening and diagnosis (fourth edition),* European communities, ISBN: 92-79-01258-4, (2006)
3. Organismo Internacional de Energía Atómica (OIEA), *Normas básicas Internacionales de seguridad para la protección contra la radiación ionizante y para la seguridad de las fuentes de radiación (NBS), Colección de seguridad Nº115*, OIEA,Viena, Austria (1997).
4. Margarita Chevalier del Rio, Pilar Morán Penco, Juan Jose Morant Echevarne, Ricardo Torres Cabrera, *Protocolo de Control de Calidad en Mamografía Digital*, Sociedad Española de Física Médica, Madrid, España (2002).
5. Michielsen, K., Jacobs, J., Lemmens, K., Nens, J.,Zoetelief, J., Faulkner, K. and Bosmans, H. "Results of a European dose survey for mammography". *Radiat. Prot. Dosim*. **129**, 1–5 (2008)
6. www.unfors.com, last accesses July 7th, 2010.
7. ICRU. International Commission on Radiological Units and Measurements, *Patient dosimetry for x rays used in medical imaging ICRU Report 74* (J. ICRU 5 (2)), (2005)
8. Pernicka F, McLean I.D. *Dosimetry in Diagnostic Radiology: An International Code of Practice, Technical Reports Series N°457*, Austria, IAEA, 23-155 (2007)
9. J. Zoetelief, M. Fitzgerald, W. Leitz, M. Sabel, *European Protocol on Dosimetry in Mammography, EUR 16263en*, European Commission june (1996)
10. National Health Service Breast Screening Programmes, *NHSBSP Equipment Report 0604 Version ,* Commissioning And Routine Testing Of Full Field Digital Mammography Systems. London: NHS Cancer Screening Programmes; 15-64 (2009)
11. M.A. Rivas Ballarín, P. Ruiz Manzano, M. Canellas Anoz, E. Millán Cebrián, J.A. Font Gómez, P. Ortega Pardina. "Estimación de dosis en radiografía de mama". *Revista de Física Médica* **4(2):** 95-100 (2003)
12. Marcelino V.A. Dantas y Maria do Socorro Nogueira, *Dose glandular e controle de qualidade da imagem em serviços de mamografia com sistema de radiografia computadorizada*, Comissão Nacional de Energia Nuclear, Centro de Desenvolvimento Da Tecnologia Nuclear, Programa de Pós-Graduação em Ciência e Tecnologia das Radiações, Minerais e Materiais, Belo Horizonte, Brasil, 2010. Last access January 6th 2011, http://www.dominiopublico.gov.br/pesquisa/DetalheObraForm.do?select_action=&co_obra=181971
13. R. Bouwman, K. Young, B. Lazzari, V. Ravaglia, M. Broeders and R. van Engen, "An alternative method for noise analysis using pixel variance as part of quality control procedures on digital mammography systems", *Phys. Med. Biol*. **54**,6809–6822, (2009).
14. M. Chevalier, P. Morán, J. Valverde, C. Núñez de Villavicencio, "Resultados del control de calidad de un sistema mamográfico de campo completo Hologic Selenia aplicando el protocolo español en mamografía digital", *Revista de Física Médica*; **9(3):** 127-132 (2008).