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LATIN AMERICAN DOSE SURVEY RESULTS IN MAMMOGRAPHY STUDIES UNDER IAEA PROGRAMME: RADIOLOGICAL PROTECTION OF PATIENTS IN MEDICAL EXPOSURES (TSA3)

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Latin American countries (Argentina, Brazil, Chile, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Mexico, Nicaragua, Paraguay, Uruguay and Venezuela) working under the International Atomic Energy Agency (IAEA) Technical Cooperation Programme: *TSA3 Radiological Protection of Patients in Medical Exposures* have joined efforts in the optimisation of radiation protection in mammography practice. Through surveys of patient doses, the region has a unique database of diagnostic reference levels for analogue and digital equipment that will direct future optimisation activities towards the early detection of breast cancer among asymptomatic women. During RLA9/057 (2007–09) 24 institutions participated with analogue equipment in a dose survey. Regional training on methodology and measurement equipment was addressed in May 2007. The mean glandular dose (D_G) was estimated using the incident kerma in air and relevant conversion coefficients for both projections craneo caudal and mediolateral oblique (CC and MLO). For Phase 2, RLA9/067 (2010–11), it was decided to include also digital systems in order to see their impact in future dose optimisation activities. Any new country that joined the project received training in the activities through IAEA expert missions. Twenty-nine new institutions participated (9 analogue and 20 digital equipment). A total of 2262 patient doses were collected during this study and from them D_G (mGy) for both projections were estimated for each institution and country. Regional results (75 percentile in mGy) show for CC and MLO views, respectively: RLA9/057 (analogue) 2.63 and 3.17; RLA/067: 2.57 and 3.15 (analogue) and 2.69 and 2.90 (digital). Regarding only digital equipment for CC and MLO, respectively, computed radiography systems showed 2.59 and 2.78 and direct digital radiography (DDR) systems 2.78 and 3.04. Based on the IAEA Basic Safety Standard (BSS) reference dose (3 mGy), it can be observed that there is enough room to start optimisation processes in Latin America (LA); several countries or even particular institutions have values much higher than the 3 mGy. The main issues to address are lack of well-established quality assurance programmes for mammography, not enough medical physicists with training in mammography, an increase in patient doses with the introduction of digital equipment and to create awareness on radiation risk and optimisation strategies.

INTRODUCTION

Incidence and mortality of breast cancer among Latin American women present the same behaviour as worldwide. Incidence has been increasing in the last two decades, placing it among the first or second type of cancer in women depending on the country. Mortality has also increased at a much lower rate. Age behaviour is also similar with a marked increase among women aged 50 years and older[(1)].

Opportunistic mammography is carried out in all countries mainly because no formal mammography screening programmes are established in the region.

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Common practice is the referral of a mammographic examination during a general/specialist practitioner consultation on a public or private health level. In this scheme, frequency of mammograms varies from 1 to 3 year intervals.

To improve the diagnostic quality of mammograms and patient radiation protection, Latin American countries have been working with the International Atomic Energy Agency (IAEA) regional programme: *TSA3 Radiological Protection of Patients in Medical Exposures.* This project has seven main areas that address patient radiation protection and optimisation: adult and paediatric radiology, mammography, interventional radiology, computed radiology, nuclear medicine and radiotherapy. Previous work on mammography generated IAEA-TECDOC 1517: *Control de Calidad en Mamografía Diagnóstica* [quality control (QC) in diagnostic mammography][2].

Project TSA3 has had two phases, mainly from an administratively point of view at the IAEA, from 2007 to 2009 and from 2010 to 2011. Software was designed to help implementation of publication TECDOC 1517[3] and during this time two additional publications from the Agency became available (Human Health Series 2 and 17)[4, 5].

The region lacks a well-established QA/QC culture, qualified personnel (medical physicist and radiographers) and strong regulations on mammography equipment. Due to the above reasons one of the project objectives was to establish baseline information regarding patient radiation protection and optimisation in mammography via a dose survey. This paper will present only findings regarding mean glandular doses (D_G) as a way to direct future optimisation activities.

METHODS

During Phase I (RLA/9/057: 2007–09) a total of 24 institutions participated in the dose survey. Only analogue equipment was included in this phase. The countries participating and the number of institutions from each are Argentina (ARG) 1, Brazil (BRA) 10, Chile (CHI) 2, Costa Rica (COS) 4, Ecuador (ECU) 1, Nicaragua (NIC) 1, Paraguay (PAR) 1 and Uruguay (URU) 4. Each institution participated with only one equipment.

In May 2007, a regional training course was held in Costa Rica for medical physicists responsible for data collection; its main objective was to train in the common methodology that was going to be used by all countries and the use of the spreadsheets. The methodology to obtain D_G is the one described in IAEA TECDOC 1517[2] and Dosimetry in Diagnostic Radiology: an International of Code of Practice[6] using the following equation:

$$D_G = c_{DG50,K_i,PMMA} s\, K_i, \quad (1)$$

where 'K_i' is the incident air kerma, 's' is the s factor which gives a correction that depends on the target filter combination and '$c_{DG50,Ki,PMMA}$' is the conversion coefficient used to calculate the mean glandular dose to a 50-mm standard breast of 50% glandularity from the incident air kerma for a 45-mm poly(methyl methacrylate) phantom.

Hands on experience at a local hospital enabled the course's participants to review methodology, handle the equipment and the specially designed spreadsheets. During this first year the IAEA bought each country the necessary equipment for the dose measurements (PTW Unidos electrometer with a mammographic ionisation chamber, PTW Diavolt, aluminum sheets, photometer, American College of Radiology (ACR) image quality phantom and other miscellaneous equipment).

At each participating institution on a first visit, the medical physicist, performed basic QC test [kilovoltage (kV_p), half-value layer (HVL), current (mA s) and field size] to assure the accuracy of the parameters that will affect the dose estimation. Later the medical physicist collected data to obtain the output of the equipment for all kV_ps used in the clinical practice; for each kV_p values of HVL were also obtained. Locally radiographers collected for each patient view: kV_p, breast thickness and mA s. Mean glandular doses were automatically estimated in the spreadsheet and the complete results were sent to the regional coordinator for future analysis.

Sample size for each participating institution consisted of 25 patients for CC and MLO views. The thickness of the breast was restricted to 4–6-cm compressed breast with a glandularity of 50% according to image evaluation by radiologist. Each view has also scored according to the EUREF group image quality criteria[7] by the radiologist, it was decided on a first regional coordinated meeting by radiologists and medical physicists that in order to guarantee to have good diagnostic images, all images <80% would be considered non-acceptable and rejected in the clinical practice and not included in the DRL calculations.

During Phase II (RLA/9/067: 2010–11) the decision was taken to include digital mammography units in the study. Each country could decide if more institutions with analogue equipment participated or only new with digital equipment. For this phase new countries entered the regional activities, and each received during 2010 a visit of a senior medical physicist (IAEA expert missions) to explain methodology and data collection. The number of participating institutions for each country showing number of (X) analogue/(Y) digital equipment) is as follows: ARG (2/2), BRA (1/10), CHI (1/0), COS (0/3), Cuba (CUB) (1/0), Guatemala (GUA) (2/1), Mexico (MEX) (0/1), NIC (1/0), PAR (0/1), EL Salvador (SAL) (1/0), Venezuela (VEN) (0/2), for a total of 9 analogue equipment and 20 digital equipment.

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New data collection sheets were developed for the digital units (since new anode/filter combinations are used and not only Mo/Mo). The mean glandular doses were also obtained by measurement of incident air kerma and patient parameters, following the methodology of IAEA Human Health Publication No. 17[5].

$$D_G = g_{53}\, c_{53}\, s\, K_i, \qquad (2)$$

where 'K_i' is the incident air kerma, 's' is the s factor which give a correction that depends on the target filter combination and 'g_{53}' is the factor that converts entrance air kerma to the mean glandular dose for the 53- mm thick standard breast and 'c_{53}' is the conversion factor which allows for the glandularity of the 53-mm thick standard breast.

Table 1. Number of institutions with analogue or digital equipment per country.

Country	RLA/9/057	RLA/9/067		Totals
	Analogue	Analogue	Digital	
ARG	1	2	2	5
BRA	10	1	10	21
CHI	2	1	—	3
COS	4	—	3	7
CUB	—	1	—	1
ECU	1	—	—	1
GUA	—	2	1	3
MEX	—	—	1	1
NIC	1	1	—	2
PAR	1	—	1	2
SAL	—	1	—	1
URU	4	—	—	4
VEN	—	—	2	2
Total	24	9	20	53

(—) means country did not participate.

RESULTS

Table 1 presents a summary of the number of participating institutions per country during each phase of the project. A total of 53 institutions participated, 33 with analogue units and 20 with digital units; of the digital units 10 were computed radiography (CR) units and 10 were DDR units.

Figures 1 and 2 show the results of D_G (mGy) for each participating institution with analogue equipment for CC and MLO views, respectively. Data analysis was performed using statistical tool of Box-and-Whisker plots. The box length is determined by the first and third quartile. The whisker values are the maximum and minimum values within 1.5 of the 'box length' (whisker below this limit correspond to maximum/minimum data of this value) and an outlier is an extreme value that is 1.5 more than the 'box length'[8].

Figures 3 and 4 show the results of D_G (mGy) for each participating institution with digital equipment for CC and MLO views, respectively.

Analysis of individual patients' mean glandular doses is shown in Figures 5–7 (analogue, CR and DDR equipment for a CC view). Similar figures were obtained for MLO projection.

Important results from this analysis are summarised in Table 2, where the percentage of patients above the BSS value of 3 mGy is presented. Also for optimisation purposes the percentage of patients >2 mGy (current achievable level in many protocols)[4, 5, 9, 10] is also presented.

Using the 75th percentile (or third quartile) one can obtain a first estimate of the diagnostic reference

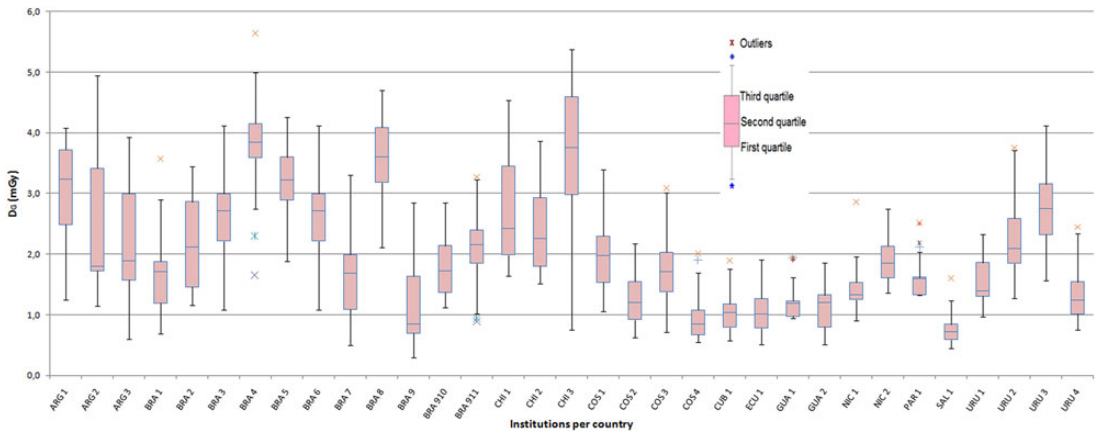

Figure 1. D_G (mGy) for each participating institution with analogue equipment for CC.

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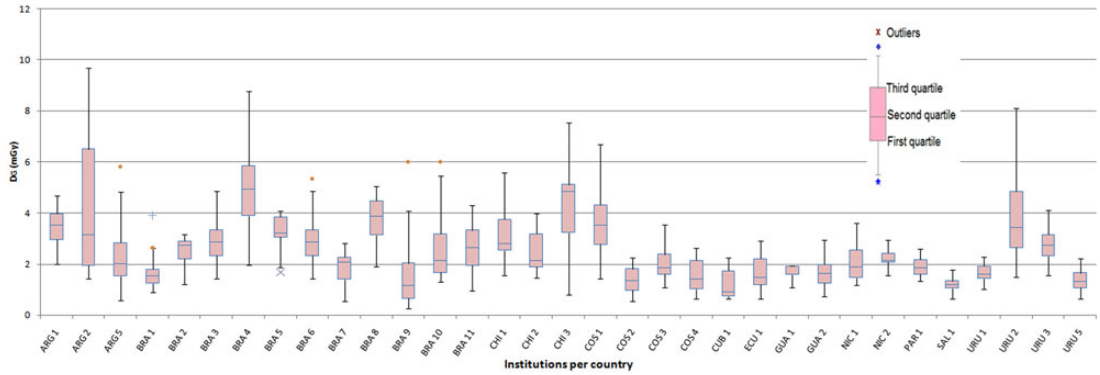

Figure 2. D_G (mGy) for each participating institution with analogue equipment for MLO.

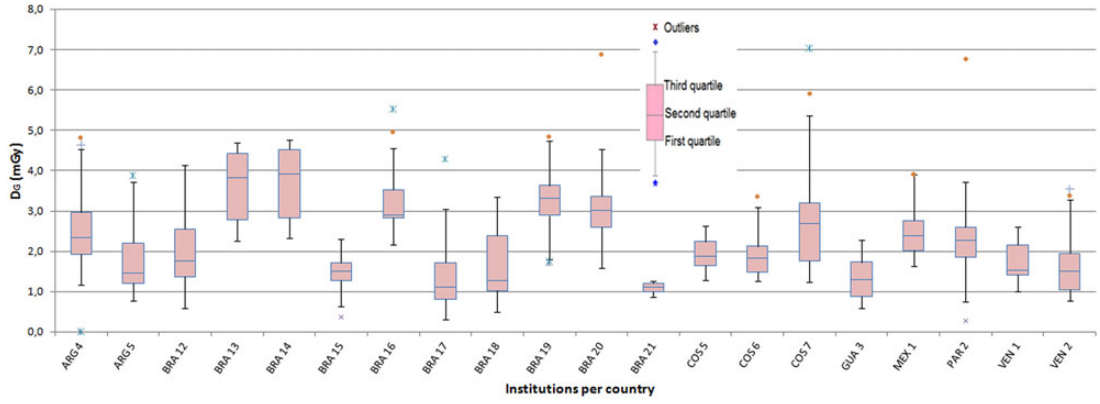

Figure 3. D_G (mGy) for each participating institution with digital equipment for CC.

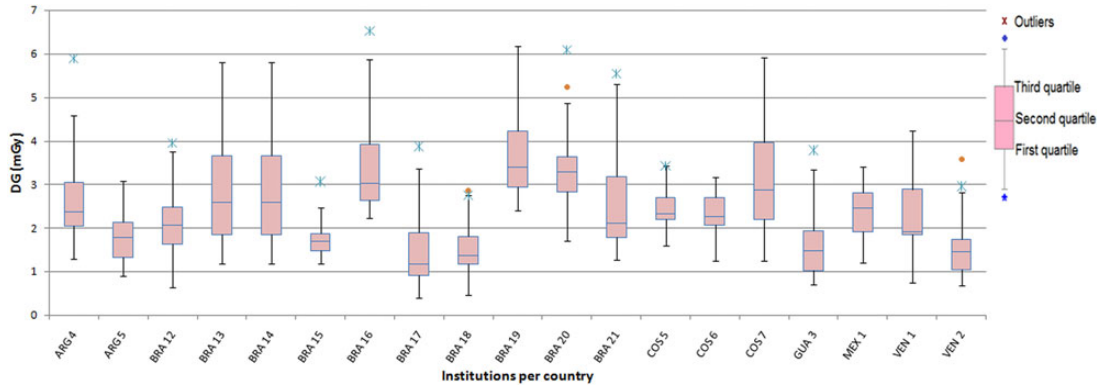

Figure 4. D_G (mGy) for each participating institution with digital equipment for MLO.

level (DRL) for a particular country (even though some do not have a representative sample) or even a first estimate for Latin American. Table 3 shows the results for both views.

DISCUSSION AND CONCLUSIONS

Good participation among Latin American countries resulted in 2262 patient doses collected from 53 institutions, 33 (62%) were analogue equipment and

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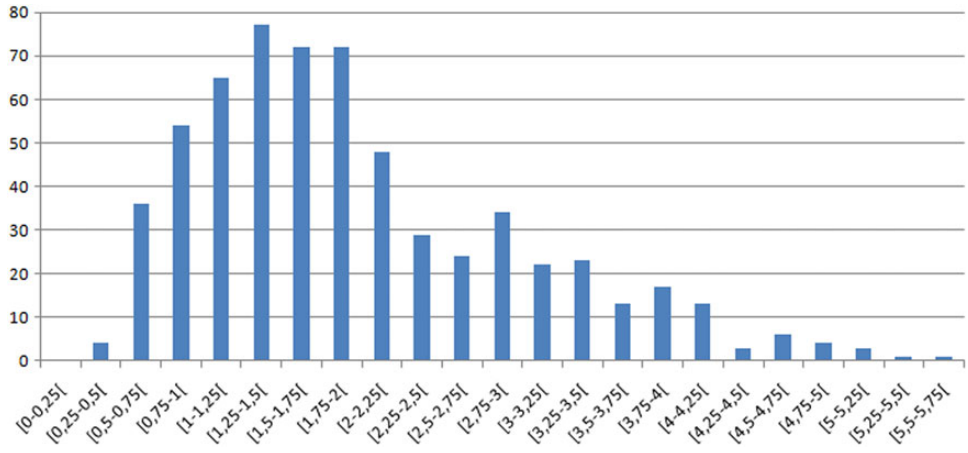

Figure 5. Frequency of D_G (mGy) for analogue equipment CC view.

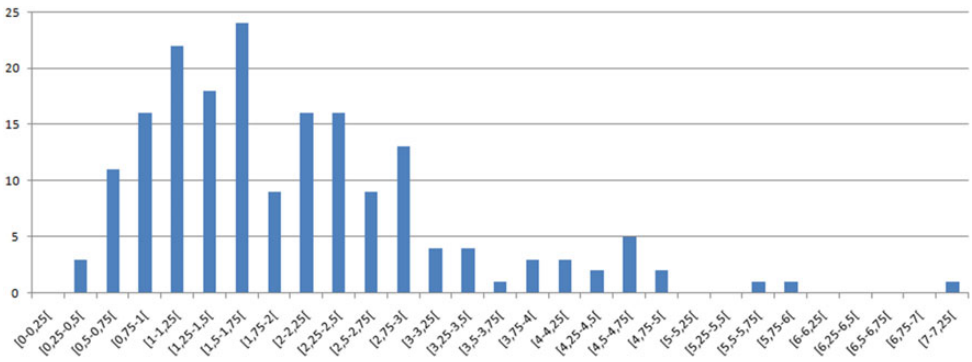

Figure 6. Frequency of D_G (mGy) for digital CR equipment CC view.

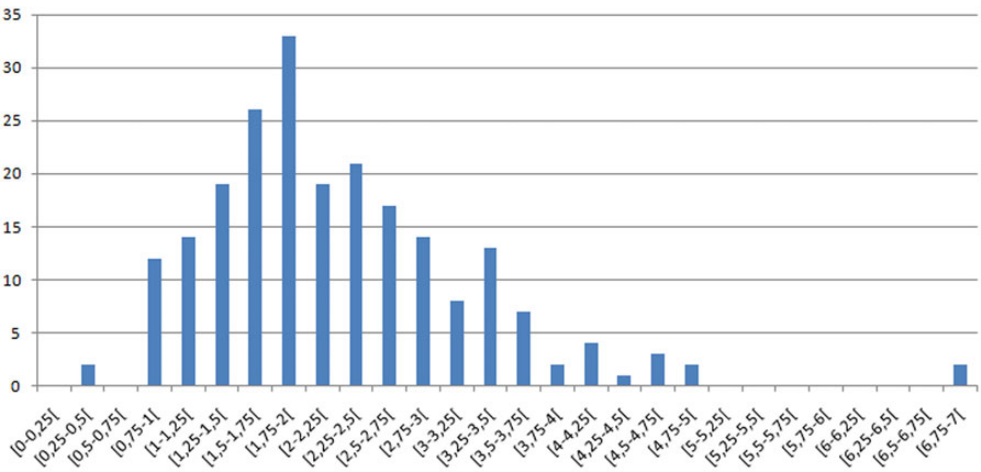

Figure 7. Frequency of D_G (mGy) for digital DDR equipment CC view.

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20 (38%) were digital equipment (with 50% CR and 50% DDR). Figures 1–4 show that there is a widespread doses among all countries; even for an individual country behaviour is not uniform among institutions. Many institutions have the 75th percentile above the recommended value of 3 mGy (analogue CC 33% institutions, analogue MLO 46% institutions, digital CC 30% institutions and digital MLO 40% institutions).

On individual patient doses the IAEA Basic Safety Standard Publication No. 115[11] has set a DRL of 3 mGy for CC and MLO projections, but recent protocols, such as the UK and European and even IAEA Human Health Series[4, 5, 9, 10] have an acceptable value of $D_G \leq 2.5$ mGy and an achievable $D_G \leq 2$ mGy and so information from Table 2 shows that there is enough room for optimisation actions in the region.

Regarding country's DRL for mammography, there is no significant decrease for digital equipment as should be expected. From Table 3, all regional DRL's values are above the new 2.5 mGy acceptable level for D_G. DRL values for digital DDR equipment are higher than for digital CR equipment.

Table 2. Percentage of patient doses (D_G) >3 and 2 mGy.

Type of equipment	CC view		MLO view	
	3 mGy	2 mGy	3 mGy	2 mGy
Analogue	17	42.5	26	57
Digital CR	15	44	23	52
Digital DDR	19	52.5	26	66

Following this dose survey as part of the activities of project TSA3, specific actions to optimise mammography practice have to be undertaken. Common problems in participating countries are lack of medical physicists trained in diagnostic radiology with emphasis on mammography. As in other countries in the world medical physicists are few and are mainly working in radiotherapy and nuclear medicine departments. Complete sets of equipment for QC tests are also rare. There is lack of regulations regarding mammography requirements in most of the countries. A mayor new problem is the introduction of digital equipment, the transition towards digital is not easy and usually optimisation procedures have to be introduced in order to lower radiation doses but still maintaining image quality. Many digital equipment enter the countries with no software capability for QC test and service engineers are not fully trained in this new technology. Image quality on analogue equipment was carried out using ACR phantom and results demonstrated room for optimisation[12]. In the new phase of project (2012–13) image quality of digital mammography equipment will be carried out in order to correlate doses with image quality. Regional activities will be focused on increasing the number of trained medical physicist and radiographers, implementation of QC/QA programmes, transition from analogue to digital, reinforcement of regulations and general awareness on radiologist and staff administration on the importance of QC programmes.

If national screening mammography programmes are introduced all above actions are urgent since excellent image quality at acceptable dose levels are mandatory and all regional actions on the

Table 3. DRLs for mammography for each country and for the region.

Country	CC			MLO		
	Analogue	CR	DDR	Analogue	CR	DDR
ARG	3.37	2.21	2.96	4.14	2.15	3.06
BRA	2.97	2.80	3.31	3.44	3.03	3.46
CHI	3.89	—	—	4.30	—	—
COS	1.98	3.20	2.24	3.36	3.97	2.70
CUB	1.18	—	—	1.73	—	—
ECU	1.27	—	—	2.22	—	—
GUA	1.32	1.73	—	1.94	1.95	—
MEX	—	—	2.77	—	—	2.80
NIC	2.11	—	—	2.46	—	—
PAR	1.62	—	2.61	2.18	—	[a]
SAL	0.85	—	—	1.35	—	—
URU	2.62	—	—	3.06	—	—
VEN	–	2.17	1.94	–	2.89	1.75
REGIONAL	2.63	2.59	2.93	3.17	2.78	3.04

(—) means country did not participate.
[a]Paraguay did not send data for digital MLO.

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optimisation of mammography practice need to be introduced without further delay.

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REFERENCES

1. PAHO. *Plan of action for the cancer prevention and control* (2008). http:/www.paho.org/English/ad/dpc/nc/pcc-fact-sheet-LAC.pdf (accessed 15 June 2013).
2. IAEA. *Control de Calidad en Mamografia*. IAEA-TECDOC-1517. IAEA (2006).
3. Somarriba,, F., Mora,, P., Chevalier, M. and Ramirez, R. *IAEA TECDOC 1517 quality in mammography software*. In: Proceedings of the 12th International Congress of the International Radiation Protection Association IRPA12: Strengthening Radiation Protection Worldwide, Buenos Aries, Argentina, 19–24 October (2008).
4. IAEA. *Quality assurance programme for screen film mammography*. Human Health Series No. 2. IAEA (2009).
5. IAEA. *Quality assurance programme for digital mammography*. Human Health Series No. 17. IAEA (2011).
6. IAEA. *Dosimetry in diagnostic radiology: an international code of practice*. Technical Reports Series No. 457. IAEA (2007).
7. EU. *European guidelines on quality criteria for diagnostic radiographic images*. EUR 16260, Luxemborg (1996).
8. Box-and-whisker plots: quartiles, boxes and whiskers. http://www.purplemath.com/modules/boxwhisk.htm (accessed 22 April 2014).
9. EUREF. *European protocol for the quality control of the physical and technical aspects of mammography screening*. EC (2005).
10. NHS Breast Screening Program. *Routine control tests for full field digital mammography systems*. NHS cancer Screening Programme Rep. NHSBSP Equipment Report 0604. NHSBSP (2006).
11. IAEA. *International Basic Safety Standards for protection against ionizing radiation and for the safety of radiation sources*. Safety Series No. 115. IAEA (1996).
12. Mora, P., Khoury, H., Blanco, D., Blanco, S., Roas, N., Kodlulovich, S., Leyton, F., Defaz, M. Y. and Gamarra, M. *Evaluación de la dosis y la calidad de la imagen en mamógrafos mediante el maniquí ACR: experiencia latinoamericana del proyecto RLA/9/057*. XII Sociedad Española de Física Médica y XII Sociedad Española de Protección Radiológica, Alicante, España del 02 al 05 junio, Senda Editorial, S.A. (2009).

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