

## Evaluation of Radiation Doses and Estimation of the Risk of Radiation-Induced Carcinogenesis in Women Undergoing Screening Mammography Examinations

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Digital Mammography is used as a screening tool to discover breast cancer at an early stage, the benefits and harms of this techniques is under scrutiny hence and Moroccan regulations governing radiation protection of patients have been strengthened, the need to investigate the dose received during screening mammography and the risk associated. This study is consisted of examining 126 mammography projections, for 63 women. All examinations were performed with a full digital mammography machine, technical and exposure parameters were recorded, statistical analysis was carried out using Microsoft Excel in order to calculate local DRLs and compare them with international standards. Cancer risk has been estimated using BEIR VII report methods. The mean glandular dose MGD was  $1,09 \pm 0,45$  mGy and  $1,26 \pm 0,74$  mGy for craniocaudal (CC) and mediolateral oblique (MLO) respectively, DRLs were 1,34 for CC view and 1,36 for MLO view. Of the 100,000 women exposed, Lifetime Attributable Risk of cancer incidence has been found to be 0,76 for CC examination, 0,88 for MLO, and 1,64 for the full mammography protocol. Established local DRLs in this study are lower compared to that of United Kingdom and France and higher compared to that of Nigeria and Australia. A potential risk of radiation-induced carcinogenesis exists, and there is a need for optimization of screening mammography practices.

**Keywords:** Breast Cancer; Radiation Biological Effects; Mammography; Radiation Protection.

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X-ray mammography offers the possibility of discovering breast cancer at an early stage, organized screening program recommends one mammography examination every 2 years for women aged 50 to 74 with no specific symptoms<sup>1</sup>. For a woman considered to be at risk, this can lead her to undergo several

mammography examinations, without counting the other examinations she will undergo during her life (CT Scans, X ray procedures). In addition, during a mammogram, a woman can have several images and receive repeated doses. This received doses from mammography examinations may be associated with a risk of radiation-induced

carcinogenesis<sup>2</sup>, annual screenings of 100,000 women aged 40 to 74 years have been projected to induce an average 125 breast cancer resulting in 16 deaths<sup>3</sup>.

A new law no.142-12<sup>4</sup> has been adopted, governing nuclear and radiological safety and security, which contains new provisions relating to radiation protection of patients, by applying the principle of justification and optimization of the doses delivered. Diagnostic reference levels (DRLs) play an important role in health-care delivery and radiation safety of patients, they are suggested radiation dose levels of the radiographic investigations above which a medical facility could review its work methods and determine if required image quality can be achieved at lower doses.

This study was to evaluate radiation doses delivered during screening mammography procedures in order to compare them with international standards, guided by Dose Reference levels (DRLs) and estimate the Lifetime Attributable Risk of Cancer Incidence due to radiological exposure.

## MATERIALS AND METHODS

### Machine specification

GE Senographe 2000D with a range of 22 to 49 for kV and 4 to 500 for mAs, a rotating anode with two different targets (Molybdenum and Rhodium), and an inherent filtration of 0.03mm Molybdenum, 0.025 mm Rhodium and 1.0 mm Aluminum.

### Exposure parameters survey

In this study, all examinations were performed with a full field digital mammography which are subject of a recent approved quality control, DICOM headers were extracted from Picture Archiving and Communications System (PACS), technical and exposure parameters from 126 projections for 63 adult patients (patients aged 45 to 55) were recorded, kV, mAs, Mean glandular dose (MGD), Entrance Surface Dose (ESD) and used filters, and statistical analysis was realized using Microsoft Excel 2016. The study was limited to screening examinations, therefore, the rest of procedures were excluded.

### Diagnostic Reference Level

In digital mammography, the diametric scale used to establish DRLs is the average dose

to the mammary gland (MGD), expressed in milligrays (mGy), and determined for an equivalent breast thickness of 45 mm, the value of the DRLs is defined from the 75th percentile of the distributions of data collected for a standard examination<sup>5</sup>, the 75th percentile constitutes a level of alert above which the practices can be considered as not optimized in term of delivered dose to the patient, considering its international use, it remains an essential indicator of DRLs.

In this study, the projections were analyzed, the median and 75th percentiles were calculated across MGDs obtained and compared to DRLs from United Kingdom<sup>6</sup>, Australia<sup>7</sup>, Nigeria<sup>8</sup>, and France<sup>9</sup>.

### Cancer risk estimation

The estimation of cancer risks following exposure to ionizing radiation has been the subject of several reports by international organizations such as the International Commission on Radiological Protection (ICRP) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) during the past few decades. These estimates have been based largely on data for survivors of the atomic bombings of Hiroshima and Nagasaki, supplemented in some instances by information from studies of medically exposed groups<sup>10</sup>.

In this study, Lifetime Attributable Risk of cancer incidence and has been estimated using BEIR VII report methods<sup>11</sup>, the most up-to-date and comprehensive risk estimates for cancer and other health effects from exposure to low-level ionizing radiation, based on epidemiological data from radiation-exposed populations and aims to estimate cancer risk induced by exposure to low-linear energy transfer radiation.

## RESULTS

### Statistical Analysis

A total of 126 projections (Mediolateral Oblique View "MLO" and Craniocaudal "CC") for 63 patients were performed during the data collection period in the medical imaging department. The mean age of patients is 50 years. The average values for weight and height were 68 kg and 1.65 m respectively.

Tables 1 and 2 present a summary of the exposure parameters details used for the screening

mammography examinations of all the women involved in the study.

In most cases, the mean glandular dose in MLO projections was higher than recorded in the CC projection due to higher mAs used in the MLO projection.

The analysis of the exposure factors showed that both kV and mAs were higher for

**Table 1.** Comparison of the MGD received in MLO and CC projections

	CC m Gy (mean±SD)	MLO m Gy (mean±SD)	Δ (%)
MGD	1,09±0,45	1,26±0,74	13,61

**Table 2.** The range of exposure details (mAs, kv and ESE ) obtained during screening mammography for 63 projections

Projection	mAs (mean±SD)	kVp (mean±SD)	ESE mGy (mean±SD)
Cranio-caudal	45,93±24,24	30,53± 1,33	5,68±3,32
Medio-lateral oblique	53,43±36,48	30,96±1,35	6,96±5,4

The mean effective tube time current, tube voltage and Entrance Surface Dose ESE for CC and MLO projections was (45,93±24,24 , 53,43±36,48) , (30,53± 1,33 , 30,96±1,35) and (5,68±3,32 , 6,96±5,4) respectively .

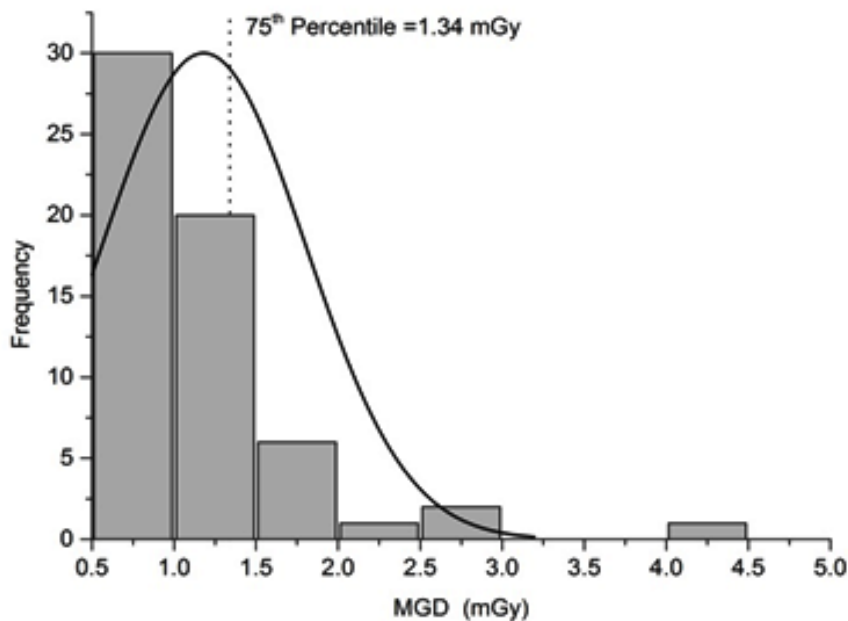
MLO views than for CC views. The MGD for this study was 1,09±0,45mGy and 1,26±0,74 mGy for craniocaudal (CC) and mediolateral oblique (MLO) respectively.

**MGD values compared to DRLs**

The diagnostic reference level (DRLs) is generally defined as the 75th percentile of the distributions of mean glandular doses observed as shown in (fig. 1) [12] .In this study, the 75th percentile is estimated for all patients based on the average glandular dose from two projections ( MLO, CC ), Table 3 present 75th percentile, median values of MGD compared with DRLs from different countries.

**Cancer Risk**

The radiation risk estimates for developing



**Fig. 1.** 75th percentile method for DRLs

**Table 3.** Comparison of calculated DRLs for mammography examination with DRLs from different countries

Projection	MGD mGy		DRLs	DRLs	DRLs	DRLs	DRLs
	Median	75th Percentile	From Aus <sup>a</sup>	From UK <sup>b</sup>	From NGR <sup>c</sup>	From FR <sup>d</sup>	This study
CC	0,98	1,32	0,88	2,5	0,63	1,6	1,32
MLO	1	1,34	1,30	2,5	1,04	1,6	1,34

a Aus: Australia[7], b UK: United kingdom [6], c NGR: Nigeria [8], d FR: France [9].

DRLs for France, United kingdom, Nigeria, Australia and this work were 1.6 mGy, 2.5 mGy, 0.63 mGy, 0.88 and 1.32 mGy for CC view, DRLs for MLO was 1.6 mGy, 2.5 mGy, 1.04 mGy, 1.30mGy and 1.13 for Fr, Uk, Ngr, Aus, and present work, respectively.

**Table 4.** Estimated Lifetime Attributable Risk of Cancer Incidence per 100,000 women undergoing mammography at age 45 – 55

Examination	Mean dose (mGy)	Lifetime Attributable Risk of Cancer Incidence per (100 000) women
CC	1.09	0.76
MLO	1.26	0.88
Mammography protocol	2.35	1.64

radiation induced carcinogenesis was performed using the data evaluated by the Biological effects of ionizing radiation committee seven (BEIR VII) relative risk model for breast cancer incidence. The BEIR report is addressing health effects from exposure to low-energy radiation, including mammography based on the number of cases per 100,000 persons exposed to a single dose of 0.1 Gy.

Of the 100,000 persons exposed, the Lifetime Attributable Risk of Cancer Incidence has been found to be 0.76 for CC examination, 0.88 for MLO, and 1,64 for the full mammography protocol (Table 4).

## DISCUSSION

The MGD value for MLO projection obtained in this study was higher than the CC projection due to the important thicknesses generated by the inclusion of the pectoral muscle, increasing beam attenuation. The results of this study were consistent with those of a pilot study

conducted in the United Kingdom in order to evaluate the radiation doses received by women undergoing mammography examinations, the mean dose was 1.7 mGy for the MLO projection and 1.4 for the CC projection<sup>13</sup>. The dose per view showed an exponential relationship to the tube time current which increase with breast thickness.

DRLs for mammography, in this study, are higher compared to that of Nigeria and Australia and lower compared to that of the United Kingdom and France (fig. 2). This difference observed in this study than those of other studies can be explained using different screening protocols and different mammography machine parameters. The results obtained is a local DRLs from a single study and may vary from one screening center to another with the change of devices and protocols, a national investigation will allow to have representative values of DRLs which intended to provide standards for dose optimization across these facilities to encourage those with median doses that exceed international guidelines to consider potential improvement avenues.

In this study, we also assessed the Lifetime Attributable Risk of Cancer Incidence after mammography screening examinations, the minimum age used in this study is 45 years and the maximum is 55 years. The risk increase with MGD, with a value of 0,76 per 100,000 women, for CC view, 0,88 for MLO view, and 1,64 for full mammography procedure. This assessed risk is based on the results obtained from women with an average age of 50 years undergoing a single screening mammography procedure, however, according to the BEIR Report, the risk decreases considerably with the age, which means that the

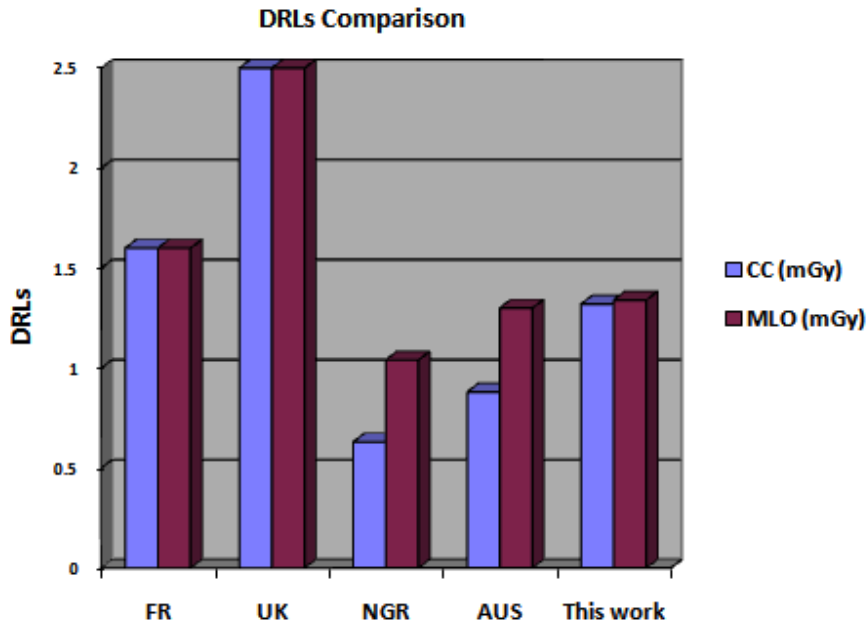


Fig. 2. Comparison of diagnostic reference levels for mammography in this work with those of other international studies

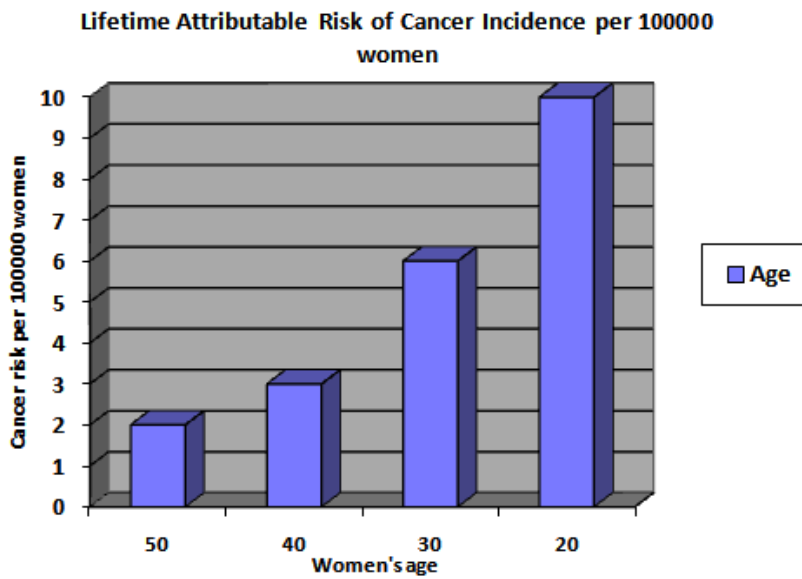


Fig. 3. Lifetime Attributable Risk of Cancer Incidence per 100,000 women undergoing screening mammography examination per age

risk is higher for women who have undergone the same exposures at an early age as shown in (fig.3), and multiple examinations according to the frequencies recommended for each case.

The same radiation doses obtained in this study may generate a much higher risk for young women who carry mutations in either the BRCA1 or BRCA2 genes and for which it is recommended

to begin screening mammography at age 25 to 30 years<sup>14,15</sup>, according to a study on estimated cancer risk from mammography procedures for young BRCA Mutation<sup>16</sup>, the lifetime risk of radiation induced cancer mortality per 100,000 women was 260 for screening at age 25 – 29 years, 200 for screening at age 30 – 34 years and 130 for screening at age 35 – 39 years.

Therefore, it is necessary to properly account for the impact of radiation while evaluating the hazard vs benefit of screening mammography procedures<sup>17</sup>. The risk of radiation-induced carcinogenesis is relatively small compared to the advantages of early detection, and it can be reduced by implementing a quality control protocol and all optimization procedures to reduce the patient dose and improve the image quality.

### CONCLUSION

The MGD for this study was  $1,09 \pm 0,45$  mGy and  $1,26 \pm 0,74$  mGy for craniocaudal (CC) and mediolateral oblique (MLO) respectively. Established local DRLs for mammography in this study are lower compared to that of UK and France and higher compared to that of Nigeria and Australia.

A potential risk of radiation-induced carcinogenesis exists in mammography because the breast is radiosensitive, the risk increases especially when mammographic examinations commence too early or are too frequent. Justification and optimization of screening mammography procedures, and implementation of a quality assurance system are highly recommended for the purpose of reducing the dose as much as possible without impacting image quality, as well as the establishment of National Diagnostic Reference Levels (DRLs) on which health professional could refer to optimize their practices.

Considering that the technical specifications of the machine used in this study are identical to those used in most mammography screening national centers, the results of this study can be considered as a preliminary estimation for the mammography DRLs in Morocco.

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