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Quality Assurance in Mammography: a Survey of 75 X-Rays Units in France

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ABSTRACT

Mammography is widely recognized as the most relevant diagnostic imaging technique to be used in the early detection of breast lesions. For this purpose, mammography units should be as reliable as possible to allow the best diagnosis to be made. A pilot survey of 75 x-ray units was conducted in France to evaluate the status of this kind of radiological equipment as well as the techniques likely to influence both image quality and breast dose. Limiting detectability was deduced from about 50 mammograms of a RMI breast phantom showed to six experienced radiologists under routine interpreting conditions. Both phantom and "in-vivo" dosimetric measurements enabled us to analyze entrance and exit dose with the associated parameters influencing image quality. Entrance doses were found to vary from 6 mGy to 24 mGy for a 4 cm compressed breast thickness, while sizes of the smallest detected microcalcifications may range from 0.20 mm to 0.32 mm. An overview of practitioner's modifications of the radiological techniques used for examining "dense" or "fatty" breast to be examined, showed a large disparity.

INTRODUCTION

In France, as in many other developed countries, breast cancer remains the major cause of disability and death among women. The number of new cases of invasive breast cancer was estimated to be 275,000 in 1981 (1) with a corresponding number of deaths of 8,900 (2).

The most relevant way to reduce this incidence relies upon the early detection of infra-clinical lesions such as tiny microcalcifications or low contrast lesions which may be currently considered as indications of malignancy. It is also widely recognized that mammography is the most effective diagnostic imaging technique to be performed in order to detect such minute details and irregular borders of lesions.

In the last two decades many countries have carried out breast cancer screening programs on asymptomatic women by exclusively using this technique (3-5).

Nevertheless, many controversies have arisen in the form of scientific debates over both radiographic techniques to be used (type of detector, number of projections...) (6-8) and epidemiological considerations (age of patients to be screened, dose risk relationship curve...) (9,10).

As far as France is concerned, some local trials are being performed and some others, even national, are likely to be scheduled in the forthcoming years. In this respect, it seemed important, from the physicist's point of view, to evaluate the status of the radiological equipment which potentially could be used. In doing so, a pilot survey of 75 dedicated mammographic units installed in both public hospitals and private radiological offices all over in France was conducted and radiological techniques (kVp's setting, anti-scattering grid, magnification...), likely to influence both breast dose and image quality, were considered.

MATERIALS AND METHODS

In 1987, the Centre d'Etude pour la Protection dans le Domaine Nucléaire (CEPN) carried out, in 52 public hospitals and 23 private radiological offices, a pilot survey the aim of which was to create a statistical data base dealing with the radiographic techniques commonly used in mammography. The number of mammographic units selected for the survey was derived from a computerized file in close cooperation with the Diagnostic Radiology Commitee of the French Health Physicists Society. This figure represents 10% of the total number of mammographic units actually operating in France as officially recorded by the Service Central de Protection Contre les Rayonnements Ionisants (SCPRI) (11).

A questionnaire was sent to all radiological centers asking for about a hundred physical parameters which may be roughly split into the following four categories: those associated with the installation itself (geometry, x-ray tube, focal spot size, target materials, filtration ...); those inherents to "optional" devices which nevertheless affect patient dose (phototimer, anti-scattering grid, compression apparatus, field diaphragm ...); those connected with the image receptor (film, screen, film processing ...) and, finally, those related to the technical procedures (kVp, exposure time, mAs product, type and number of projections, practice modifications as a function of the breast density...).

From the collected data, three categories of units, corresponding to the most representative mammographic sets, were selected in order to perform both dose and image quality measurements. This selection was essentially based upon technical characteristics such as focus-to-film distance (FFD), focal spot size and target material (molybdenum or tungsten).

These three selected categories were a " 500 T" and a "Sénographe I" both

made by the Compagnie Générale de Radiologie (CGR) and a "Mammo diagnost " made by Philips. The Senographe I contained a fixed Mo target with the beam filtered by 0.5 mm Al equivalent, and the two others were equiped with a rotating Mo target with a filtration of either 0.5 mm Al or 0.03 mm Mo. Concerning the focal spot size, Senographe and Mammo diagnost had only one focus of 0.6 mm, whilst two foci were available on the 500 T (0.1 mm and 0.3 mm). No grid was installed on the Senographe and its FFD ranged from 10 cm to 50 cm, the other units having a fixed FFD of 60 cm.

Concerning the evaluation of the image quality, the RMI's Mammographic Random Phantom, Model 152B, was used. It consists of a 4 cm thick lucite base that holds 16 wax blocks containing various objects, the size of which allows to simulate masses (0.25, 0.50, 0.75, 1.00 and 2.00 mm), fibrous structures (0.40, 0.54, 0.60, 0.75, 0.89 and 1.12 mm) and microcalcifications (0.20, 0.24, 0.28, 0.32 and 0.40 mm). The location of the blocks can be randomly moved to prevent bias due to the observer's memorization. Thickness of the entire phantom gives, for effective energies commonly encountered in mammography, an attenuation similar to that of an average compressed breast of 4 cm.

About 50 radiograms of the phantom, taken under different technical conditions (kVp, mAs ...), were randomly shown successively to six experienced radiologists in usual interpreting conditions (viewing box, magnifying glass). Credit concerning information on image quality was given for objects correctly identified by three viewers or more.

From the dosimetry point of view, two sets of measurements were performed using thermoluminescent dosimeters (TLD) ($Li_2B_4O_7$/Mn pellets) which were previously calibrated against an X-ray beam for energy values ranging from 15 KeV to 1 MeV. The reading out system used was a "Toledo 654". The first set of measurements was carried out on a phantom made of different thicknesses of lucite which enabled estimates of entrance skin doses, exit doses and depth doses. The second set was carried out on 16 patients in order to compare the phantom doses with those actually received during an examination.

For practical reasons, all investigations related to dose and image quality were realized on six (two for each category) dedicated mammographic units chosen among those having participated to the survey. Since the objective of the survey was basically to reflect the present situation of mammography, no preliminary calibration of the selected x-ray units was performed and radiological equipments associated to each installation (image recorder, processing, grids) were those routinely used.

RESULTS

The survey

- of the 75 units considered, about 85% are equipped with a Mo fixed or rotating anode (respectively 15% and 70%) and the remaining ones are equipped with a fixed or rotating W anode (respectively 6 % and 9 %).
- distribution of nominal focal spot size is shown in Figure 1. Three out of four x-ray tubes have only one focus, the size of which generally ranges from 0.3 to 1.2 mm, while, when a second focus is available, its size is of 0.1 mm.
- 40% of the installations do not allow mammograms to be taken a with a FFD above 48 cm.
- only 60% of the practitioners actually use the phototimer, although 72% of the total number of units are thus equipped.
- an anti-scattering grid is installed on 47% of the mammography systems considered and on only one third of these magnification technique is possible.
- neither direct film mammography nor Xerox plate is used in the whole sample of participating centers and 12 screen-film combinations, often different from those suggested by manufacturers, have been found (see Figure 2). In about a quarter of these centers, films are processed on machines that

operate with parameters exclusively dedicated to mammography.
- kilovoltage settings for a 4 cm "average" breast show large discrepancies and range from 19 kVp to 42 kVp with a mean value of 28 kVp all target materials together (see Figure 3).
- practitioner's modifications of technique for a "dense" breast or a "fatty" one appear as one of the most important sources of disparity encountered in the survey. In diagnosing a "fatty" breast for instance, some radiologists tend to increase physical parameters namely : kilovoltage (16%), exposure time (5%) and phototimer sensitivity (6%). Conversely, some others, tend to decrease the same parameters (9%, 12%, 12% respectively), 15% of radiologists make no modifications and the remaining 25% have no opinion.

Regarding a "dense" breast examination, almost all radiologists increase these parameters : kilovoltage (32%), exposure time (19%), both kilovoltage and milliampere-second product (28%), 10% keep parameters unchanged and, finally, 11% have no opinion.

- besides mass screening considerations, breakdown of the currently practiced projections is shown on Figure 4.

Dose and Image Quality

Regarding entrance skin dose and optical density, findings obtained with the previously mentioned phantom of lucite are detailed in Table 1 as a function of the kilovoltage. Indicated values rely upon conditions "routinely" used in the considered radiological centers. As it can be deduced from the table, the corresponding average entrance skin dose is 12.2 mGy while, according to the kilovoltage, doses may vary by a factor of five. However such discrepancies can be interpreted and linked to a series of physical parameters that may have an influence on the received dose, namely : speed of detector system (12, 13), beam quality (13, 14), choice of both exposure time and kilovoltage (15-17), calibration of phototimer (18), type of anti-scattering grid (13, 19), film processing (20).

On each unit considered, depth dose measurements enable us to estimate a mean glandular breast tissue dose value which was on average about 12% of the entrance skin dose with a corresponding exit dose of 2%. This latter value generally agreed with the "in vivo" dose values (see Table 2) which indicated that the lucite phantom was a good representation of the average breast in terms of energy absorption.

Turning to the image quality assessment, limit detectability is detailed in Table 3 as deduced from the radiologist's observation of the RMI's phantom mammograms taken under routine interpreting conditions. As one can note, in only one case (500 T unit No I), observers have detected the finest objects that are embedded in the phantom, what means that almost all structures are imaged (15 out of 16 wax blocks). In other cases, quality of the image is less accurate, and the resulting loss of information may be significant (only 5 out of 16 wax blocks are seen on Senographe unit No I). This variation can be attributed to the same causes previously referred to as influencing the dosimetry. The impact of the kilovoltage applied on limiting detectability has been considered and has shown notable potential for improving the image quality (eg. sizes of the smallest detected microcalcifications: 0.20, 0.28 and 0.32 mm at respectively 25, 28 and 31 kVp on Mammo diagnost unit No I). In the same manner, using either anti-scatter grid or magnification techniques have improved detectability of the phantom structures with a corresponding ncrease of the entrance dose of 2.5 and 5 respectively.

DISCUSSION

A first general comment about the results deals with the necessity of ırmonizing the various parameters which can interact with both dose and age quality. This might be achieved by introducing quality control cedures. Indeed, checking the beam quality seems the first action to be ertaken in order to ascertain for instance the reliability of kilovoltage. So

the large range of kilovoltages encountered in the survey (see Figure 3) could probably be restricted with a consequential real effect of reducing dose while improving image quality. In this context, although excellent contrast has been frequently obtained between 28 kVp and 30 kVp with the molybdenum target-molybdenum filter combination (50% of the sample size) and screen-film system, as recommended by the National Council on Radiation Protection and Measurements (18), findings have shown that a more realistic range (from 23 kVp to 30 kVp) could be envisaged depending on the quality control procedures of each unit considered.

Furthermore, estimates of optical densities associated with routine operating conditions suggest that the calibration of phototimer should be suited to the kilovoltage actually used as a function of the receptor sensitivity. In the same way, skin entrance dose values might be lowered by using exposure times shorter than one second. On the contrary, in spite of the increase in entrance skin dose, anti-scatter grids significantly improve the image quality and their use should be promoted on a larger scale.

Despite the small number of x-ray units studied in this pilot survey, all these considerations, together with clinical aspects (eg.: examination techniques towards the variation of the breast density), call for a need for organizing a national Quality Assurance programme in mammography in France. Besides quality control, such a programme might obviously include many activities like preventive maintenance, equipment calibration, training and in-service education of technologists and spreading of information.

Only under such conditions, and particularly in the context of a national breast mass screening project, would the quality of mammograms then be guaranteed with a consequential real benefit for patients in terms of reliability of diagnosis and dose reduction.

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Table 1: Dose and optical density results as a function kilovoltage.

	PHILIPS MAMMODIAGNOST-U I	PHILIPS MAMMODIAGNOST-U II	CGR SENOGRAPHE 500 T I	CGR SENOGRAPHE 500 T II	CGR SENO I I	CGR SENO I II
21 kVp	n.m	n.m	n.m	6.8 * 0.25 **	26.7 0.71	16.2 0.79
25 kVp	11.5 1.00	8.1 1.50	15.6 1.33	8.9 0.73	**24.0** **1.85**	13.6 1.08
28 kVp	**8.6** **1.30**	**4.6** **1.40**	**18.3** **1.90**	7.8. 0.92	18.5 2.13	12.8 1.28
31 kVp	5.5 0.96	2.9 0.58	13.2 1.95	**6.2** **0.96**	14.7 2.21	**11.5** **1.50**
Film Screen	Kodak PE 205 Min - R	Agfa MR 3 Min - R	Kodak PE 205 Min - R	Kodak PE 205 Min - R	Min - R Min - R	Ortho - MA Min - R

[shaded box] routine operating conditions
* Entrance skin dose (mGy)
** Optical density.

n.m : not measured.

Table 2: "In vivo" dose measurements and resulting optical densities.

	Patients	kVp	Thickness* (cm)	Entrance Skin Dose (mGy)	Exit Dose (mGy)	Optical Densities
500 T	n° 1	32	3	24.9	0.71	1.3
	n° 2	31	2	12.8	0.44	1.2
	n° 3	32	5	34.6	0.85	1.2
	n° 4	30	2	9.2	0.93	1.4
	n° 5	32	2	16.2	0.55	1.0
	n° 6	32	4	17.1	0.91	1.3
	n° 7	32	5	26.4	0.71	1.2
	n° 8	32	4	12.6	0.57	1.2
SENO I	n° 9	28	4	9.8	0.39	1.1
	n°10	28	4	9.7	0.47	1.2
	n°11	28	4	10.2	0.55	1.3
	n°12	28	4	14.1	0.71	1.3
	n°13	28	4	14.8	0.29	0.9
	n°14	28	4	8.2	0.64	1.2
	n°15	28	3	9.4	0.51	1.2
	n°16	28	5	17.1	0.77	1.3

* compressed breast.

Table 3: Limit detectability (mm) resulting from the interpretation of the RMI phantom mammograms.

	PHILIPS MAMMODIAGNOST-U I	PHILIPS MAMMODIAGNOST-U II	CGR SENOGRAPHE 500 T I	CGR SENOGRAPHE 500 T II	CGR SENO I I	CGR SENO I II
Masses	0.75	0.75	0.25	0.75	2.00	1.00
Fibers	0.60	1.12	0.60	0.89	0.89	0.89
Micro-Calcific.	0.28	0.24	0.20	0.24	0.32	0.28

Figure 1: Distribution of focal spot sizes (mm).

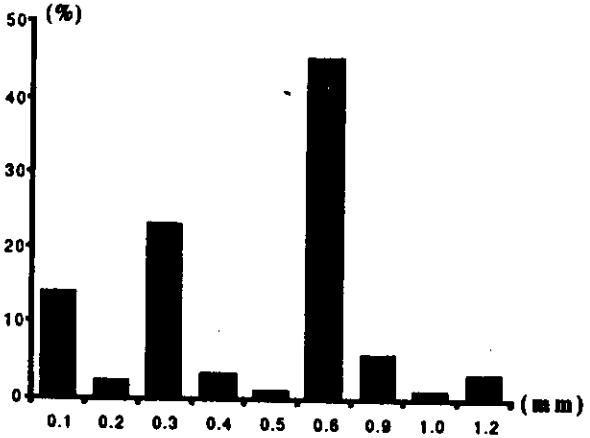

Figure 2: Screen-Film combinations encountered in the survey.

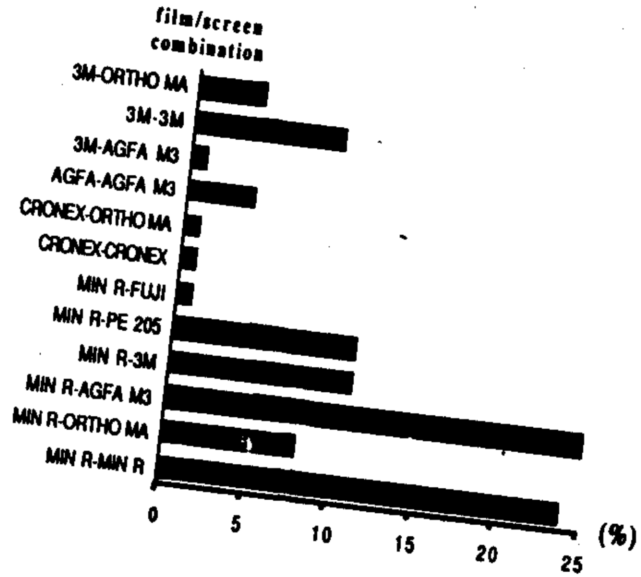

Figure 3: Histogram of kilovoltage for a cranio caudal projection.

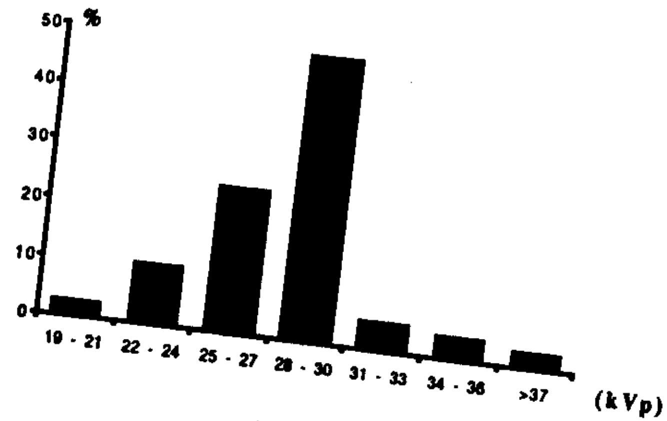

Figure 4: Breakdown of projections routinely used during an examination of one breast.