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TRAINING COURSE ON DOSIMETRY AND DOSE REDUCTION TECHNIQUES IN DIAGNOSTIC RADIOLOGY

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"CONSTANCY CHECK PROCEDURES FOR MAMMOGRAPHY EQUIPMENT"

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These are preliminary lecture notes, intended only for distribution to participants.

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CONSTANCY CHECK PROCEDURES FOR MAMMOGRAPHY EQUIPMENT

As we all know, Mammography is the examination of the breast with x-rays and film-screen combination.

The characteristic of the breast is that its various tissues are composed of materials with similar atomic numbers and, consequently have similar linear attenuation coefficiants.

So, in order to image the breast with x-ray, with satisfactory contrast, the interraction of the x-rays with breast tissues have to be through the photoelectric effect.

SLIDE 1

As you remember, in the photoelectic effect the absorption of energy is proportional to $1/E^3$ and the mass absorption coefficient is proportional to Z^3.

So, in order to have the maximum difference in absorption between tissues of similar composition (as it is in the breast), we must use low energy photons and therefore have the photoelectric effect.

SLIDE 2

In this slide it is seen that, for example, fat and muscle can best be distinguished when very low photon energy is used.

Spectra from diagnostic x-ray generators, as we all know, comprise of the bremmstrahlung and the characteristic of the target material. Their shape depends on the applied voltage, wave form, target material and filtration.

With a high atomic number anode (ex. tungsten) the spectrum consists almost entirely of bremmstrahlung radiation while using a low atomic number anode and low tube voltage, the bremmstrahlung production is reduced and then the characteristic radiation is dominant.

SLIDE 3

In this slide the spectra of tungsten and Mo amode under the same conditions is seen. For Mo. characteristic radiation is dominant and, for mammography where the maximum kilovoltage used is 35 kVp, the K-characteristic radiation has a band between 17.9 and 19.5 kV, which is optimum.

SLIDE 4

The effect of the filtration is seen in this slide. Mo filter cuts off the bremmstrahlung and the x-ray band that remains, is only the characteristic of Mo of the anode.

Thus, from the two last slides, it is obvious that the use of Mo anode and Mo filter in mammography is justified.

The low penetration x-rays that are needed (according to what we have said) for imaging the breast. result in absorbed dose which may be significant.

The first use of x-rays in imaging the breast, was in xeroradiography. The average dose was about 55 mGy per view.

The first film used was an industrial one -Kodak AA- and the average dose was 100 mGy (range from 35 to 170 mGy).

The Lo-dose system was introduced in 1973 and lowered the average dose to 13 mGy (range from 2 - 50 mGy).

This system was consisted of a single emulsion film and a high definition intensifying screen packed in a flexible vacuum cassette. With this, maximum sharpness and resolution was achieved.

Later, in 1975, the Lo-dose/2 system was introduced. It used faster screen (sacrificing some sharpness) and the dose was lower.

The systems of film-intensifying screen which are in use to day, give dose/ per view ranging from 2 to 20 mGy.

(We must always have in mind that using faster screens we sacrifice in sharpness, and increasing film speed, less photons are used to form the image and so, noise is increased. Therefore a compromise has to be made).

Now, is there a risk of breast cancer induction after exposure to irradiation? An extended study based on surveys of tuberculosis patients who had undergone repeated fluoroscopic examinations to the chest and consequently received dose to the breasts, atomic bomb survivers in Japan and mastitis patients treated with radiotherapy) was done by Boice et al in 1979.

Although precise quantification of the radiation risk of low dose exposures is not possible, from the analysis of the results it is shown that irradiation increases the risk of breast cancer development and that:

a. The dose response relationship is consistent with linearity, and

b. The risk per Gray at low and high doses is similar.

All these indications make us very cautious about the doses delivered to the breasts during mammography.

On the other hand, mammography is a very valuable tool both for diagnosis of symptomatic women and in preventive medicine through screening examinations.

But, though there is no opposition in using mammography in symptomatic cases, in screening, in which a whole population is irradiated while a small part of it expects some profit, there have been extended discussions. And the dicision to use this examination in screening was taken on one strong condition:

That mammographic equipment should be in good condition and properly callibrated so that the following objectives could be met:

1. The image reaching the radiologist must have the best possible diagnostic information necessary to detect even the smaller lesions.

2. The image quality must be stable with respect to information content and optical density.

3. The dose to the breast is As Low As Reasonably Achievable (the ALARA concept) for the information required.

Image quality depends on the radiographic technique used, provided that the equipment performs according to its specifications.

On the other hand, absorbed dose to the breast depends on:

- Breast thickness and composition, kilovoltage used, the antiscatter grid used, compression of the breast, speed of the film-screen combination and O.D. of the film.

We could say that the term "Image Quality" indicates the accuracy with which details can be perceived in an image.

Factors affecting mammographic Image Quality are:

Radiographic Contrast

Radiographic Sharpness (Blurring) and

Artifacts

Let us see what influences each of these factors:

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Radiographic Contrast depends on: Subject Contrast and Receptor (film and screen) Contrast.

Subject contrast is due to:

a. Absorption differences in breast (thickness, density, atomic number)

b. It depends on: Radiation Quality which is affected by: Target material, kilovoltage and filtration

c. It depends also on Scaltered Radiation which can be mastered by: Beam limitation, proper compression and use of an antiscatter grid.

On the other hand, the film and screen contrast depends:

a. On the film type (from the mean gradient of the film's characteristic curve)

b. On processing, which depends on: Chemistry, developer and fixer temperature and processing time

c. On the optical density of the film (it has to be in the linear part of the curve) and

d. On fog, which could depend on the storage conditions, safelights or light leakage in the darkroom.

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The next parameter that affects Image Quality is the "Radiographic Unsharpness" (Radiographic blurring) which can be due to: Motion, Geometry and Film-Screen system.

Motion can be eliminated (controled) by proper compression of the breast and using short exposure times.

Geometry can be optimized by using the right focal spot size and the right distances.

For the film-screen system, the blurring is influenced by the screen construction (thickness, particle size) and the Screen-film contact.

SLIDE 7

Last parameter that influences "Image Quality" is the Artifacts which can result from the handling of the films (dust, fingerprints), from the processing procedure (dirt, cylinder marks, etc.), from the screens and cassettes etc.

SLIDE 8

To ensure good Quality and Consistency of our image, Quality Control checks should be carried out, monitoring all the Physical and Technical parameters of the radiographic system.

In doing so, a protocol is needed, containing the descriptions and frequency of these checks and the acceptable values of the parameters involved.

The European Union, in the framework of "Europe Against Cancer", in order to ensure that mammography screening in all its members is of comparable quality, has produced a document

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which includes the "European Protocol". It is this protocol that we are going to follow.

In summary the Q.C. checks concern the following:

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1. We start with the checks related with the Geometry of the system.

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The focal spot size is the main parameter affecting the resolution of the system.

There are several accessories to use for measuring the focal spot size: Pinhole camera, slit camera. But the proper one and the most convenient for mammography units is the star pattern with a spoke angle of 1° or 0,5° degree.

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From the blurring diameter D of the magnified image taken with a non screen film (and without grid), and using the formula:

$$f = \frac{\pi \times \theta}{180} \times \frac{D}{M - 1}$$

we calculate the focal spot size.

We do this measurements during the acceptance testing and then we check it every year (or in case a rapid decay of resolution is apparent) to ensure that no deterioration of the focus exists.

The x-ray field alignment check helps us to ensure that the field size covers all the film, but that it does not extend outside the breast support table by more than 3mm towards the chest side.

This check is done with two cassettes, one under and one over the breast support table, the second one extending a few cms out of the table.

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2. For the Radiation Quality we check the Accuracy and Reproducibility of the tube voltage, which, as we already said, affects the radiographic contrast of the image.

   The method is a non invasive one and a digital kVp-meter, specially designed for mammography (with the proper range of kVp) is used.

   The accuracy of the indicated kVp is required to be better than +/-4% and the reproducibility +/-2%. The frequency of the check is proposed to be 6 months.

The second check that concerns Radiation Quality is the assessment of the HVL of the beam for 28 kVp and Aluminum of purity equal or better of 99,5%.

The recommended value for the HVL is 0.3 to 0.4mm Al equivalent.

Because, on one hand, less filtration gives excess dose to the skin and on the other hand, image quality deteriorates rapidly with increasing filtration. it is important that the HVL is not outside the recommended values.

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3. Radiation Quantity

In order to have a standard O.D. of the images, we must have the same quantity of radiation reaching the film no matter what the thickness and composition of the breast is, or what kilovoltage is used.

The Automatic Exposure Control system (A.E.C.) helps us to achieve it - if it works properly.

In order to check the performance of this system we measure the O.D. of films taken with differing phantom thickness (2 to 6 cm perspex) thus the object thickness compensation is checked.

Also the O.D. of films taken with standard thickness and kilovoltage ranging from 26 to 30 kV, is measured to check the kilovoltage compensation.

According to the protocol the limiting values for those tests is 20% acceptable variation and 10% desirable variation of the O.D.. The frequency is every six months.

We also check the reproducibility of the system by measuring the O.D. of films taken with the same phantom thickness and the same kilovoltage. Acceptable and desirable values of O.D. variation: 10% and 5% respectively.

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4. Scatter Radiation

In order to eliminate the scatter radiation reaching the film, an antiscatter grid is used, especially with thicker breasts. On the other hand, the use of the grid increases the dose to the breast. So we have to compromise.

The grid system factor gives the ratio of the dose to the breast with an antiscatter grid, to the dose to the breast without it. According to the Protocol, this factor should be smaller than 3.

This is a test to be done after the installation of the unit and in case exposure time or dose increases suddenly.

A film of O.D. = 1 is taken using the grid and another one of the same O.D. without the grid. The dose is measured for the two exposures and their ratio gives the grid system factor. Taking two films; one of O.D. below 1 and one with O.D. above 1, we improve accuracy.

Scatter Radiation can also be eliminated with the proper compression of the breast. The compression device has to compress the breast uniformly. So we measure the distance in each corner between bucky surface and compression device when a foam rubber is compressed.

5. Image Receptor Checks

The image receptor, as we have said, consists of a cassette with one intensifying screen, in close contact with a film which has a single emulsion.

The main checks concerning this chapter are:

1. Intercassette sensitivity

With a standard exposure for each cassette and measuring the O.D. on the reference point (6cm from the chest end of the film and midway in the other direction) we can estimate the intercassette sensitivity. Desivable range of the variation of O.D. not greater than 10%. Acceptable: Not greater than 15%.

2. Processor

Checks concerning the processor are:

a. Measurement of developer and fixer temperature

b. Measurement of the processing time

3. Films

A film is exposed daily on a light sensitometer. After processing, its characteristic curve is plotted (optical density against wedge number) and the following are measured:

a. Base + Fog (measured on the unexposed part of the film). The O.D. has to be less than 0.2. Otherwise we search for the reason: Storage, light leakage, temperature.

b. Speed It is the wedge number in which the O.D. is unit.

c. Mean gradient: (γ) of the film which affects greatly the contrast of the image.

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The Mean Gradient is calculated as the slope of the line throuhg the points

$$Di = Dmin + 0.25 \quad \text{and}$$

$$D2 = Dmin + 2.00$$

The acceptable values according to the protocol are from 2.8 to 3.2 or at least > 2.6.

A graph of the day to day values of b + f, speed and contrast, helps very much in having an image of the function of our processor and darkroom versus time.

Acceptable variability versus time for all the parameters: <10%.

4. Artifacts

In doing the checks of the image receptor and the processor, the search for artifacts on the image is quite essential. The type of the artifact leads to the conclusion of which part of the imaging chain fails.

Dust artifacts or from the cylinders of the processor, or the cassettes etc.

5. Darkroom

In the Image Receptor checks we can classify also the darkroom checks which are:

a. Light leakage

b. Safelights

c. Cassette leakage

d. Film hopper leakage

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6. <u>System properties</u>

1. <u>Reference dose</u>

The reference dose is the entrance surface dose for 4.5 cm perspex phantom with the use of the A.E.C. system or with manual exposure, measured as close as possible to the reference point (6cm from the chest wall end and half way in the other direction) and 28 kVp.

The acceptable and desirable values are: Less than 12 mGy or less than 10 mGy correspondingly.

2. For the Image Quality of the system the following are also measured every week:

a. Spatial Resolution. with acceptable limit "over 14 lp/mm" in both directions.

b. Contrast visibility or Threshold contrast visibility, with limiting value: 1.3% contrast for 5-6mm details.

Both these parameters are measured on a film taken using a specialy designed phantom for mammography.

3. <u>Tube Output</u>

The tube output gives us the mGy/mAs in a certain distance from the focus and for certain kilovoltage. It is quite important as, for instance, too low a value could indicate problems with the tube voltage waveform (rectification?). The frequency of this check is once a year or if problems are suspected.

4. Leakage Radiation:

Using films to localise any leakage and then measure it with and appropriate ionisation chamber.

7. Viewing Boxes

Last check is the measurement of the brightness of the viewing boxes as well as the homogeneity of their illumination.

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To perform all the mentioned checks, some specialized equipment is needed.

We already have mentioned some of them (kVp-meter, star pattern, sensitometer etc.).

In the last SLIDE a complete series of the needed equipment with their ~~possibilities~~ and their callibration requirements are presented.

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