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FACTORS CONTROLLING THE QUALITY OF RADIOGRAPY AND THE QUALITY ASSURANCE

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Introduction

There are various factors controlling the quality of X-ray pictures. This paper provides a brief note enlightening the important points to be observed to produce a good radiograph of acceptable quality. Before going into the details, it is apt to remember the great German scientist Wilhelm Conrad Rontgen who discovery this invisible rays on 8^{th} November 1895. This discovery has become a boon to the entire medical field for diagnosis and treatment.

X-rays that come out from the window of the X-ray tube are called primary beam. That pencil of radiation at the geometric centre of this primary beam is said to be the central ray. The wave length of X-ray is one billionth of an inch. They are penetrating in nature. They penetrate through all materials. The penetrating power of X-rays depends upon atomic number, thickness of the part of the body to be traversed and the density of the material (Ref Fig.1). For instance, bone absorbs more X-rays than flesh. Flesh absorbs more than air. That is the reason in a chest radiograph we see different densities depending upon the rate of absorption by the body tissues. This helps us to distinguish and differentiate the different parts in the image. This is otherwise called contrast. Hence, the contrast — the photographic effect on the film can be defined as the degree of differences in density between, around and adjacent areas. The density can be defined as the photographic effect producing different degree of blackness on the film measured by light absorption through it.

The factor that controls contrast is said to be KV and the factor that controls density is termed as mAs i.e. the product of milliampere and the duration of exposure.

Formation of Radiographic Image

The radiographic image is produced by radiation transmitted in varying amounts through the subject by

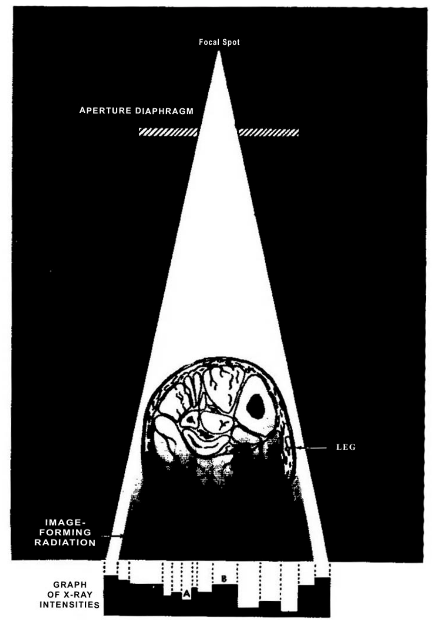

Fig 1. Diagram that illustrates the passage of the X-ray beam through a leg, and the resulting variation in intensity of image-forming radiation.

activating silver halide grains in an emulsion present in the film and by producing black deposits of silver. The action of X-rays in combination with intensifying screens is amplified many times. Thus, a latent image is recorded on the film. By subjecting this film to chemical processing, a real permanent image can be produced which can be viewed through transmitted light. For proper recording of the radiographic image, the following are essential:
(1) radiant energy, (2) subject (patient) to record, (3) photo-sensitive material and (4) chemicals for processing.

Characteristics of a good radiograph

The image produced should have (1) sufficient sharpness and (2) sufficient radiographic contrast.

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Sharpness of the radiographic image

The radiographic image is a shadow image. It is made by the body intercepting radiation. In practice, these shadows always possess some diffusion of outline and the total degree of diffusion is a composite of several factors. These can be divided into three main groups:

(a) Factors connected with the geometry of shadow formation known as geometric factors.

(b) Factors connected with the subject and its movement known as motional factors.

(c) Factors connected with the recording of the image known as photographic factors.

Geometric factors of unsharpness depends upon: (see Fig.2)

(i) The size of the X-ray source (target or the focal spot) — smaller the focal spot lesser the image unsharpness.

(ii) The distance between the X-ray source and the recording surface which is the film (larger the distance lesser the unsharpness).

(iii) The distance between the film and the subject being radiographed. (closer the distance between the film and the subject lesser the unsharpness).

Motional factors affecting unsharpness

(i) Involuntary: Peristaltic action in the abdominal viscera and the heart beat.

(ii) Voluntary: Movement of the body sufficiently blurs the shadows outline.

Photographic effect of unsharpness

(i) Intensifying screen: It is said that the capacity of an emulsion to resolve detail are influenced by grain size, contrast and the extent to which it may absorb or scatter light.

The salt screens are commonly made of calcium tungstate crystals. The dimension of these are expressed in microns (a micron being a thousandth part of a millimeter). Even the smallest lesion which could be absorbed on a radiograph is many times larger and its size is normally expressed in terms of one millimeter or more.

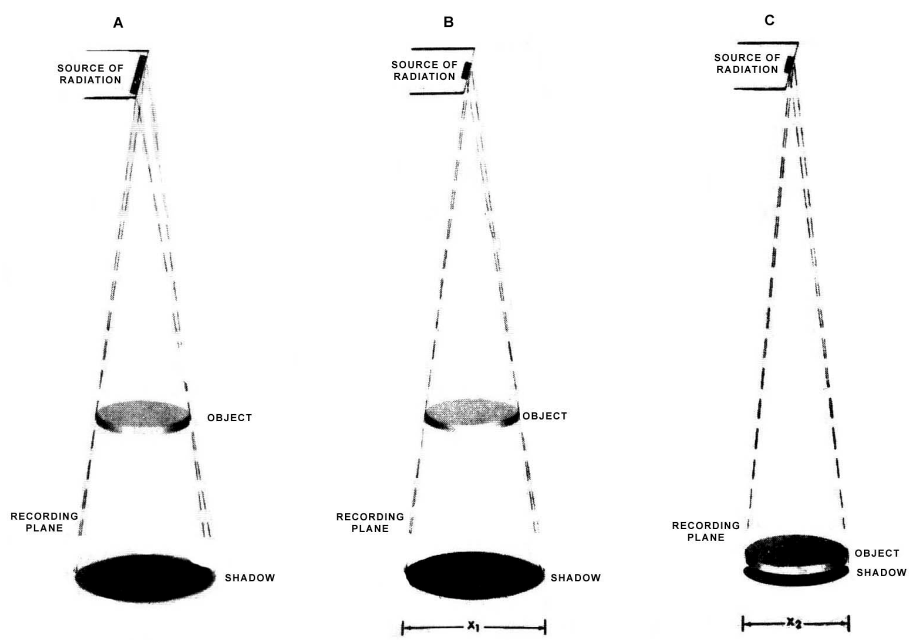

Fig. 2 Diagrams showing geometrical effects on image sharpness. A: Unsharpness caused by a large focal spot and long object-film distance. B: Improvement in sharpness produced by a small focal spot. C: Superior result of a small focal spot and minimum object-film distance. Notice the enlargement (x1) caused by a long object-film distance as compared to the more accurate size (x2) produced when the object is close to the film.

These crystals fluoresces as a separate entity under action of X-rays. The image is therefore produced by many such separate sources of light. These separate light sources result in images with a certain diffusion of outline. The extent of this diffusion depends on the size of the light emitting crystals and also upon the distance of the crystal from the film since there is divergence of screen light.

Hence, it can be concluded that screens made of larger crystals and deeper layers of crystals are faster — reducing the exposure time which results in greater screen unsharpness. Screens made of very fine grains and thin layer of crystals usually produce a high definition which results in minimum amount of screen unsharpness requiring longer exposure time. Film screen contact should be good to avoid unsharpness.

(ii) Emulsion factors: Film base is coated with light sensitive material called silver bromide crystals suspended in a suitable binding agent to make photographic emulsion. This sensitive emulsion is spread on base called polyester base (polyethylene terephthalate resin). When X-rays impinge on a photographic emulsion the latter gets converted into black deposits of silver and a latent image is formed.

These silver bromide crystals on being struck by the X-rays produces light, whose sideways dispersion leads to unsharpness of the image. This is minimised by giving anti-halation backing to the film which reduces the light getting reflected back to the emulsion from the base.

Besides, the above, was should know that contrast of the radiographic image is controlled by three factors viz., (1) film contrast, (2) processing chemicals and (3) radiation factors of objective contrast.

Film contrast: Film contrast which is inherent in the film depends upon the size and sensitivity of the silver bromide crystals.

Processing chemicals — Factors involved are:
(a) Type and constitution of developing solutions
(b) Temperature of the developer
(c) Freshness of the developer
(d) Agitation of the film in the developer

Radiation factors of objective contrast — These are:
(a) Quality of primary radiation
(b) The scattered radiation reaching the film and its effects on the image.

Primary radiation: A change in penetration of X-rays which is otherwise controlled by KV alters radiation contrast within the subject.

Scattered radiation: The X-rays that did not penetrate through the body are not entirely absorbed by the body tissues. Some of the radiations scatter in all directions by the atoms of the object struck very much like light being dispersed by a fog. These secondary rays are scatter radiations. These radiations adversely contribute to the formation of a good image. On the contrary it produces an overall haziness super-imposed on the image. The effect of this overlying intensity is to reduce contrast and hence to decrease the visibility of gradations in the image. These can be overcome by using potter-bucky diaphragm (See Fig 3).

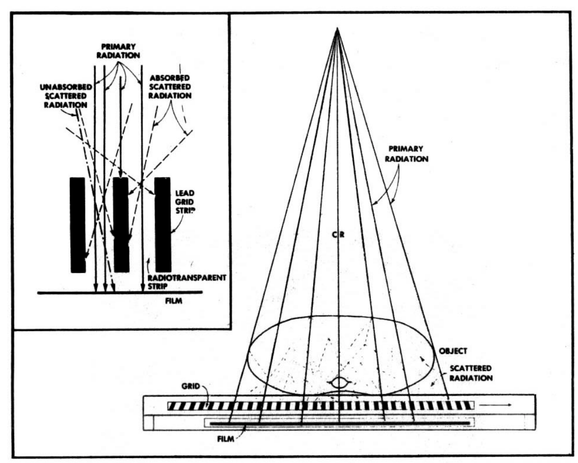

Fig. 3 Upper left: Diagram of a small section of a grid, showing the manner in which a large proportion of the scattered radiation is absorbed, and image-forming radiation passes through. Right: Diagram of a Polter-Bucky diaphragm.

Exposure factors in diagnostic radiography

The exposure factors are:
1. Tube voltage expressed in KV
2. Tube current expressed in milliampere
3. Duration of exposure expressed in seconds

Tube voltage

This alters the quality of X-ray beam, its penetrating power and its intensity, as the colour and the brightness are separate characteristics of a beam of visible light.

Tube current

Quantity of X-rays emerging from the X-ray tube which is proportional to the intensity of radiation and the same is recorded on the milliammeter.

Duration of exposure

Duration of radiation emerging out of the X-ray tube is measured in seconds. Duration of exposure of tube current control above controls quantity of X radiations which is measured in mAs.

Tube film distance (Fig 4)

X-ray beam is divergent from its source and it covers an area which will increase in size with the distance from the source. The energy of the beam is therefore spread over a large area and the intensity is thus diminished as per the inverse square law which states that intensity of light or X-rays reaching the film is inversely proportional to the square of the distance. From the above it can be inferred that (1) Exposure time can be decreased when KV is increased. (2) mA is raised when the tube film distance is shortened. (3) Exposure time must be increased when KV is lowered. (4) mA is lowered when tube film distance is increased.

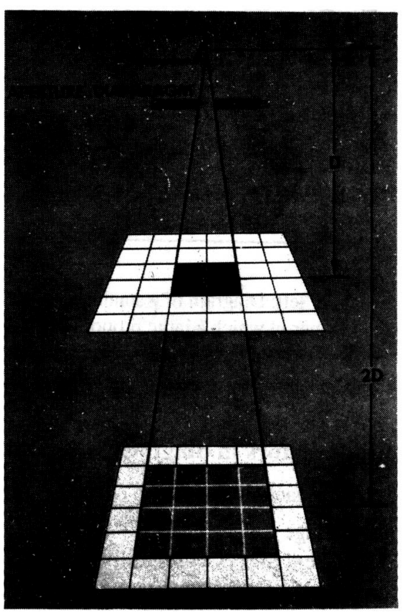

Fig.4 Diagram showing how the effect of an x-ray beam is altered by the changing focus-film distance

Variables modifying selection of exposures

The following factors are to be observed while selecting the exposure:

1. Type of the unit
2. Use of filters
3. Size of field
4. Use of secondary radiation grid
5. Speed of film
6. Use of intensifying screens
7. Developer and development technique

Quality assurance in diagnostic radiography

Quality assurance programme for diagnostic X-ray units is aimed to ensure that the image produced is consistently of high quality giving maximum diagnostic information with minimum radiation exposure to the patient at minimal cost.

This will include quality control of the correctness and consistency of the various radiological parameters like (1) tube potential, (2) tube current, (3) time of exposure, (4) filtration, (5) focal spot size, (6) radiation output, (7) field size, (8) film screen contact, (9) grid alignment, (10) film processing condition, (11) powerline condition etc. If these parameters represent their expected values, then the image will have required density, contrast and definition.

By this, repeat X-rays can be avoided thereby saving valuable films and reducing the radiation dose to the patient and the operator. Besides prolonging the life of the X-ray tube, delay in diagnosis can be avoided.

The following points enlightens the effect to different variables that affect the image in diagnostic radiography and the type of test tools proposed to measure various parameters.

Improper alignment of optical and radiation field introduces distortion in the image and is likely to cause deletion of essential information for diagnosis.

Larger fields than required increase the radiation exposure and scatter effect, which in turn reduce the quality of image. To verify the adequacy of beam alignment, a specially marked fluoroscopic screen is used.

The density of the image varies with the exposure. Defective timers cause inaccurate exposures. This results in difficulty in standardising exposure timers for various X-ray examinations. The accuracy and reproducibility of the timer can be tested using a spin top rotated by a motor at a constant known revolutions per second.

For a given technique consecutive exposures should result in identical densities. Similarly, constant

KVP and mAs irrespective of combination of mA and time should result in same densities. Further, the output should be linear with mA and time. These parameters can be checked by measuring the output at various conditions using a pocket dosimeter. This will also be useful to determine the adequacy of filtration.

The focal spot size is the region of the target from which X-rays originate. The resolution that can be obtained in an X-ray image and its sharpness depend on the focal spot size.

The contrast in a radiographic image vary with KVP selected. The improper calibration of KVP can result in incorrect exposure and poor diagnostic information. In order to check the correctness of KVP calibration, a cassette known as "Wisconsin KVP test cassette'' is used.

In a radiography the image is generally produced by sandwiching the film between two intensifying screens. Improper contact between screen and film will result in poor quality of the image. This can be checked by keeping a specially made wiremesh on the suspected cassette and make an exposure.

Alignment of radiographic grid for distance, centering and correct side facing the focus are essential to reduce scattered radiation reaching the film. Improper alignment can produce non uniform density in the film. In addition to the above, the temperature of processing solutions, the time of development, fixing and washing should be standardised taking into account the manufacturer recommendations. The variation of speed or sensitivity of emulsion on the film also alters the quality of radiograph very much.

Hence, quality of film, quality of developer, temperature and time of development are to be standardised to get optimum results acceptable to reader.

At last, the important factor is power line condition which changes the quality of radiograph very much. Hence, it is suggested that always X-ray unit should be connected to higher voltage if there is a provision so that the current drawn from the line is less for the same voltage. Hence, the voltage drop is less likely and indicated KVP will be actual KVP during the exposure. This will definitely improve the image quality because the power drawn from the line is same with lesser current and hence the voltage drop during the exposure is less. In India, we have generally 440 V 50HZ, 220V 50HZ. Best among the two is 440V 50HZ, if there is a provision in the X-ray unit.

References

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2. Fundamentals of radiography: Medical Division, Eastman Kodak Company, Rochester 4, N.Y.
3. Paper published in Workshop conducted under the auspices of IARP by SR Das.

FIVE PRINCIPLES TO BE FOLLOWED WHILE CHOOSING X-RAY EQUIPMENT:

- The quality of the images must be excellent;
- The equipment must be safe for both patients and personnel;
- The equipment must be easy to install and use;
- The equipment must be reliable and usable even when the electrical supply and other services are substandard;
- The equipment should need minimal maintenance care.

Source: *Palmer PES & Holm T: The basics of diagnostic imaging; Wld Hlth 1995,* ***May-June****, 12.*