Evaluation of development time effect on X-ray film density

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ABSTRACT

The aim of this study was to find out the effect of the different development time on X-ray film density in removing any discrepancy incurring due to processor related variables. One hundred double emulsion films were irradiated and were produced using 100 sensitometric strips with 21 steps each. The films were processed with different processing time with a gap of 10 s. Optical density was measured at 5 places and the mean net density value was calculated. Base plus fog densities of each film and densities of the 3 un-irradiated areas were also measured. Significant changes were observed in the base plus fog values and the optical density values of the X-ray films at varying development times. The lowest base plus fog of 0.17 was measured at 10 s developing time and the highest base plus fog of 0.36 was measured at 150 and 160 s. The observed changes of average net density values were in the range of 1.95 to -0.00267. The highest net density value was observed on the 21st step of sensitometric strips with a developing time of 50 s. The results of the present study indicate that there is a positive relationship between the base plus fog densities and the developing time when other factors are controlled. At 70 s, the base plus fog density value exceeded the limit of 0.25 which is clinically unacceptable. Net density value of the present study was within the accepted limit for the selected development time periods.

INTRODUCTION

Diagnostic radiography is a predominant medical procedure to ameliorate medical diagnosis by varying grades of blackness of particular body structures. To successfully achieve the above goal, all techniques and equipment should be in excellent standard in other to ensure that the clinical images produced have the best diagnostic quality (Mangset and Izang, 2010; Brüssau et al., 2001). Radiographic image can be described from an important point of visibility of details and it is a measure which an object can be clearly discerned. The radiography image visibility compromises of various factors and one of such major influential factor is a characteristics of equipment. Radiographic density (optical density) is a characteristic of an X-ray film which can be simply defined as the amount of blackening on the radiograph. It is influenced by X-ray beam quality, type and thickness of irradiated tissue as well as the chemical processing conditions. The density is determined by the number of photons present in a given thickness of tissue which influences the photon stopping power that the tissue possesses. If the density or thickness of the tissue doubles, the number of photons reaching the film should be halved and radiographic density also should be halved (Brüssau et al., 2001).

Processing film is a strict science governed by rigid rules of chemical concentration, temperature, time, and physical movement. Studies have shown that processor
variability is the single most important cause of retakes (Peer et al., 2001). Whether processing is done by hand or automatically by machine, excellent radiographs require a high degree of consistency. Because of that, the importance of the processing conditions has become more evident over the last decade. Though optical density depends on tissue composition, it could be changed by preliminary factors like chemical processing conditions (Changizi et al., 2006; Blendl and Buhr, 2001). Developing time, developing chemicals and their temperature are considered as some factors to affect the optical density of the radiographic films (Thornley et al., 2006). In European Guidelines on Quality Criteria for Diagnostic Radiographic Images (1996), it is mentioned that darker film may be associated with a relatively higher patient dose or over development along with the following key points for X-rays film densities:

i. The range of the mean optical density of a clinical radiograph should normally lie between density units (D) of 1.0 and 1.4.

ii. The minimum film density is usually in the range of 0.1 to 0.2 density units, which is designated the base plus fog density and is the density of the film base and any inherent fog not associated with exposure. The optical density value of fog and film base should not exceed D = 0.25.

iii. For the diagnostically relevant parts of the film, the overall range of optical densities should lie between 0.5 and 2.2.

The aim of this study was to find out the effect of the different development time on X-ray optical density to remove any discrepancy incurring due to processor related variables which may spoil the patient’s film images and contrast, leading to retake.

MATERIALS AND METHODS

The study was carried out at the Radiography unit, Faculty of Allied Health Sciences, University of Peradeniya. One hundred double emulsion Fuji films with the size of 18 cm × 24 cm were irradiated one by one to the light with the help of a sensitometers (Unilight S/AS/S CINE, IBA Dosimetry GmbH, Germany) at the darkroom giving the same conditions of illumination, temperature level and the humidity to produce 100 sensitometric strips with 21 steps each. After the each exposure, the film was processed using a manual film processing system with different processing time starting from 10 to 200 s with a gap of 10 s. Initially, the chemical containers were emptied and thoroughly cleansed, then they were filled with new solutions of developer and fixer. The first processing was done two days later, to allow for stabilization of the new solutions. The temperature levels of the developer, fixer and water were always checked with the help of a thermometer (IBA Dosimetry GmbH RT 01) before and after processing and were regulated to 23–25°C. Film processing were performed only if the temperature was stabilized into the required level. To maintain the same concentration of the chemicals at every time, replenishment was taking placed after processing of the 25 films. To verify the pH level of the developer, water and fixer solutions, a pH meter (e-181-sensiION+PH1, HACH, USA) was used. Assumption was made that film to film variation was negligible and the processing chemicals were in same concentration for each film. In order to find out the relationship of the development time with the X-ray film density, the optical density was measured by means of a digital transmission densitometers (Unlight D/AD/D TR/ADA, IBA Dosimetry GmbH, –Germany) after the drying process. The optical density was measured at 5 places (1st step, 6th step, 11th step, 16th step and 21st step) of the sensitometric strip on each film and the mean net density value was calculated. At the same time, to determine the base plus fog densities of each film, the densities of the 03 un-irradiated areas was also measured. The data were analyzed using the SPSS package Version 17.

RESULTS

The relationship between the base-plus-fog densities and the different developing time are shown in Figure 1. The base plus fog values were found to be in the range of 0.17-0.36 when the development time was varied from 10 to 200 s. Lowest base plus fog of 0.17 was measured at the 10 s developing time and the highest base plus fog of 0.36 was measured at the 150 and 160 s. The average net density values were determined by considering the base plus fog densities.

The average net density values on sensitometric strips of each 05 steps, 1st, 6th, 11th, 16th and 21st for different developing time from 10 to 200 s are shown in Figure 2.

The observed changes of average net density values were in the range of 1.95 to -0.00267. The highest net density value was observed on 21st step of sensitometric strips with the developing time of 50 s and the minimum net density values were reported for the 1st step of the sensitometric strips. There were very few net density values reported and these were less than the base plus fog densities on the 1st step.

DISCUSSION

The formation of images of the internal body structures affiliates interplay between numerous factors. To accomplish the exact balance between patient dose and image quality, it is required to understand the way in
Figure 1. Base and fog densities versus Developing time.

Figure 2. Average net density versus developing time.
which the images are constructed. As can be inferred from the previous studies (Peer et al., 2001), film processing is one of the most important factors influencing the quality of the radiographic image using screen-film technology. The study done by Sharma et al. (2012) on light sensitometry of mammography films at varying development temperatures and times that they found when rise in development time from 1 to 6 min had an appreciable impact on the optical density. It increased from 3.54±0.03 at 1 min to a maximum value of 3.71±0.01 at 4 min. Wallace (1995) concluded that density is an important quality which needs to be checked on a radiograph. Fauber (2000) also stated that a radiograph must have sufficient density so that anatomical structures of interest are seen clearly and the radiograph deemed optimal, diagnostic and acceptable. He further said that it is the responsibility of the radiographer to find out and solve what factors are causing the problem of density error.

During this study effect of the different degrees of the exposure, temperature, pH level and the different processing solution for each film were controlled. The films were taken from the same box of film each day, because the films were made in batches and there could be a slight difference from film batch to film batch. The developing time was the only variable that has changed from film to film.

Lowest density (more often called D-min or base plus fog density) is a result of the transparent base and a slight chemical fogging of the film emulsion. Chemical fog occurs because a few silver halide crystals can spontaneously develop, even though they received no exposure. The results of the present study indicate that there is a positive relationship between the base plus fog densities with the developing time when the other factors were controlled, which is in consensus with the findings of Thunthy et al. (1991). An increase in the base plus fog density can be caused by over processing a film. This fact is really important, since it could be optimized to reduce patient dose by avoiding the retake. European Guidelines on Quality Criteria for Diagnostic Radiographic Images (1996) recommends that the optical densities of fog and film base should not exceed D=0.25. But the present study results indicate that after 70 s of developing time, the base plus fog density value was exceeding the limit of 0.25 and it is not clinically accepted. However the study reveals that although the developing time was increased until 200 s the maximum net density value did not go beyond 2.0. The net density value of the present study is within the accepted region recommended by the European Guidelines on Quality Criteria for Diagnostic Radiographic Images (1996). The results of the present study indicate that there is a positive relationship between the base plus fog densities with the developing time when the other factors were controlled. But after specific time limit constant net density values were yielded. At 70 s, the base plus fog density value exceeded the limit of 0.25, which is clinically not acceptable. But the resulted net density value of the present study was within the accepted limit for the selected development time periods.

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REFERENCES


