Evaluation of Sensitometric Properties of Radiographic Films at Different Processing Solutions

[1] Mojiri M , [2] Ghazi Khanloo Sani K, [3] Moghim Beigi A

***Abstract*—**The aim of this study was to compare the sensitometric properties of commonly used radiographic films processed with chemical solutions in different workload hospitals. The effect of different processing conditions on induced densities on radiologic films was investigated. Two accessible double emulsions Fuji and Kodak films were exposed with 11-step wedge and processed with Champion and CPAC processing solutions. The mentioned films provided in both workloads centers, high and low. Our findings displays that the speed and contrast of Kodak film-screen in both work load (high and low) is higher than Fuji film-screen for both processing solutions. However there was significant differences in films contrast for both workloads when CPAC solution had been used (*p=0.000* and *0.028*). The results showed base plus fog density for Kodak film was lower than Fuji. Generally Champion processing solution caused more speed and contrast for investigated films in different conditions and there was significant differences in 95% confidence level between two used processing solutions (*p=0.01*). Low base plus fog density for Kodak films provide more visibility and accuracy and higher contrast results in using lower exposure factors to obtain better quality in resulting radiographs. In this study we found an economic advantages since Champion solution and Kodak film are used while it makes lower patient dose. Thus, in a radiologic facility any change in film processor/processing cycle or chemistry should be carefully investigated before radiological procedures of patients are acquired.

***Keywords*—**Sensitometry, densitometry, Radiographic film, processing solution

I. Introduction

DIAGNOSTIC radiology is the medical procedure to improve health care by varying degrees of blackness of particular anatomical structures. To effectively achieve this goal, all instruments, equipments and materials used must be in excellent conditions to ensure that the image produced has the best quality[1,2]. The radiography image visibility be affected by film contrast, speed of radiographic film and also base plus fog. Tissues information transmitted to recorder system like films by attenuation of x-rays. The tissues such as bone and soft tissue have different attenuation coefficients and make a primary pattern which should be displayed on recorder[2]. The most important agent in this procedure is processing solution. Although final contrast depends on subjects contrast but the role of film contrast and processing solution compounds should not be ignored. While subject contrast depends on tissue thickness, atomic number of the subject and the radiation energy, film contrast could be changed by fundamental factors like characteristic curve, film density and also processing method[3,4]. It means film design is not only the parameter that determines it's performance, since it has been well known processing conditions through different factors can affect film characteristics. Developing time, developing chemicals and their temperature are considered as some factors to affect the sensitometric characteristics of the radiographic films[5]. There are many manufactures that produce processing chemicals in order to use in diagnostic imaging. These processing solutions are applied with different film-screens in diagnostic departments, so quality of images may be vary due of different compounds of film, screen and also processing chemicals[6,7]. The aim of this study was evaluate sensitometric characteristic x-ray films in combination with different chemicals processing to determine the best results in terms of radiographic contrast and relative film speed.

II. Materials And Methods

Fuji and Kodak film in size 24*30 were used in this study and were irradiated by an X-ray tube (Shimadzu model R-20 with 1mm Al filtration) at 63 kVp and 13 mAs. The exposure factors were optimized by the sufficient X-ray beam to get the best quality image and resolution. The distance between target and film was 100 cm and 1mm Al was total filtration of radiography machine. To determine film response as contrast and speed, we traced the characteristic curve for each film. In order to obtain different exposure logarithm, an aluminum step wedge with 11 steps in 5 mm thickness for each one was used[2,8]. Two processing solutions were evaluated in combination with two mentioned films which are common in use in hospitals. Champion (England) and CPAC (Belgium) are more available processing chemicals in Iranian hospitals so in this investigation were examined. Besides that we compared film response to different processing solutions in two hospitals with high and low workloads. The number of films processed in these radiology departments during same time was significantly different. Whereas high workload hospital have to recharge and change processing solution every week, so 6 days of every week was determined to examine the combination of films-screen and one processing solution. For the other center we considered two weeks including 12 main workdays to test response of the films in existence of one processing solution. Every day Fuji and

[1] Radiology Department, Paramedical school , Hamadan university of medical science, Hamadan , Iran . mojiri@umsha.ac.ir
[2] Radiology Department, Paramedical school , Hamadan university of medical science, Hamadan , Iran . Ghazi@umsha.ac.ir
[3] Moghim Beigi A , Department of Biostatistics and Epidemiology, Research Center for Health Sciences, Hamadan University of Medical Science, Iran moghimbeigi@umsha.ac.ir

Kodak films were exposed by placing the step wedge in the same position and exposure factors with one radiology machine but processed by two processing machines in two different workload centers. Totally 48 films irradiated, processed and evaluated by densitometer. To obtain similar position, we considered same time and temperature for both processing machines in 90s and 31^{o} C. To estimate relative speed for every condition we used necessary wedge thickness to density one plus fog so more wedge thickness is equal to more density. Both films and processing solutions were compared in density one plus fog and relative contrast assessed by calculation of maximum and minimum densities for each exposed film and compared in different conditions due of film type combine with processing solution.

III. Results

In order to comparison of speed for two different radiography films, we calculated wedge thickness which equaled with density one plus base fog. Therefore we firstly traced characteristic curve for each exposed film according to obtained densities and wedge thickness in mm. Then the amount of thickness to obtain density one above base plus fog was determined. The obtained data were analyzed by SPSS software. The relative results were summarized in table 1.

TABLE II
THE WEDGE THICKNESS TO ESTIMATE SPEED FOR TWO FILMS AND TWO PROCESSING SOLUTIONS IN TWO DIFFERENT WORKLOADS

Name	N	Wedge thickness mean	Std. Deviation	95% confidence level	
				Lower level	Upper level
Fuji	24	29.6750	3.2867	28.547	30.803
Kodak	24	30.9417	2.5413	29.814	32.069
Champion	24	31.2708	3.5992	30.143	32.399
CPAC	24	29.3458	1.7917	28.218	30.474
Low workload	24	29.6333	3.5929	28.506	30.761
High workload	24	30.9833	2.0586	29.856	32.111

According obtained results, Kodak film has shown more speed. It delivered from more necessary wedge thickness to obtain density one above base plus fog. The same results revealed for Champion solution and statistical analysis displayed a significant difference between processing solutions regarding speed (*P=0.01*) but no any significant difference shown between two films in %95 confidence level. Consequently this result has been repeated for high level workload to make more speed. Moreover relative contrast which presents difference between maximum and minimum densities in acceptable range (0.25 up to 2) in comparison to reference contrast evaluated for all exposed films in different solution conditions according in evaluated densities by film densitometry. Table II shows relative contrast among two studied films and Champion and CPAC as the two used processing solutions in two different hospital workloads.

TABLE II
RELATIVE CONTRAST AMONG THE TWO DIFFERENT SOLUTIONS AND TWO USED FILMS IN THIS STUDY AT TWO CENTERS WITH DIFFERENT WORKLOAD

Name	N	Relative Contrast	Std. Deviation	95% confidence level	
				Lower level	Upper level
Fuji	24	0.7592	0.1081	0.697	0.821
Kodak	24	0.8138	0.0826	0.752	0.876
Champion	24	0.7671	0.1686	0.705	0.829
CPAC	24	0.8058	0.1318	0.744	0.868
Low workload	24	0.7708	0.1379	0.709	0.833
High workload	24	0.8021	0.1644	0.740	0.864

It has been revealed that better contrast is obtained for Kodak film against Fuji. According in Three ways variance analysis, there is no any significant difference between contrast of two surveyed films and used processing solutions and centers with different workloads, although it has been recognized CPAC has better performance.Besides that, we analyzed density base plus fog for the groups of exposed films in two types. Table 3 summarized relative results to compare. It is obviously delivered that density base plus fog for Kodak film is more lower than the other one and statistical analysis displayed significant difference for the observed fogs between two studied films (*P=0.003*) and also for used processing solutions and two hospitals with different workload (*P=0.05* and *P=0.01* respectively).

TABLE III
BASE PLUS FOG DENSITY FOR EACH SOLUTIONS AND FILMS AT THE TWO CENTERS WITH DIFFERENT WORKLOAD

Name	N	Base plus Fog	Std. Deviation	95% confidence level	
				Lower level	Upper level
Fuji	24	0.3412	0.0947	0.308	0.375
Kodak	24	0.2683	0.0820	0.235	0.302
Champion	24	0.3283	0.0973	0.295	0.362
CPAC	24	0.2812	0.0885	0.248	0.315
Low workload	24	0.3358	0.1002	0.303	0.369
High workload	24	0.2738	0.0800	0.240	0.307

In addition we found that reduction potential of the developer in CPAC solution occurs slightly during application time, while there is a threshold for induced contrast in second or third days of using Champion solution and reduction potential is mostly shown after these work days. So the maximum difference between high and low density which reveal difference among exposed and unexposed silver halide crystals, confirms optimum potential of the developer that in following our investigate, stability of Champion is better than CPAC.

IV. Discussion

The films included in this study are commonly used in most radiology departments and they are adequate to display variety of the sensitivity characteristics of the used films in our departments depending to processing chemicals solutions. In this study we observed that the speed as a sensitivity characteristic of investigated films are sensitive to the processing conditions while for the contrast is not true so the type of film and chemical solution will not be effected on films' contrast. Consequently the characteristics of the films mainly speed and contrast are the interesting prospects for radiologists and medical physicists since it could be optimized to reduce patient dose by improvement of films' speed and utilized the maximum contrast to obtain best image quality in processing conditions. Implication of Kodak film that induced more speed in comparison to Fuji, should be noticed as an important protective aspect by reducing patient dose and it could be related to combination of mentioned film with the screen in the same model. The present observation similar to other report showed that using Kodak film instead of Fuji enhances system's speed. For instance, Brennan's investigation confirmed that system speed increases with coefficient 1.26 while Kodak replaced in 50 kV[9]. Moreover our findings indicate that Kodak has better contrast in comparison to Fuji. This is turn implies that in a radiologic procedures where a good quality should be thoroughly occurred, Kodak film presents more acceptable results. The implication of using high contrast films are briefly mentioned in different quality control protocols such as the European version[10]. These results are confirmed with the other survey around panoramic films and states the film speed and radiographic contrast are 1.3 and 1.2 times higher for Kodak Ektavision than for Fuji super HR-S[11]. But apart from the implication of high contrast films may have clinical practice especially for fatty tissues to improve image quality, some time reduction of contrast required in some reasons such as for visualizing dense tissues for instance in mammography[12]. Champion chemical solution made better results regarding speed for the tested conditions and there was a significant difference between speeds while Champion and CPAC solutions were used (P=0.01). It is confirmed by Aidan McGraths' experiments as a radiographer supervisor over 15 years. The relative statement around Champion solution which published in business site, has compared with the other chemical solutions regarding speed and contrast. Although it displayed contrast in the range of medium or even low level in some products, but it's speed is noticeable and high in every products[13]. so it will be not necessary to apply longer exposure time and high mA. It could be effectively reduce patient dose during radiological procedures. In a same condition for processing time and temperature, CPAC processing solution had the best contrast in comparison to Champion solution, therefore using mentioned solution can caused good visibility and accuracy than the other. Whereas the components of developer solution such as Phenidone and especially Hydroquinone are responsible to make higher contrast so the amount of these might be the main reason to obtain better contrast result induced application of CPAC solution[3,14]. Concerning the CPAC solution as the first one in ranking for tested condition regarding contrast, could not compare with the other studies because there is not any published data on this subject. Moreover we found that density base plus fog induced film processing in both surveyed films were more than what expects (up to 0.25) and it varies between 0.26 to 0.56 and it is much higher than the amounts (0.1 up to 0.11) found in the other study on different blue and green sensitive films[4]. it could be related to film deposing method. Base plus fog density for Kodak film and CPAC processing solution were lower than Fuji and Champion and a significant difference was observed between films and also between solutions in 95% confidence level (P=0.003 and P=0.05 respectively). This may indicates that the processing solution which makes high density base plus fog, has less potassium bromide as restainer than the other and explained that lower exposure factors can produced acceptable image density[15]. Finally, an important remark should be made concerning the comparative evaluation of processing solution in terms of potential stability. The Hekmatian survey exhibits more stability and greater created density for Champion solution through application time and it is same to what we found in current study[16]. It would be suggested to consider more replenishment during application period of solution while CPAC exists in processing machines. It is same to condition if the processor is subject to long period of stand-by, a degree of aerial oxidation, therefore it is necessary to employ a higher replenishment rate rather than busier machine.

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