The Effect of Varying Amounts of Hydrogen Peroxide of a Fixer Solution on the Optical Density of X-ray films

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Abstract: Processing of radiographic films plays an essential part of the imaging chain in screen –film radiography. A correct and safe processing of radiographic films is important because the quality and diagnostic acceptability of the images rely significantly on this important step. In this study, ten experimental solutions, with varying amount of hydrogen peroxide, were prepared and used as a fixing solution in the manual processing of x-ray films. The optical density and the characteristic curves of the films that were processed with the experimental solutions were evaluated, analyzed, and compared to the films processed with a standard fixer. Additionally, the archival qualities of the films treated with the experimental solutions were evaluated during a six month period (DAY 0, DAY 90, DAY 180). The optical densities of the films processed in experimental fixers show no significant difference compared to the films processed with the standard fixer. Furthermore, the archival qualities of the films treated with experimental solutions are comparable to that of the films processed with the standard fixer

Keywords: *Fixer, Photography, Radiographic Imaging, Archival Quality, Optical Density*

INTRODUCTION

In screen film radiography, diagnostic images are produced when the x-ray beams hit the silver halide (95% AgBr + 5% AgI) grains embedded in an x-ray film (Bushberg, et al. 2012). Upon exposure to radiation, the light sensitive silver halide grains stores a latent image which is formed in the film. This latent image is converted into a diagnostic information when the film is processed with chemicals that develops and fixes the film (Bushberg et al, 2012 and Bushong, et al, 2009).

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The correct processing of radiographic films is an important step in the imaging chain in screen film radiography. Gray, et al (1983) stated that x-ray film processing demands the most attention because of the inherent sensitivity of the film. During processing, the x-ray film goes through five important steps: developing, stopping the development, fixing, washing and drying.

In the processing stage, the film is exposed to different types of chemical solutions for controlled periods of time.

Development stage occurs when the developing agents give up electrons to convert the silver halide grains to metallic silver (Szwajewki et al., 1995). Grains that were exposed to radiation develop more rapidly and the developer converts all these silver ions into metallic silver. Proper temperature control is essential in this stage to ensure that exposed grains are efficiently transformed into pure silver, while keeping the unexposed grains as silver halide crystals (Szwajewki et al., 1995.).

During the washing stage, water is used to stop the complete conversion of silver halides to elemental silver (Hendricks, et al., 2007). The fixer then removes the unexposed silver from the fixing bath and only dissolves the silver halide crystals, thus leaving the metallic silver behind (Bushong 2009 and Bushberg, et al. 2012).

During the processing of x-ray films, the fixing process demands the most attention because fixing significantly affects the formation of diagnostically acceptable images. The role of the fixer is to stabilize the image, remove the remaining unexposed silver halide crystals, and to harden the gel emulsion of the film. Additionally, the fixer also serves as an acidifier that neutralizes the alkalinity of the film (Hendricks, et al., 2007). Failure to remove the remaining silver halides would result to unnecessary film fogging and, worst, the loss of the necessary diagnostic information (Bushong, et al 2009).

The fixing process is normally achieved by treating the film with a solution of thiosulfate salt or ammonium thiosulfate (Haye et al., 1997) with a combination of ferrous EDTA, a known chelating agent.

The acidic nature of fixer solutions often cause eye and skin irritation to radiologic technologists working in the darkroom. The need to protect themselves from direct contact with the fixer is now a necessary precautionary measure. The acidity of the fixer is considered a work-related hazard on the part of radiographers and radiologic technologists.

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The United States Environmental Protection Agency, through the Resource Conservation and Recovery Act (RCRA) classifies x-ray fixer solutions as environmental hazards (hercenter.org, 2016). This means that fixer wastes requires necessary post-processing before they are allowed to be disposed off in ordinary sewers and waterways. The high content of chemicals and silver halides makes x-ray fixer solution not only an environmental threat but also a hazard to the general health and well-being of the worker.

The need for an occupationally safe and environmentally friendly material for x-ray film processing is of paramount importance. A safe solution is not only intended for the protection of the environment but also for the general safety of the people working in diagnostic film processing. There is then a need for an alternative fixer solution that is environmentally friendly This is the general direction of this research.

Fyson et al. (1997), presented in his patent a fixing solution made from common materials such as sodium hypochlorite and cyanide ions. In their work, Fyson et al (1997) argued that a mixture of sodium hypochlorite, and a small amount of cyanide ions can be used as an alternative fixer in film processing. Furthermore, they claim that this solution is more environmentally safe than the commercially available thiosulfate-based fixer.

It has been widely known that hydrogen peroxide is highly reactive with silver halides (Haye et al., 1997). Hydrogen peroxide is also commonly used in fixer solutions of photographic films. There are limited studies, however, on the applicability of using hydrogen peroxide as a component material for radiographic fixer solutions. Furthermore, there has been no reported study that used hydrogen peroxide as an alternative fixer. After a thorough study this is the first study that attempted to use this material.

In this study, an experimental fixer solution made from hydrogen p eroxide and sodium hypochlorite was prepared and the image quality of the films processed using this fixer was evaluated. Specifically, this research answers the question of whether the optical density of the x-ray films processed with the experimental fixer is significantly different to the films processed with a standard fixer. Lastly, the archival quality of these films was evaluated during a six month period.

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MATERIALS AND METHODS

Preparation of the experimental fixer

Ten experimental fixer solutions were prepared in this study with the amount of hydrogen peroxide varied for each solution. The combination of the materials is as shown in table 1. The materials were mixed together in a clean container at a constant room temperature (30^{0}C). The chemicals used in developing the x-ray films were stored in a container in the correct order (developer, water, fixer).

Table 1.Preparation of the experimental fixing solution

Solution	Bleach	Water	Salt	Hydrogen Peroxide
SOL1	2.5 mL	1 L	300 g	0.5 mL
SOL2	2.5 mL	1 L	300 g	1.0 mL
SOL3	2.5 mL	1 L	300 g	1.5 mL
SOL 4	2.5 mL	1 L	300 g	2.0 mL
SOL 5	2.5 mL	1 L	300 g	2.5 mL
SOL 6	2.5 mL	1 L	300 g	3.0 mL
SOL 7	2.5 mL	1 L	300 g	3.5 mL
SOL 8	2.5 mL	1 L	300 g	4.0 mL
SOL 9	2.5 mL	1 L	300 g	4.5 mL
SOL 10	2.5 mL	1 L	300 g	5.0 mL

The concentration of H_2O_2 is 3%
The bleach used is 5% w/w NaOCl

Preparation of test films

An aluminum step wedge phantom was placed on top of a 11 x 14 in. intensifying screen containing a green sensitive, 400-speed class x-ray film (see figure 1).

The x-ray machine of the radiologic technology department was used to expose the step wedge using a constant factor of 60 kVp, 6.30 mAs, and a constant source to image distance (SID) of 100 cm. These factors were used in all trials.

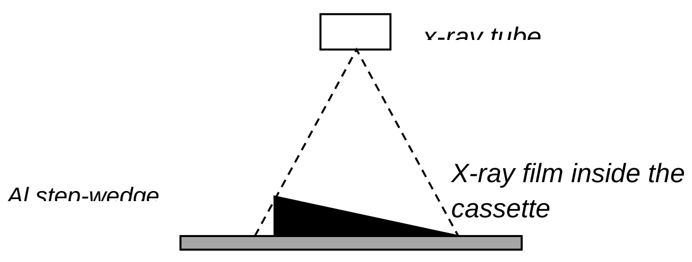

Figure 1. Set up used in the preparation of the test film.

Developing of the test films

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On DAY 0, the films (coded F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, and FS) were soaked in the developer solution for five minutes and then rinse in fresh water for one minute. After which, the films were then dipped on the experimental (SOL 1 – SOL 10) and standard (STD) fixing solutions for 15 minutes. In this process, film F1 is dipped in solution SOL1, F2 on SOL2, and so on. The film coded FS was dipped on standard (STD) solution. After the fixing process, the films were washed with running water to prevent hypo retention. The films are then allowed to dry in the hanger.

Evaluation of the Optical Density

After drying, the optical density of the step wedge images on the films was measured using a densitometer. Three measurements were gathered for each step number. Measurement of the optical density is repeated on DAY 90 (3 months) and DAY 180 (6 months) to determine the archival quality of the produced films.

RESULTS AND DISCUSSION

The measurement of the optical density of the films treated with experimental and standard fixers are illustrated by the graph shown in figure 2. In this curve, the value of the optical density (OD), for a particular film sample (e.g. F1), were plotted with respect to the step number of the wedge phantom. From the figure, it can be observed that characteristic curve of the films treated with fixers SOL 2 to SOL10 are not significantly different from the characteristic curve of the film treated with the standard fixer. Close analysis of the optical density values shows that the measured OD's are not significantly different (OD < 0.15 units). The maximum allowable OD deviation in screen-film radiography is 0.15 units (Gray, et al, 1980 and WHO, 2004).

This result indicates that SOL2 up to SOL10 fixers is comparable to the standard fixer. Furthermore, the characteristic of the films processed in the alternative fixer is not significantly different to the film treated with the standard fixer. We can then safely claim that the experimental solution can be used as an alternative fixer in manual x-ray film processing.

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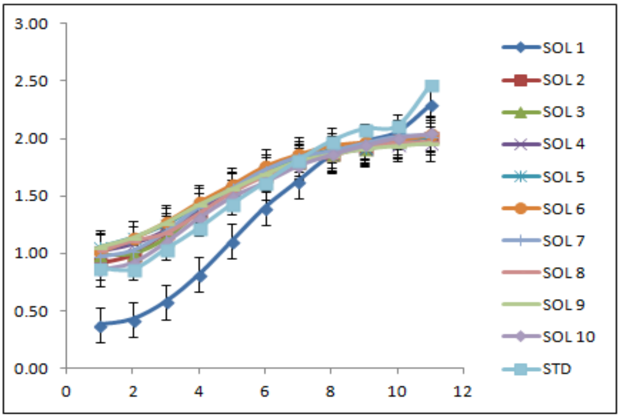

Figure 2. Characteristic curves of x-ray films (DAY 0) treated with experimental (SOL1 – SOL 10) and standard fixers (STD).

To further evaluate the capability of the alternative fixer, we compared the mid-step OD values of the films. The mid-step OD value is the optical density provided by the 6th step of the step-wedge phantom. The mid-step OD is significant because this is the range of optical density that is important in image formation and in film analysis. The result of the measurement is provided in figure 3.

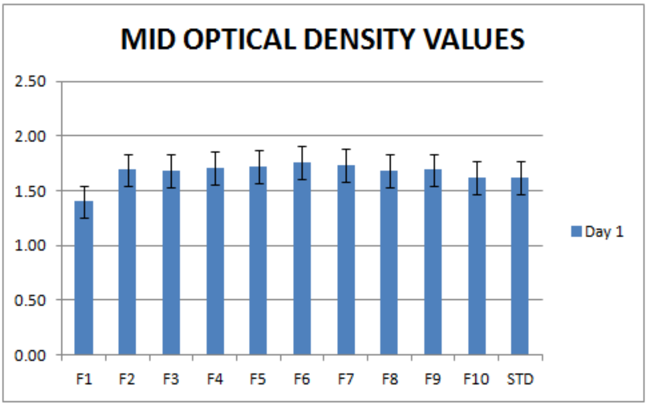

Figure 3. Mid-step OD values of the films treated with experimental and standard fixing solution (taken on DAY 0)

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We can see from the bar graph that the mid-step optical densities of the films (F2 to F10, STD) are not significantly different from each other (± 0.15 OD units) because the OD values are overlapping with each other. In an actual clinical setting, overlapping OD values mean that the image quality that will be produced from each films are not significantly different. This result suggests that films F2 to F10 have a comparable film optical density property to that of the film treated with the standard fixer.

Film F1 which was treated with solution SOL1 is the only film that produced a mid-OD that is significantly different from all the other films. We explain that a very small amount of hydrogen peroxide in the solution is not enough to remove the unexposed silver halide thus giving a film that appears to be under exposed. The role of a fixing solution is to remove any undeveloped silver halides in the x-ray film. Failure to remove the undeveloped silver halides results to a less optimum diagnostic x-ray image. From this result, we can conclude that varying the amount of hydrogen peroxide in the experimental fixer did not significantly change the image quality, as reflected by more consistent optical density measurements, of the exposed x-ray films. We could therefore say that the amount of hydrogen peroxide is not a significant factor during the fixing process provided the minimum amount of hydrogen peroxide is at least one milliliter.

Archival Quality of the Films

Having succesfully shown that the prepared solution can be used as a fixer in developing x-ray films, it would be an interest for us to determine the effect of this solution to the achival qualities of the developed films. The films were stored in the file storage area in the darkroom for six months (180 days). After 90 and 180 days the optical density of the films were again measured and the characteristic curves plotted for each experimental films. The characteristic curves of the films are shown figures 4. It can be observed from all the characteristic curves that the range of measured optical densities of the films for DAY 0, DAY 90, and DAY 180 did not significantly deviate by from each other. This implies that the film image qualities did not degrade significantly. This only suggests that the films treated with the experimental fixer have acceptable archival characteristics.

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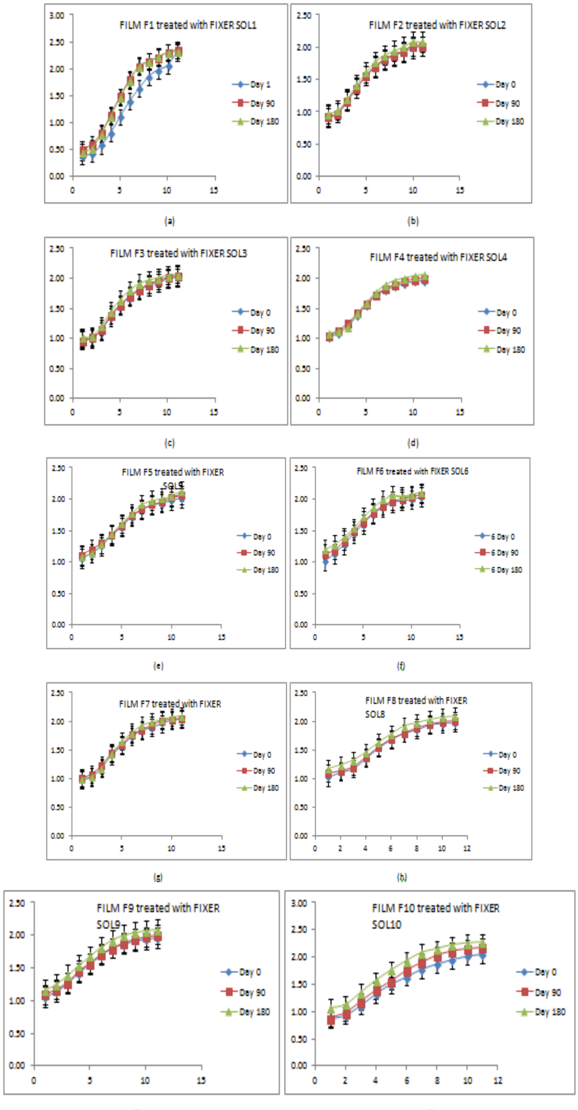

Figure 4. Characteristic curves of films F1 to F10.

The optical density of the films did not degrade for the six month period because the fixing solution successfully remove the remaining unexposed silver halide and hardened the gel emulsion (Hendricks, et al 2007). Successful removal of silver halides is important prevent film fogging. Furthermore, neutralizing the

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alkalinity of the film significantly improves the overall stability of the emulsion (Hendricks et al 2007 and Bushong, 2009) thus making them resistant to environmental factors.

The mid-OD of the films was also measured during the six month period. The result is shown in figure 6. The mid-OD of the films F2 to F10 are not significantly different from the mid-OD values of the standard film, STD. This data only strengthen our claim that the image quality of the films treated with experimental fixers are not significantly degraded and thus, have an acceptable archival quality.

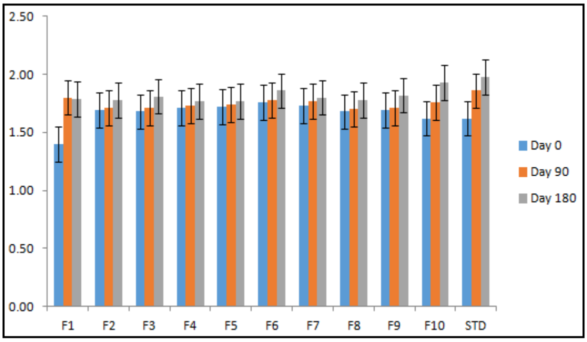

Figure 5. Mid-OD values measured for six months (DAY 0, DAY 90, DAY 180)

CONCLUSION

The research successfully shown that the fixer solution prepared in this study was able to fix the x-ray films and effectively provided a film with optical densities not significantly different from those processed using a standard fixer. The study also showed that the quality of the produced images is not internally dependent on the amount of the hydrogen peroxide once a minimum or base value is met. In this study, 1.0 mL per 1.25 L of fixer solution (1L H_20 and 2.5 mL bleach) is the minimum amount of hydrogen peroxide solution is the minimum. Furthermore, the quality of the films, in terms of their archival quality, was shown to be stable through the six month period. Finally, this experimental research concludes that a solution prepared from a mixture of hydrogen peroxide and sodium hypochlorite can be used as an effective fixing solution in screen-film radiography and that the amount of hydrogen peroxide is not a limiting factor in the solution.

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REFERENCES

Bushong S., (2009). Radiologic Science for technologies. Physics Biology and Protection, 9th ed. C&E pulishing inc. towards academic and professional excellence 893 EDSA south triangle, quezon city Philippines, p.198

Bushberg, JT, Seibert, JA, Leidholdt, EM, Boone, JM. (2012). The Essential Physics of Medical Imaging, 3rd Ed. Lippincott Williams & Wilkins, A Wolters Kluwer 2001 Market Street Philadelphia, PA 19103 USA, pp.209-217.

Fyson JR, Evans GB, 1997. Method of Processing Photographic Silver Halide, Eastman Kodak Company, Rochester N.Y.

Haye SC, Bertucci SJ, Schmittou ER, 1997. Photographic Elements with a non rehalogenating Peroxide bleaching composition, Eastman Kodak Company, Rochester N.Y.

Hendricks K, revised by Joe Iraci (2007) Processing ContemporaryBlack-and-White Photographic Films and Papers for Maximum Permanence

Healthcare Environmental Resource Center.(April 25, 2016) www.hercenter.org/dental/xraywastes.html

Sousa, H. (April 25, 2016), caffenolcolor alternative to fixer bath. Retrieved from http://caffenolcolor.blogspot.com

Szajewski RP, Buchanan JM. (1995). Method of Bleaching and Fixing a containing high iodine Emulsions Eastman Kodak Company, Rochester N.Y

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