Caffenol-C as an Alternative Developer Solution in X-ray Image Development

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Abstract: One of the most important concerns of a radiologic technologist is to strengthen health protection during the practice of his/her profession by increasing self protection when performing image development inside the darkroom as well as when disposing exhausted standard developer solutions. This experimental study used a research-made survey data checklist as data gathering instrument to assess the efficacy of caffenol-C solution when it comes to developing radiograph as well as decreasing the health risks of the radiologic technologist when processing images. Results of the study revealed that caffenol-C is an effective alternative developer solution when used with the same standard darkroom environment and technical factors. Likewise, results showed that it provides a good quality radiograph nearly the same with the one's being developed in a standard developer. It was revealed that a developer solution does not necessarily need high-strengthened solutions to obtain an image. The only main key is proper combination and preference of acidic and basic compounds. It was recommended that the caffenol-C solution must undergo filtration process to further reduce the artifacts caused by some particles that were not completely dissolved.

Keywords: caffenol-C, standard developer solution, basic compounds, acidic compound

INTRODUCTION

Developer solutions are of great significance when it comes to film-developing and such are well-known by photographers and medical personnel of the radiology department. Standard developer solution is defined by Sprawls (1995) as a chemical reducing agent responsible for the development of latent image detailed on the film's emulsion into manifest image. Most common brands of developer solutions are Fujifilm and Kodak. Both differ for manual and automatic processors. Developer solution works

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by reducing sensitized grains in the image as it adds electrons which transform positive ions of silver into silver atoms. All of the factors involving image fogs, film speed and contrast are based on the capacity of developer solution (Huda & Slone, 2009).

For so many years, photographers are very much involved in developing different kinds of developers, different brands and application. One of the most controversial improvised developer solutions is known as the caffenol-C. Caffenol-C or caffenol is made up of coffee, sodium carbonate (washing soda/soda ash), and vitamin-C (ascorbic acid) powder which works in the same way as the standard developer solution used in image development of creative photography. Caffenol is commonly used by photographers to develop their pictures in black and white. There are no exact origins of the said study; though the said substance was proven effective as an alternative developer mixture for film development (Essl, 2011).

Unlike the standard developer solution, caffenol solution is not harmful to the human body since it is largely made up of caffeinated coffee (Derrick, 2011). Ascorbic acid is the most acidic content contained in Caffenol-C solution; and its amount is very minimal that it is safe to use even during skin contact. Masking is a must when mixing solutions because the ingredient namely sodium carbonate have probable toxic effects when inhaled or swallowed (Uddin, 2013). Caffenol-C solution is practically cheaper compared to the usual developer solution made from different kinds of chemicals. It is an environment-friendly mixture and it does not have strict mandatory rules regarding its disposal. Any individual with complete knowledge about the chemistry of this solution can make it at home without complicated precautionary measures.

This study is focused in its main objective of providing an alternative standard developer solution that is less hazardous and more environment-friendly to human as well as in developing economical advancement with the use of cheaper and more accessible ingredients.

MATERIALS AND METHODS

Testing Location

This study was performed in the x-ray laboratory darkroom of Lyceum of the Philippines University-Batangas with the guidance of a registered radiologic technologist.

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Caffenol-C Preparation

Materials that were used in the said experiment are caffenol-C (which is composed of coffee, sodium carbonate and ascorbic acid), Fujifilm fixer solution, tap water, 8x10 and 10x12 Fujifilm or Kodak films and improvised chemical tanks. A 240 grams of powdered black coffee (Nescafe) was combined to 1 liter of tap water in a fiber plastic tank. After the homogenous mixing of water and coffee, 150 grams of sodium carbonate was added to the solution with continuous mixing. After the dissolution of sodium carbonate, 15 grams of ascorbic acid powder (pulverized generic tablet) was added immediately.

Commercial Developing Solution Preparation

The developer and fixer solution was transferred in proper order (developer, water, fixer) in a basin inside the darkroom. Same duration of film soaking from Caffenol-C was observed and done with proper masking and gowning.

X-ray Imaging

Using an 8x10 Kodak x-ray film, the pixy phantom's hand was exposed with the technical factor of 100mA, 55kVp and 0.08seconds using a non-digital Shimadzu x-ray machine. A 10x12 Fujifilm x-ray film was used in exposing a larger anatomical part of the body.

Image Development

In developing the radiograph using caffenol-C, the film was first immersed in the caffenol-C mixture for 5 minutes and then carefully soaked to water for 1 minute. The film was dipped again, this time, at the fixer solution for about 5 minutes to remove undeveloped silver halide crystals. After immersing the film to the fixer solution, the radiograph was washed in running water for 10 minutes. Then, the film was placed in a film hanger inside the darkroom to dry.

Commercial Developer Solution Imaging Process

For the standard image developing process, the following sequences were followed. Using the same anatomical part of the pixy phantom with consideration to the conventional way of developing a radiograph, the film was first soaked to the developer solution for 5 minutes, following a 1- minute film dipping to water to remove excess developer solution. After the development phase, the film was immersed to the fixer solution for the same

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duration and was finally washed in running water for 10 minutes. The radiograph was safely clipped in a film hanger and was left to dry.

Evaluation of Radiographs

The differences between radiographs developed using the standard developer solution and caffenol-C solution were analyzed by 5 registered radiologic technologists and 5 resident radiologists who are recently working in the hospital (public or private) to further prove if the quality possessed by the radiograph being developed in caffenol-C solution is enough to serve as an alternative solution for the usual developer used in x-ray image processing. The radiographic characteristics that were assessed are resolution (if lines and curvatures of the anatomical details are not blurred and completely seen), contrast (no white or black fogs seen in the images), artifacts (no foreign objects that could obscure the images) and density distribution (well blended and even density color of the radiograph). All of the criteria were rated from 1-5, 1 as the lowest and 5 as the highest.

Statistical Analysis

The method used in the statistical analysis is the Wilcoxon-Mann-Whitney two-independent sample non-parametric test.

RESULTS AND DISCUSSION

The researchers exposed several anatomic parts of the pixy anthropomorphic phantom. Two sets of exposed films were prepared and subsequently developed in different types of developing solution. The first set of films were developed using a standard developing solution (Fujifilm solution). The other set of exposed films were processed using the Caffenol-C solution. The darkroom conditions such as room and developer temperature, for both types of developer, were controlled.

The researchers successfully developed the exposed films using Caffenol-C as the developing solution, but it was noticed that although the images are well-developed with its complete anatomical details, the contents of the solution are not well-dissolved which caused the images to gain some artifacts during film development.

The films developed used both the Caffenol-C and standard solutions are presented in figures 1 and 2. Figure 1 refers to the

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films processed in standard developer solution while figure 2 is for films developed using the caffenol-C solution.

Figure 1. Radiograph of right hand and forearm of the pixy phantom using Fujifilm x-ray developer solution

Figure 2. Radiograph of right hand and forearm of the pixy phantom using Caffenol-C based developer solution

It is reflected from the figures that both the standard and the Caffenol – C based developers successfully produced diagnostically acceptable images. Furthermore, qualitative inspection of the images showed that both developers successfully processed the films producing the desired level of anatomic details.

To further determine whether quality of images developed from caffenol-C and standard developer are comparable, five (5) radiologists and five (5) registered radiologic technologists were asked to render evaluation of films. The images were scored, for

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each image quality criteria, from 1 to 5, with 1 being the lowest and 5 the highest.

Table 1. Image Quality Scores of Films Developed in Caffenol-C and Standard Developer

Image Quality Criteria	Type of developer	Number of Sample	Mean	Standard Deviation
Resolution	Standard Developer	10	3.40	1.26
	Caffenol-C	10	3.60	0.84
Contrast	Standard Developer	10	2.20	0.79
	Caffenol-C	10	3.20	0.42
Artifacts	Standard Developer	10	2.80	0.79
	Caffenol-C	10	3.00	1.15
Density	Standard Developer	10	2.70	1.25
	Caffenol-C	10	3.50	1.08

The results of the experts' evaluation are presented in tables 1 and 2, as shown below. Table 1 shows the mean and standard deviation of the scores, as evaluated by the ten experts. The mean score for image sharpness of standard developer developed films is 3.60 while Caffenol-C based solution is 3.40. There is a considerable amount of film fog that affects the cotrast (score = 2.20) observed on films developed using standard developer as compared to those processed using the Caffenol-C (score = 3.20). This could be attributed to the developing processes as well as the reducing agent of the Caffenol-C based developer.

Despite the presence of fog on the films, the experts agree that the anatomic detail needed in the image is acceptable. There is a very slight difference in the experts score on the presence of artifact, 3.00 and 2.80, for films developed using Caffenol-C and standard developers, respectively. It is argued that the presence of artifacts is not due to the nature of the developers but is attributable to the developing process itself. There is also an observed difference in density distribution for both films such as having better density distribution as compared to films developed using the experimental solution.

Inferential statistical test were used to determine whether the differences in the image quality mean scores between experimental and standard developer produced films is

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statistically significant. Since the data are of ordinal type, we used the non-parametric Wilcoxon-Mann-Whitney two-independent sample non-parametric test. The image quality criteria were independently grouped according to the type of the developer used.

Table 2. Test of Statistical Difference in the Image Quality Criteria of Films Developed in Standard and Caffenol-C Developers

Statistical Test	Image Quality Criteria			
	Image Sharpness	Film fog	Artefacts	Optical Density
Mann-Whitney U	44.00	16.00	45.50	30.500
Wilcoxon W	99.00	71.00	100.50	85.500
Z-number	-0.470	-2.918	-0.374	-1.527
p-value (two-tailed)	0.639	0.004	0.708	0.127

It is observable that three of the image quality criteria have a p-value greater than 0.05. These are image sharpness, artifacts, and even density distribution. Only the film fog criterion has a p-value of less than 5%. Results of this statistical analysis indicated that in terms of image sharpness, artifacts, and even density distribution, the mean score of images processed using both standard and experimental developers are not significantly different. This implied that both types of developer produced films with almost the same level of image quality.

Benzene rings (carbon atoms) are also found in coffee. According to Williams (1995), two of these clusters of electrons were responsible in initiating image formation in radiograph development. Both standard developer and Caffenol-C solution contain this organic property. This is the reason why Caffenol-C based solution scored nearly the same as the standard developer solution when it comes to resolution rate. On the other hand, we may notice that there is a wide gap of difference in the score of contrast comparison which was said earlier, could be attributed to the developing process of the radiograph which caused large amounts of film fog. Aside from the way the x-ray film is being developed, this could also be caused by acidity that is credited to the amount of vitamin C powder used, since it is responsible for balancing the strength of the solution, making it possible for the developing agent to work (Berrangé, 2013).

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When it now comes to acquired artifacts, the coffee itself is a great contributor. Since we cannot increase the temperature of the tap water, some particles of it were not properly dissolved. Another great factor that caused artifact development is the sodium carbonate. Because it is in the form of powder (O'Neil, 2006), its larger particles are hard to dissolve, causing it to stick to the film while being developed. This led the score of Caffenol-C to increase compared to the standard developer solution when it comes to artifact rating.

The last measure of image quality includes density. According to Naidu (2003), ascorbic acid is a very effective reducing agent. It helps a lot in oxidizing the environment of the solution while the film is under development (Roberts, 2012). In Table 1, we may notice that Caffenol-C score is much higher when it comes to density rating compared to the score of the film developed from standard developer solution. This is due to the Vitamin C powder content of the Caffenol-C. Although Caffenol-C gave a much darker appearance in the radiograph, it is still with considerable visibility of anatomical details.

CONCLUSION

Caffenol-C can be used to process x-ray films with comparable result to that of films processed with a standard solution in terms of resolution, contrast, artifacts and density.

RECOMMENDATION

It is recommended that the caffenol-C solution must undergo any filtration process to further reduce the artifacts caused by some particles that are not completely dissolved. Further testing of other imaging techniques is warranted.

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