The Profile of Delay Erasure Time and Imaging Plate Sizes to Dark Noise Evaluation in Carestream Computed Radiography System

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Abstract. Increasing delay time between erasure and image acquisition can lead to the appearance of dark noise on the Computed Radiography (CR) imaging plate (IP). The purpose of this study is to investigate the time delay of the last erasure that can be affected in dark noise appearance of four sizes Carestream CR’s imaging plate in Radiology Laboratory of Poltekkes Kemenkes Semarang. This study used a quantitative experimental method. Each size of IP was exposed with one of Hand, Cranium, Chest, and Abdomen anthropomorphic phantom, read on CR, and left for 0 hours, 1 hour, 3 hours, 6 hours, 9 hours, 12 hours and 24 hours to produce blank images. The blank images after post-processing were evaluated with qualitative and quantitative criteria. Qualitative criteria produced uniformity images, without ghost images artifact. While quantitative criteria were determined by the exposure index value, pixel value, and pixel value standard deviation calculated by ImageJ. The results of this study showed that all of the IPs did not pass the criteria. Dark noise appeared in 0 hours after the last erasure shown from un-uniformity images, ghost images artifact, PV, and PVSD were overpassed the standard values. Dark noise has increased the time delay between last erasure and subsequent use. The imaging plate must be erased before it acquires the next images.

1. Introduction

Most current radiography examinations have been using digital technology, one of them is Computed Radiography (CR). The use of CR is more advantageous than the screen-film system because it has faster acquisition and image processing, wide dynamic range, easy contrast and brightness adjustment, and electronic cropping [1]. Computed Radiography (CR) is an image digitization process that uses sheets or photostimulable plates for image data acquisition [2]. CR systems consist of image receptors, an image reading device, and a workstation [3]. In most of the Imaging Plate (IP) on the CR, the system is exported, processed, deleted and then stored in the processing unit to be loaded on the next cassette so that it is ready to CR systems, the IP's are exposed, processed, erased, and then stored either within the processing unit for future loading of the cassettes or inside the loaded cassettes ready for use again [2]. Report No. 93 of the American Association of Physicists in Medicine (AAPM) regarding Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems explains that all IPs in the inventory must first be erased with the full erasure cycle to ensure removal of all residual signals from background radiation and other radiation sources. Erasure test [3] or evaluation of dark noise on
IP called dark noise evaluation [4] was conducted to ensure that the CR reader system removed the previous latent image. Incomplete erasure creates an artifact known as dark noise [3].

The dark noise can be described as any response from IP without any radiation exposure for image acquisition [2]. During the time that intervenes between an IP's erasure and its next use (idle time), the IP is exposed to background radiation. This background signal collected by the plates from either background radiation or nearby sources may affect the image quality of the next image recorded on the plate [5]. Dark noise increases with increasing time delay and it is recommended that IPs be erased before they are used to acquire images if the last erasure was done more than 24 hours earlier [2].

The usage of IP in the Radiology Laboratory Poltekkes Kemenkes Semarang is rare so IP last time use with the next use can be said to be uncertain. This can cause dark noise throughout the IP. CR system being used only at a laboratory schedule. Conditions in the laboratory different than in hospitals which is the usage of CR and IP is more frequent so erasure IP more often even IP idle time can be calculated. The inconsequence of quality control in computed radiography has 5 years since the replacement of imaging plate and yearly quality control not assessed it can cause of dark noise increased in radiography images cumulatively so disturbed the original quality images that produced.

Previous research by Khalifah and Brindhaban in 2011 [2] tested the time delay from zero hours to seven days without any exposure on IP (IP that used from another manufacturer). Another similar study by Muhogora et al. in 2011 [6] and O Rampado et al. in 2006 [7] tested three other manufacturers' IP sizes and Lim Bo Yeon et al. in 2009 [8] tested by one IP size with the manufacturer as the author. The purpose of this study is to obtain erasure time and size of IP against dark noise evaluation and the delay time from the last erasure which caused dark noise on IP to prevent dark noise effect subsequent acquisitions images.

2. Methodology

The study was a quantitative experimental study conducted at the Radiology Laboratory Poltekkes Kemenkes Semarang and was carried out by using CR Carestream DirectView Classic System with calibrated IP PQ screens (general purpose) in four sizes: 18 x 24 cm, 24 x 30 cm, 35 x 35 cm and 35 x 43 cm. Four calibrated IPs were exposed with Hand PA, Cranium AP, Chest PA, and Abdomen AP phantom using Siemens Luminos RF Classic Type 30030 X-ray System. The IPs that have been exposed were read to the CR reader and delay time 0 hours, 1 hour, 3 hours, 6 hours, 9 hours, 12 hours, and 24 hours are applied. After delay time is applied, the IPs were read again so that twenty-eight blank images without exposure and four images with the phantom as objects are obtained. Twenty-eight blank images without exposure are shown in Table 1.

| Post-Processing Images Setting | Table 1. Post-Processing Images Setting |
|-------------------------------|----------------------------------------|
| AAPM No. 93                   | \[\text{Window Width} \] 512            |
|                               | \[\text{Window Level} \] Exposure Index (EI) |
|                               | \[\text{Edge Enhancement} \] No        |

Dark noise evaluation was performed according to qualitative and quantitative criteria [3]. Qualitative criteria were observed directly on the CR digitizer monitor by inspecting at the presence of ghost images and obtaining image uniformity. Quantitative criteria is shown in Table 2. PV and PVSD were calculated in the region of interest (ROI) of 80 % of the blank image area using ImageJ software with a 16-bit DICOM image type.
3. Result and Discussion

1) The Result Delay Erasure Time and Sizes of Imaging Plate to Dark Noise Evaluation

The result of this study could be seen in Table 3. The qualitative criteria assessed by ghost images that increase the delay time so the ghost images were more visible. All ghosts were visible, except on the IP 24 x 30 cm where ghost images appeared in the entire delay time. Ghost images started to appear from a 3-hour delay time on IP 35 x 35 cm. Meanwhile, on IP 18 x 24 cm and IP 35 x 43 cm, ghost images started to appear from a 9-hour delay time. The AAPM criteria are based on ghost images after some delay time has been fulfilled, some are not. Qualitative criteria showed no image uniformity. The AAPM criteria resulted in un-uniformity blank images that were appeared in the entire delay time in all IP tested.

Whereas on IP 35 x 43 cm and IP 18 x 24 cm, the remaining signals are able to be removed with one erasure cycle. Ghost images found in this study results in leftover signals that are cumulatively recorded as time increases. Cumulatively remnants signals look like areas that are blacker than other areas. This blackened area is exposed to high exposure doses. The results of this study seen ghost images are in accordance with the statement of [8] that ghost images will increasingly appear if the longer delay time from the last erasure.

The IP has a linear response to the exposure of high-dose x-ray radiation such as overexpose that can cause plate saturation of IP [9]. As a result of this plate saturation that causes an inability of CR readers to erase the remaining signals or latent images that cannot be erased just one erasure cycle. Inadequate erasing could show ghost images of previous exposure [10]. The remaining signals that were not erased resulted in ghost images in the blank images obtained from this study. Ghost images on IP 24 x 30 cm for Cranium phantom and IP 35 x 35 cm for Chest phantom must use a high exposure to produce an image coupled with the use of a grid on exposure, ghost images resulting from the remaining high-dose exposure signals.

The absence of uniformity of image in all the blank images produced was due to the dark noise formed of black spots scattered randomly on the image. Increases dark noise, the appearance of ghost images and artifacts results in the unevenness of the grayscale image. The banding artifact has a horizontal orientation at IP 18 x 24 cm and a vertical orientation for other IP sizes. These banding artifacts arise due to contact or pressure between the reader of the CR part (roller) with IP, especially in the IP coating layer, resulting in darker grayscale values according to the width of the roller and will reduce the thickness of the IP layer as time goes by.

The quantitative assessment could be seen in Figures 1, 2, and 3. The EI was found to be less than 80 so that it met the AAPM standard criteria. The EI increased during the increasing time delay and the darker noise production in all IP sizes (Figure 1). Increasing of EI shows a very strong linear relationship which was proved by linear coefficient values of more than 0.8.

![Figure 1](image1.png)  
**Figure 1.** Dark Noise Evaluation Test by EI of All IP Sizes vs. Increased Delay Time Between Last Erasure

![Figure 2](image2.png)  
**Figure 2.** Dark Noise Evaluation Test by PV of All IP Sizes vs. Increased Delay Time Between Last Erasures
**Table 3.** Results of The Dark Noise Evaluation on the Overall IP Size of the Tests of Delay Erasure Time and IP Sizes in the Radiology Laboratory Poltekkes Kemenkes Semarang

| No | IP Size (cm) | Delay Time (h) | Qualitative Criteria | Quantitative Criteria | Note (Accepted/Not Accepted) |
|----|--------------|----------------|----------------------|-----------------------|-----------------------------|
|    |              |                | **Ghost Image** | **Uniformity** | **EI** | **PV** | **PVSD** |                     |                |
|    |              |                | No (×) | Yes (✓) | <80 | <80 | <4 | AAPM Number 93 (2006) Criteria |
| 1  | 18 x 24      | 6   | ×*  | 22* | 2059.70 | 79.99 | Not Accepted |
|     |              | 9   | ✓   | 22* | 2043.59 | 93.50 | Not Accepted |
|     |              | 12  | ✓   | 22* | 2062.78 | 114.64 | Not Accepted |
|     |              | 24  | ✓   | 22* | 2049.86 | 139.81 | Not Accepted |
|     |              | 0   | ✓   | 30* | 2050.80 | 287.21 | Not Accepted |
|     |              | 1   | ✓   | 26* | 2035.83 | 134.28 | Not Accepted |
|     |              | 3   | ✓   | 31* | 2045.51 | 127.21 | Not Accepted |
| 2  | 24 x 30      | 6   | ✓   | 30* | 2051.02 | 185.29 | Not Accepted |
|     |              | 9   | ✓   | 37* | 2038.96 | 225.29 | Not Accepted |
|     |              | 12  | ✓   | 32* | 2049.25 | 192.26 | Not Accepted |
|     |              | 24  | ✓   | 39* | 2027.50 | 207.69 | Not Accepted |
|     |              | 0   | ✓   | 40* | 2040.92 | 192.26 | Not Accepted |
|     |              | 1   | ✓   | 42* | 2049.25 | 207.69 | Not Accepted |
|     |              | 3   | ✓   | 45* | 2033.82 | 242.95 | Not Accepted |
| 3  | 35 x 35      | 6   | ✓   | 45* | 2043.60 | 172.97 | Not Accepted |
|     |              | 9   | ✓   | 30* | 2051.02 | 185.29 | Not Accepted |
|     |              | 12  | ✓   | 42* | 2049.25 | 192.26 | Not Accepted |
|     |              | 24  | ✓   | 39* | 2027.50 | 207.69 | Not Accepted |
|     |              | 0   | ✓   | 40* | 2040.92 | 192.26 | Not Accepted |
|     |              | 1   | ✓   | 42* | 2049.25 | 192.26 | Not Accepted |
|     |              | 3   | ✓   | 45* | 2033.82 | 242.95 | Not Accepted |
| 4  | 35 x 43      | 6   | ✓   | 27* | 2048.25 | 113.57 | Not Accepted |
|     |              | 9   | ✓   | 29* | 2050.78 | 145.06 | Not Accepted |
|     |              | 12  | ✓   | 32* | 2043.78 | 170.56 | Not Accepted |
|     |              | 24  | ✓   | 42* | 2055.66 | 267.05 | Not Accepted |

Note:
- With (*) : Fulfilled the Criteria
- Without (*) : Passed the Criteria

The CR Carestream system uses EI as an indicator of exposure that has a relationship with the incidence of air kerma [11]. EI can be influenced either by artifacts and sizes of IP. EI shows the average pixel value on the ROI determined by the CR system of an image. The EI value of this study shows the EI increased as increasing in the time delay between the last erasure. This is due to the nature of IP which is very sensitive to radiation as well as to background radiation that passes through laboratory building gaps recorded on IP as dark noise. As the delay time increases, dark noise from background radiation is recorded cumulatively on the IP so that EI will have an increase. The consistency and decrease of EI in this study can be influenced by the condition and size of the IP also the presence of banding artifacts or dark noise itself.

The PV values were more than 2000 so they did not pass the AAPM standard criteria. The PV fluctuated within increasing delay time. This fluctuation shows a linear relationship between the
increasing of delay time and the relation of dark noise that is very weak and is showed by a linear coefficient worth less than 0.5 (Figure 2).

The PV values fluctuations at each delay time occurred in the entire IP due to the presence of banding artifacts that appear on each image of this study. These artifacts appear inconsistently like a faint look (gray) or clearly visible (black or white) that is different in each image of this study. This causes the fluctuations in the value of PV combined with the presence of dark noise that spreads randomly to the image.

The PVSD values obtained were more than 4 so they did not pass the AAPM standard criteria. The PVSD values showed a standard deviation of pixel values increases during the increasing delay time from the last erasure. The relationship is very strong, indicated by the linear coefficient’s values above 0.90 (Figure 3). The temperature at the test was 26°C-27°C while the humidity or relative humidity (RH) was 71.5% -79%.

The PVSD is indicated by the grayscale standard deviation calculated in the ImageJ software. The very high PVSD value exceeds the AAPM acceptance criteria due to post-processing settings in AAPM's dark noise evaluation as well as PV. The value of PVSD increases within increasing delay time due to increasing dispersion or variation of the average pixel value. High PVSD shows that the data points are widely spread from distance values [12]. Increased PVSD shows that the dark noise more obtained as well as increasing delay time from last erasure.

2) The Delay Time of Erasure of The IP That Can Cause Dark Noise from Four IP Sizes

The last erasure that caused dark noise on four Carestream IPs started at a delay time of 0 hours. It proved the hypothesis of this study is on the presence of dark noise (Ha) after the application of delay time from the last erasure to dark noise evaluation and the presence of dark noise from delay time of 0 hours (Ha). The hypothesis results is presented in Table 3 showing that dark noise evaluation of the blank images did not pass the AAPM criteria in all IP size. In table 3, the graphic used as a measurement to conclude whether the value passes the AAPM criteria or not. The results of dark noise evaluation that did not pass the AAPM acceptance criteria in every delay time applied to all IP sizes and even dark noise appeared at the 0-hour delay (Figure 4 row 2) after the last erasure, due to the lack of uniformity of the study results. In addition, dark noise and ghost images appear more clearly as time increases (Figure 4 in the center to right images). Another reason for the high PV and PVSD is the condition and the age of the IP that has exceeded the recommended criteria. Recommended IP to be replaced are maximally every 5 years [13], but the IP used for this 2019 testing was produced in 2011. The over 5 years of IP replacement caused the appearance of comparative artifacts on each image, the repeated use of IP at certain times without proper handling by students also can reduce the quality of IP over time.
Figure 4. Phantom Radiographs of All Size IP with The Delay From The Left to Right: The Radiographs were produced by Exposing The Phantom; The First Radiograph that has The Ghost Images Artifacts; The Radiographs with The Most Noise Artifacts.

The erratic use of IP in the laboratory for a long time caused a dark noise due to the accumulated background exposure so that it cannot be erased in one erasure cycle of the IP. In practice, this study can be a reference for computed radiography users especially for Carestream users in hospital or non-hospital purposes to make sure that the system has a consistent quality control such as dark noise evaluation.
4. Conclusion
Dark noise increased with the increasing delay time from the last erasure. The results of this study can be used as a basis for carrying out IP erasure routines before being used for image acquisition when the last erasure time is unknown. It can also be applied to erase the IP in every radiographer’ work shift (in hospital).

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