# REDUCTION OF THE ANODE-HEEL EFFECT IN COMPUTED RADIOGRAPHY IMAGES USING AN IMAGE RESTORATION TECHNIQUE

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## ABSTRACT

The purpose of this study was to reduce the anode-heel effect of an x-ray tube on computed radiography (CR) images using an image restoration technique. First, we prepared anode-heel effect images of both hands in postero-anterior (PA) view, both hands in PA/oblique view, and one foot in PA view by exposing anthropomorphic phantoms and CR imaging plates to x-rays. Second, background images were generated by x-irradiation to CR imaging plates (without anthropomorphic phantom) using the same parameters and experimental settings as used for the anode-heel effect image generation. Third, anode-heel effect functions were created by fitting natural logarithmic functions on the plotted profiles of the gray values of the background images. Finally, the anode-heel effect images were adjusted with use of the anode-heel effect functions to obtain restored images. We found that high gray values on the anode side of the CR images were eliminated in all three radiographic projections. Using such an image restoration technique to reduce the anode-heel effect on CR images may help radiologists to improve their diagnostic accuracy.

**Keywords:** CR, heel effect, plot profile, restored image

## 1. INTRODUCTION

An anode-heel effect is a common phenomenon in an x-ray tube. This effect causes variation in x-ray intensity along the cathode-anode axis of the x-ray tube [1].

The intensity is lower toward the anode side than the cathode side of the x-ray target. The quality of a radiographic image is decreased due to this anode-heel effect and may lead to diagnostic error [2]. Such images are referred to as 'degraded images'.

Image restoration techniques are used for recovering an image from a degraded version [3]. 'Degraded functions' are the characteristic functional factors that reduce image qualities, e.g., image compression, image transformation, image transfer, image blurring due to object movement, anode-heel effect, etc. The degraded images have been restored by making corrections for specific degraded functions [ 4 ] . Correcting non-uniformity of intensities due to the anode-heel effect may produce meaningful improvement in the quantitative measurements on digital images [5, 6].

The purpose of this study was to reduce the anode-heel effect in computed radiography (CR) images using an image restoration technique. Image profile plots were compared between the degraded and restored images.

In practice, both hands [postero-anterior (PA) and PA/oblique] and one foot (PA) projections are commonly requested by radiologists in the Golden Jubilee Centre, Salaya, Nakorn-pathom, Thailand. We focused on reducing the anode-heel effects on both hands (PA and PA/oblique) and one foot (PA) images.

## 2. MATERAILS AND METHODS

***Preparing anode-heel effect images from anthropomorphic phantoms:*** We prepared degraded images which demonstrated the anode-heel effect and called these 'anode-heel effect images'. Anthropo-morphic phantoms were positioned to be imaged in three different projections, i.e., both hands PA, both hands PA/oblique, and one foot PA (Fig. 1).

The phantom was exposed to x-ray imaging, then the anode-heel effect images were generated. The x-ray machine and CR system used in this study were the Quantum medical imaging QUEST HF SERIES X-ray machine and FUJIFILM FCR XG 5000 reader with FUJIFILM PCR type CC cassettes of the Golden Jubilee Centre.

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(a) (b)

***Fig 1:*** Anthrophomorphic phantoms were placed on CR imaging plates to set three radiographic positionings, (a) both hands (PA and PA/oblique) views, and (b) one foot (PA) view, to achieve the anode-heel effect images.

***Fig 2:*** CR imaging reader

***Table 1:*** Exposure parameter settings and sizes of CR image plates used in each projection.

| Positions | kVp | mAs | mA | SID (cm) |
|---|---|---|---|---|
| Both hands (PA and PA/oblique) | 50 | 2 | 100 | 100 |
| Foot (PA) | 54 | 4 | 100 | 100 |

CR imaging plate sizes and exposure parameters used for creating the anode-heel effect images are presented in Table 1. Finally, the CR imaging plates were read using the CR image reader (Fig. 2).

***Creating anode-heel effect function:*** We generated the anode-heel effect functions by exposing CR imaging plates to x-rays (without using the anthropomorphic phantoms) for the background images. Same exposure parameters and cassettes sizes, which had been used to create the anode-heel effect images (Table 1), were employed to create these background images (Fig. 3).

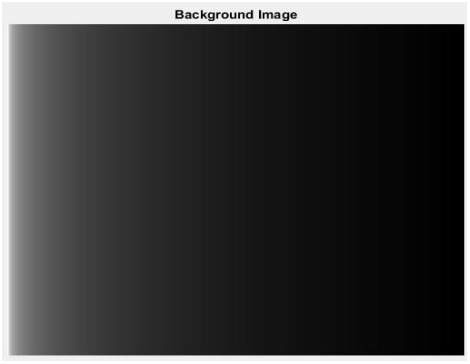


***Fig 3:*** A background image presents a non-uniform intensity of x-ray field on a CR image due to an anode-heel effect. Pixel size is 2505 x 3015.

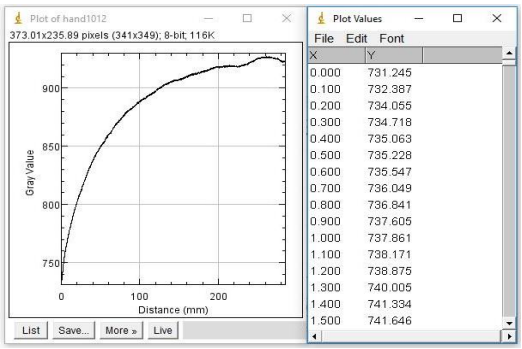


***Fig 4:*** Measurements of mean gray values using ImageJ software.

***Table 2:*** Anode-heel effect functions were generated from background images

| Projection | Fitted anode-heel effect function |
|---|---|
| Both hands (PA and oblique) | $Y = 46.227\ln(X) + 580.25$, $R^2 = 0.957$ |
| Foot (PA) | $Y = 94.349\ln(X) + 187.71$, $R^2 = 0.959$ |

Y = Mean gray value; X = Pixel number

The CR imaging plates were read using the CR image reader. The background images were exported to the ImageJ ij150-win-jre6 software (National Institutes of Health, Bethesda, MD, USA). Region of interest (ROI) was automatically created as a rectangular shape and placed to cover the whole area of a background image. Mean gray values were measured and plotted using the plot profile tool (Fig. 4).

Natural logarithmic functions were fitted to the plotted mean gray value profiles. Finally, fitted anode-heel effect functions of the both hands (PA and PA/oblique views) and one foot (PA view) images were generated (Table 2).

***Subtraction of anode-heel effects on CR images:*** The anode-heel effect images were subtracted from the fitted anode-heel effect functions (Table 2) to achieve the restored images. MATLAB R2017a (The MathWorks, Inc, MA, USA) was used for this process. Profiles of mean gray values of the restored images were plotted. The profiles of mean gray values were compared between those of the anode-heel effect images and the restored images.

## 3. RESULTS

Plotted gray values along the horizontal distances of both hands PA, both hands PA/oblique, and the one foot PA images were compared between the anode-heel effect images (before subtraction) and the restored images (after subtraction) and are presented in Figs. 5 to 7, respectively.

For both hand PA and both hand PA/oblique images, we found that mean gray values on the left hand (anode) side of the image was reduced after subtracting by the anode-heel effect reduction functions (see arrows on Figs. 5 and 6). Mean gray values of the restored images of the left hand side became symmetric with those of the right hand (cathode) side.

For the foot PA images (Fig. 7), an anode-heel effect occurred on the left hand (heel) side of the anode-heel effect image (arrow in Fig. 7a). After subtracting by the anode-heel effect function (Table 2), the mean gray values along the horizontal axis of the restored image became uniform and the anode-heel effect on the left side of the image was eliminated (arrow in Fig. 7b). The uniform intensity of the restored images provided a better basis for decisions on diagnosis.

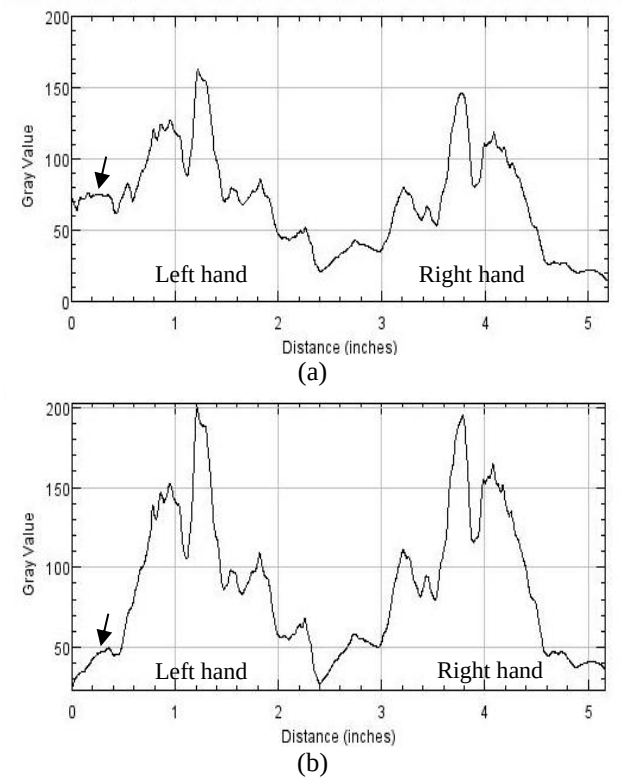


***Fig 5:*** Plotted mean gray value profiles of both hands PA images compared between before (a) and after (b) reduction of the anode-heel effect (arrows).

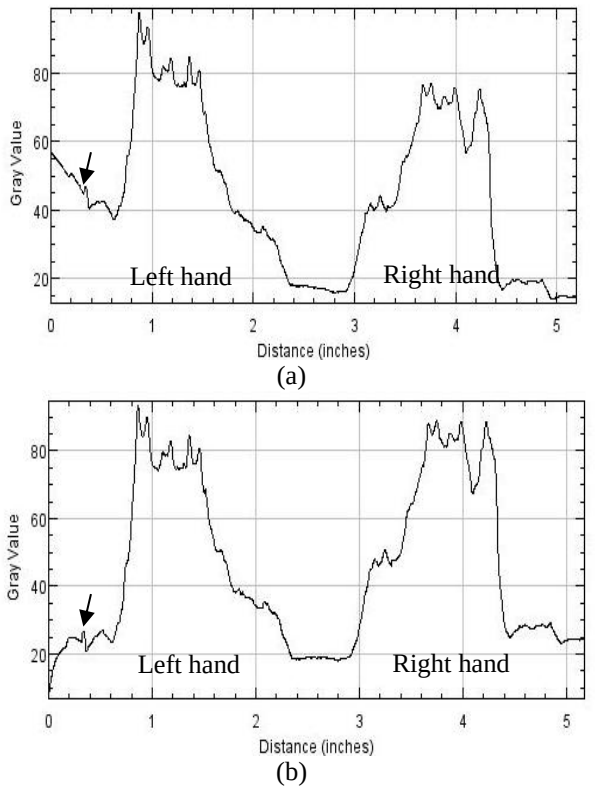


***Fig 6:*** Plotted mean gray value profiles of both hand PA/oblique images compared between before (a) and after (b) reduction of the anode-heel effect (arrows).

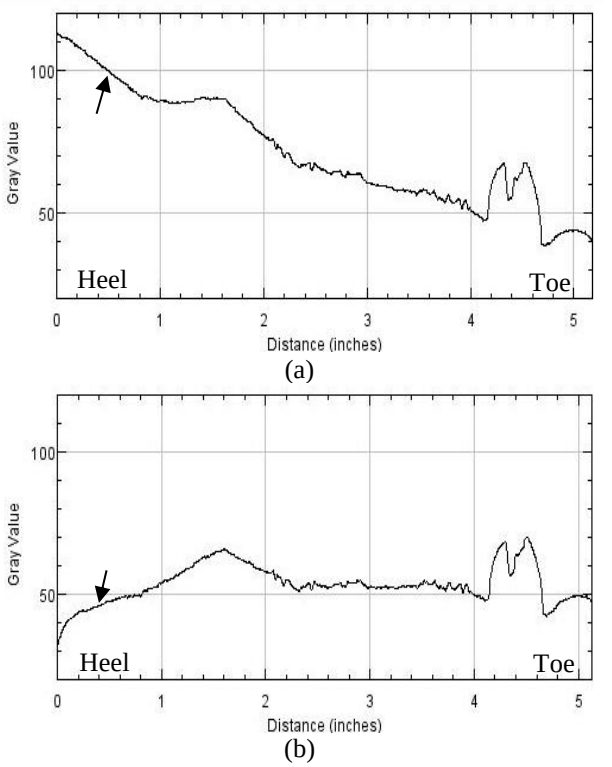


***Fig 7:*** Plotted mean gray value profiles of foot PA images compared between before (a) and after (b) reduction of the anode-heel effect (arrows).

## 4. CONCLUSION

This study used an image restoration technique to minimize the anode-heel effect on CR images. Plotted profiles of the restored images present reduction of the anode-heel effect and demonstrate better homogeneities of the mean gray values along the horizontal length of the images. These changes may help radiologists identify abnormalities on the CR images. Further research should include studies of the use of image restoration techniques, such as subtraction of the anode-heel effect, on the CR images of patients with pathology and on images from digital mammography.

## 5. ACKNOWLEDGEMENT

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