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Effect Of Heel Effect Anode On Image Homogeneity Based On X-Ray Collimation Light Beam Area

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ABSTRACT

The Anode Heel effect is the difference in X-ray intensity due to the slope of the anode target plane. The X-ray intensity at the cathode is more significant than on the anode side. Differences in X-ray intensity affect the radiographic image, especially the density value. Heel Effect Anodes in radiological examinations are used on objects with different thicknesses. This study aimed to determine the Effect of Heel Effect Anodes on Image Homogeneity Based on X-Ray Collimated Light Beam Areas. The samples used three collimation area sizes (18x24 cm, 24x30 cm, 35x43cm). Each collimation area is carried out three times exposure. The resulting radiograph is divided into several quadrants, and density measurements are taken. Then the analysis was carried out by finding the difference in the density of each quadrant on each radiograph by performing univariate analysis, and then bivariate analysis was carried out. Homogeneous images can be seen from the density difference value on one radiograph that cannot be more than 0.1. The results showed a significant effect from the anode to the cathode on the collimation area of 18x24 cm, 24x30 cm, and 35x43cm on the density value with p = 0.000. There is a difference in the anode to cathode relationship category concerning density; the collimation area of 18x24 cm has a reasonably strong relationship.In contrast, the relationship is strong in the collimation area of 24x30 cm and 35 x 43 cm. The relationship is positive. The closer to the cathode, the greater the density. The greater the collimation area, the stronger the difference in density homogeneity on the radiograph. The closer to the cathode, the greater the density produced. There is a significant difference between the area of the irradiation field and the density, and it is recommended that during an inspection, the thick object is placed on the cathode side, and the thin object is placed on the anode side to produce optimal image quality.

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1. INTRODUCTION

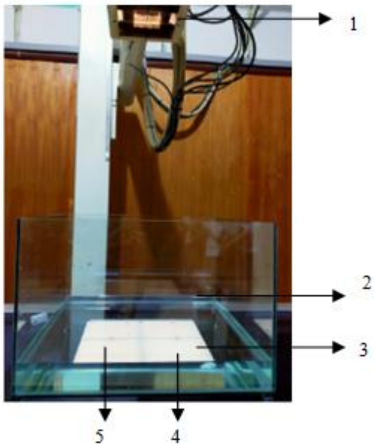
The purpose of the quality control program is to ensure that the imaging equipment used produces good image quality with the minimum dose received by the patient[1]. Image quality is a requirement to show the accuracy or representation of the patient's anatomy in the radiograph. An image that clearly shows the structure and soft tissue are said to have a good quality image. In comparison, the image is displayed to have poor quality if it contains images that are difficult to differentiate from the human eye. The poor quality of the radiographs can lead to repeated examinations and can even lead to misdiagnosis[2].

Factors used to evaluate analog image quality are density, contrast, spatial resolution, and distortion. Meanwhile, digital image quality parameters include brightness, contrast, resolution, distortion, exposure index, and noise. Density on radiographic film[3] is defined by the degree of blackening. The main factors that affect density are current (mA) and time (s) [4]. Other factors that affect density are tube voltage (kV), the thickness of the object being examined, temperature/time in the developer solution, grid ratio, screen film, and Source Image Distance (SID). The intensity of the X-rays produced strongly influences the formation of a radiographic image. The intensity that comes out can be seen from the density of the radiographic film[5] [6]. The radiation intensity coming out of the cathode is greater than the anode side, which is called the anode heel effect. The Anode Heel effect is the difference in X-ray intensity caused by the slope of the anode. The X-ray intensity in the cathode region is greater than in the anode side. The difference in X-ray intensity will affect the radiographic image, especially the density value[7]. Utilization of the Anode Heel Effect in a radiological examination[8] is used on objects that have different thicknesses of objects[9][10]. The thicker object is placed on the cathode side and the thin object on the anode side to get good image quality. A study showed that the difference in intensity from cathode to anode when using a Source Image Distance (SID) of 40 inches could vary up to 45%. This depends on the angle of the target at the anode. The anode Heel Effect will be visible using a short SID and large file size[5].

The author made initial observations on the use of SID 100cm with a collimation area of 24x30 cm, the standard deviation of the density was in the range of 40-49, while on irradiation, the collimation area of 35x45cm had a standard deviation of 35-106. The more the standard deviation difference, the more the density value is not uniform. A good X-ray intensity can be seen from the homogeneity of the density value in each area with a difference of less than 0.10 [4] . This study aimed to determine the effect of the anode hell effect on the density and homogeneity of the image based on the area of the collimated light beam.

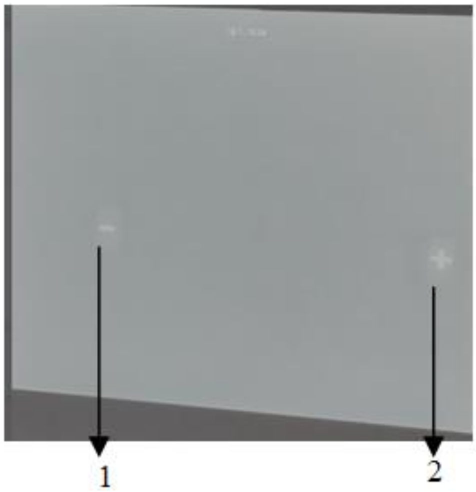
2. METHOD

This study used three samples of collimation area (18x24 cm, 24x30 cm, 35x43cm). Tests were carried out on each irradiation collimation area by placing a homogeneous object on the imaging plate as a glass vessel filled with water with a height of 10 cm. Based on preliminary observations, the water level of 10 cm is capable of producing significant scatter radiation. The distance between the focus tube and the imaging plate is 100 cm. The Imaging Plate is given a marker (+) for irradiation under the cathode side and (-) for irradiation under the anode side[11]. The irradiation field area was 18x24 cm, 24x30 cm, and 35x43 cm. Each irradiation area was taken five times for the validity of the radiographs with a fixed exposure factor of 60 kV, 100 mA, and 0.10 s. The imaging plate is processed using a computed radiography device. The resulting image is printed without changing the existing image quality parameters.



Information :
1. Collimator
2. Vessel Filled with Water
3. Imaging Plate
4. Anode Side Collimation
5. Cathode Side Collimation

Figure 1. Data Retrieval



Information:
1. Cathode Area (-)
2. Anode Area (+)

Figure 2. Radiograph At Collimation 18x24 Cm

Furthermore, each radiograph is divided into ten areas starting from the irradiating area on the anode side as area 1, area 2, and so on towards the cathode irradiation side until area 10. Each area is measured for density in each area three times, and the average density value is calculated for each area. Then a statistical test was conducted to determine the effect of the anode hell effect on the density and homogeneity of the image based on the area of the collimated light beam.

3. RESULTS AND DISCUSSION

The results of the univariate analysis of the density values on the radiograph according to the collimation field area are shown in the following Table 1.

Table 1. Results of Univariate Analysis of Density Values on Radiographs with

No	Measurement Area	Density (Mean ± Std Deviasi ; Min – Max ; Median)
1	1	2,26 ± 0,05; 2,17-2,32 ; 2,27

2	2	2,40 ± 0,01; 2,38-2,42 ; 2,40
3	3	2,43 ± 0,01 ; 2,42-2,44 ; 2,43
4	4	2,43 ± 0,01 ; 2,42-2,44 ; 2,44
5	5	2.44 ± 0.01 ; 2.42-2.45 ; 2.44
6	6	.2,43 ± 0,02 ; 2.40-2,46 ; 2,43
7	7	2,42 ± 0,02 ; 2,39-2,45 ; 2,43
8	8	2,42 ± 0,21 ; 2,39-2,45 ; 2,43
9	9	2,45 ± 0,03 ; 2,40-2,48 ; 2,46
10	10	2,45 ±0,03 ; 2,40-2,48 ; 2,46

In Table 1, the lowest density is in area 1 of 2.26 and the highest is in area 10 with a density of 2.45, the difference between the highest and lowest is 2.45-2.26 = 0.19

Table 2. Results of Univariate Analysis of Density Values on Radiographs with Collimated Light Beam Area 24 x 30 cm

No	Measurement Area	Density (Mean ± Std Deviasi ; Min – Max ; Median)
1	1	2,19 ± 0,05 ; 2,14-2,27 ; 2,19
2	2	2,38 ± 0,01 ; 2,37-2,39 ; 2,38
3	3	2,40 ± 0,02 ; 2,37-2,42 ; 2,40
4	4	2,43 ± 0,01 ; 2,42-2,44 ; 2,43
5	5	2,43 ± 0,01 ; 2,42-2,44 ; 2,43
6	6	2,42 ± 0,01 ; 2,41-2,43 ; 2,42
7	7	2,41 ± 0,01 ; 2,40-2,42 ; 2,42
8	8	2,42 ± 0,02 ; 2,39-2,44 ; 2,43
9	9	2,43 ± 0,02 ; 2,41-2,45 ; 2,44
10	10	2,48 ± 0.01 ; 2,47-2,50 ; 2,48

The lowest density is in area 1 of 2.19 and the highest is in area 10 with a density of 2.48, the difference between the highest and lowest is 2.48 – 2.19 = 0.29.

Table 3. Results of Univariate Analysis of Density Values on Radiographs with Collimated Light Beam Area 35 x 43 cm

No	Measurement Area	Density (Mean ± Std Deviasi ; Min – Max ; Median)
1	1	1.98 ± 0,04 ; 1,94-2,04 ; 1,98
2	2	2,24 ± 0,02 ; 2,23-2,27 ; 2,24
3	3	2,31 ± 0,03 ; 2,27-2,36 ; 2,31
4	4	2,34 ± 0,04 ; 2,28-2.39 ; 2,34
5	5	2,35 ± 0,05 ; 2,27-2,41 ; 2,36
6	6	2,36 ± 0,05 ; 2,29-2,43 ; 2,37
7	7	2,36 ± 0,04 ; 2,30-2,42 ; 2,37

8	8	2,37 ± 0,03 ; 2,33-2,41 ; 2,37
9	9	2,37 ± 0,02 ; 2,34-2,39 ; 2,37
10	10	2,39 ± 0,03 ; 2,33-2,42 ; 2,40

The lowest density is in area 1 of 1.98, and the highest is in area 10 with a density of 2.39, the difference between the highest and lowest is 2.39 -1.98 = 0.41.

The results of the density values in each collimation area of each radiograph show an inhomogeneous image, this can be seen from the difference in density values from the univariate test results on the collimation field area of 18x24 cm of 0.19, 24x30 cm of 0.29, and 35x43 cm of 0.41.

Furthermore, a bivariate test was carried out to determine the relationship between the effect of the density value on the irradiation collimation area. The normality test of the data shows that the p-value is less than 0.05 in the sense that the data is not normally distributed, so the analysis of the relationship test uses non-parametric statistics with Kendall's tau_b test with the following results:

Table 4. Test results of Kendall's tau_b density values at three different sizes of Collimated Light Beam Area

No	Cassette Size	Parameter	Test Result	Information
1	18 x 24 cm	Significance	0,000	There is a significant relationship between density and the anode-cathode side of the cassette
		Strong Relationship	0,46	Strong enough
		Relationship Direction	Positif	The closer to the cathode, the higher the density value
2	24 x 30 cm	Significance	0,000	There is a significant relationship between density and the anode-cathode side of the cassette
		Strong Relationship	0,60	Strong
		Relationship Direction	Positif	The closer to the cathode, the higher the density value
3	35 x 43 cm	Significance	0,000	There is a significant relationship between density and the anode-cathode side of the cassette
		Strong Relationship	0,61	Strong
		Relationship Direction	Positif	The closer to the cathode, the higher the density value

In the three sizes of the collimated light beam, here, the anode-cathode gives a significant relationship to the density, we can see the significant value of the test results is

0.000, or the value is less than 0.05. Density increases in value from the anode to the cathode. In the 18x24cm irradiation field, the correlation value of 0.46 falls in the range of 0.26-0.5, which means it is quite strong. In the irradiation field area of 24 x 30 cm and 35 x 43 cm, the correlation value is in the range of 0.51-0.75, which means that the irradiation field area and density value have a strong relationship.

The anode heel effect is the difference in the intensity of the X-rays coming out of the X-ray tube due to the slope of the target plane at the anode. The slope of the target plane causes the intensity of the X-rays that come out on the cathode side to be greater than on the anode side. The X-ray intensity is worth 100% at the central ray line or the center of the ray, and the X-ray intensity increases when the direction of the beam shifts towards the cathode and the anode. The intensity decreases. The anode Heel Effect will be visible using a short SID and large file size[5].

To achieve high image quality, a radiograph must meet several aspects that must be assessed.. The quality of film-based radiographic images was evaluated based on Density, Contrast, Spatial resolution, and Distortion. The digital image quality parameters include brightness, contrast, resolution, distortion, exposure index, and noise[5]. The density of the radiographic image can be measured using a densitometer. A good X-ray intensity can be seen from the homogeneity of the density value in each area with a difference of less than 0.10 [4].

The results of the univariate analysis showed that using an 18x24 cm irradiation field, the lowest density value was 2.26, and the highest was in area 10, with a density of 2.45. The highest and lowest difference was 2.45 - 2.26 = 0.19. On irradiation with a collimation area of 24x30 cm, the lowest density value is 2.19, and the highest is in area 10, with a density of 2.48. The difference between the highest and lowest is 2.48 – 2.19 = 0.29. while in the collimation area of 35x43 cm, the lowest density value is 1.98, and the highest is in area 10 with a density of 2.39, the difference between the highest and lowest is 2.39 -1.98 = 0.41.

From the results of these measurements, we can see a difference in density values in the total collimation field, from 0.19 in the 18x24 cm collimation field to 0.29 in the 24 x 30 and 0.41 in the 35 x 43 cm irradiation field. The more significant the collimation field, the higher the density value range so that we can see the effect of the Anode hell effect on image homogeneity based on the collimation area. A good X-ray intensity can be seen from the homogeneity of the density values in each area with a difference of less than 0.10 [4]. This can also be seen from the results of the statistical analysis.

1. There is a significant difference between the anode-cathode side and the resulting density with p-value = 0.000 on all cassette sizes.
2. There are different categories of relationship on the size of the cassette, 18 = Strong enough, 24 and 43 = Strong.
3. The relationship is positive. The closer to the cathode, the greater the density.

The results of this study can be applied by radiographers when conducting radiographic examinations. In the radiographic examination, many radiographers use large cassettes, exceeding the object because of the editing facilities on the image on the computer and ignore the position of the cathode and anode, even though this study shows a significant difference in density values between under the anode and cathode side beams, the larger the size of the cassette. The greater the influence of the heel effect. The anode heel effect can also be applied to radiographic objects that are long and have different thicknesses, where the thick side is placed under the cathode, and the thin side is placed under the anode side to produce optimal image quality.

4. CONCLUSION

The results showed a significant effect from the anode to the cathode on the collimation area of 18x24 cm, 24x30 cm, and 35x43cm on the density value with p = 0.000. There is a difference in the anode to cathode relationship category concerning density; the collimation area of 18x24 cm has a fairly strong relationship. In contrast, the collimation area of 24x30 cm and 35 x 43 cm has a strong relationship. The relationship is positive; the closer the cathode, the greater the density. There is a significant difference between the area of the irradiation field and the density. The radiographer should use an imaging plate/cassette according to the object being examined and pay attention to the position of the cathode and anode when conducting the examination. Effect of the Anode Heel Effect on the density value can be used in examining long objects with different thicknesses where thick objects are placed on the cathode side, and thin objects are placed on the anode side to produce image quality.

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