International Journal of Health Sciences
Available online at www.sciencescholar.us
Vol. 4 No. 3, December 2020, pages: 75-82
e-ISSN: 2550-696X, p-ISSN: 2550-6978
https://doi.org/10.29332/ijhs.v4n3.467

Anode Heel Effect Application with Step Wedge Against Effect of Signal to Noise Ratio in Computed Radiography

Ni Nyoman Ratini[a], I Made Yuliara[b], Windaryoto[c]

Manuscript submitted: 27 September 2020, Manuscript revised: 18 October 2020, Accepted for publication: 09 November 2020

Corresponding Author [a]

Keywords

AHE;
computed radiography;
image;
SNR;
step wedge;

Abstract

It was researched on the application of *Anoda Heel Effect* (AHE) with a *step wedge* on the effect of *Signal To Noise Ratio (SNR)* on *Computed Radiography (CR)* has been carried out. This research was conducted on a 21 step wedge with two treatments, namely the application of AHE and without the application of AHE. This measurement is repeated three times on radiographs to obtain a total image of six images (without the application of AHE as many as three images and with the application of AHE as many as three images). The results of taking radiographs using AHE and without AHE were measured using the RadiAnt Dicom Viewer program. The SNR value on the step wedge image without the AHE application has an average of 26.89. The SNR value on the step wedge image using AHE is 60.54. The results of the correlation test (Pearson correlation test) on the SNR showed that there was a significant and very strong effect of the application of AHE on the step wedge on the SNR in CR (p-value <0.001 and the R-value ranging from 0.600 to 0.799). A positive R-value indicates the same direction, meaning that with the application of AHE, the higher the SNR value, the better the image quality and the easier to distinguish noise.

Contents

[a] Department of Physics, Faculty of Mathematics and Natural Sciences, Udayana University, Denpasar, Indonesia
[b] Department of Physics, Faculty of Mathematics and Natural Sciences, Udayana University, Denpasar, Indonesia
[c] Department of Physics, Faculty of Mathematics and Natural Sciences, Udayana University, Denpasar, Indonesia

1 Introduction

Radiological examination is one of the supporting examinations in the health sector in diagnosing disease (Ratini et al., 2019). To produce a quality radiograph, it is necessary to understand the concept of radiography to the quality of the X-rays released from the tube. The quality of X-rays is the ability of X-rays that can be measured by their penetration of the object that is passed before producing a radiograph (Sudin et al., 2015). The intensity of X-rays issued from the anode has different strengths (Carlton & Adler, 2012). The difference in the X-ray intensity distribution is caused by the angle of inclination formed by the anode in the diode tube which is called the *anode heel effect* (Carlton & Adler, 2012).

The anode heel effect is caused by the angle of the target plane in the range of 7° to 20° on the anode side, this indicates that there is a difference in X-ray intensity between the anode and cathode sides. The intensity formed on the cathode side will be greater than the intensity on the anode side so that the intensity of the X-rays produced at the anode end will be smaller and the X-rays emitted from the anode part are weakened before penetrating the object material of a different thickness so that it can affect the quality of the radiograph (Kenneth, 2014). The application of heel effect anodes is not only applied in conventional radiography but can also be applied in the digitalization era. Computer-based radiographic examination techniques have been developed to produce more detailed and useful images in providing diagnostic information using computed radiography (CR) (Korner et al., 2007; McInerney & Terzopoulos, 1996; Maintz & Viergever, 1998).

Computed radiography (CR) is an image digitization process that uses a sheet or photostimulable plate for image data acquisition where the imaging technique uses digital sensors to capture images that will affect image quality (Korner et al., 2007). The application of the anode heel effect is very helpful in obtaining quality images of body parts by showing a significant variation in thickness along the horizontal axis of the X-ray plane, this can produce optimal image quality (Gede et al., 2020). To meet optimal image quality, a radiograph must meet several aspects to be assessed on a radiograph (Desai et al., 2010; Larsson et al., 2003). Based on the description above, the researcher wants to examine more deeply the application of anode heel effect to lumbosacral radiographs, so that a study is conducted on how the effect of "Application of Anode heel effect (AHE) with Stepwedge on the effect of Signal To Noise Ratio (SNR) in Computed Radiography (CR)".

2 Materials and Methods

This research was conducted at the ATRO Bali Radiodiagnostic Laboratory. Tools used in this study is an X-ray plane, Computed Radiography (CR), Imaging Plate (IP), CR scanner, 21 step wedge with an additional thickness of 1.5 mm each step, and the RadiAnt DICOM VIEWER program software (Medixant, 2016). Before carrying out the study, the X-ray plane was turned on and a warm-up procedure was performed with the collimator facing the examination table. The step wedge is positioned in the center of the computed radiography (CR) cassette with collimation of the size of the step wedge, where the thickest part is placed in the cathode direction and the thinner portion is placed in the anode direction for AHE application and vice versa (without AHE application). Central ray or direction of rays perpendicular to the middle of the step wedge. The collimator is set with an FFD of 100 cm. The exposure factor is adjusted by the X-ray tube voltage (kV) of 60 kV, the current x time of 5 seconds. Next, do the exposure and perform the image reader process on computed radiography (CR) (Gibson & Davidson, 2012; Cowen et al., 2007; Ma et al., 2013). This step is carried out 3 times in taking radiographs. After the image results are obtained as many as 6 images (without the application of AHE as many as 3 images and with the application of AHE as many as 3 images), then the data will be measured SNR value using the RadiAnt Dicom Viewer program. One of the SNR value measurements is shown in Figure 1 below:

Figure 1. SNR measurement on Stepwedge without and with AHE application

3 Results and Discussions

From this image, the I_s and σ_b values are read, for each step with a total of 21 steps using the ROI (Region of Interest) area of 0.355 cm^2-0.358 cm^2. The calculation determines the SNR value using the formula (Desai et al., 2010):

$$SNR = \frac{I_s}{\sigma_b}$$

where I_s is the signal mean value and σ_b is the standard deviation value of the noise area. Furthermore, the six images were calculated as shown in Table 1 and Table 2.

Table 1
The calculating results of SNR value without anode heel effect application

Step (mm)	Thickness (mm)	Image I			Image II			Image III		
		Mean Sign (I_S)	*SD Noise* (σ)	*SNR*	*Mean Sign* (I_S)	*SD Noise* (σ)	*SNR*	*Mean Sign* (I_S)	*SD Noise* (σ)	*SNR*
1	31,5	159,72	4,243	33,14	231,11	4,243	61,47	230,61	6,341	46,17
2	30,0	139,36	6,341	28,91	208,23	6,341	55,38	210,62	2,20	42,17
3	28,5	128,83	4,374	26,73	199,48	2,107	53,05	202,01	7,197	40,44
4	27,0	120,77	4,315	25,06	192,33	2,338	51,15	194,21	4,243	38,88
5	25,5	113,7		23,59	185,64		49,37	187,54		37,55
6	24,0	108,38		22,49	181,45		48,26	183,22		36,68
7	22,5	104,50		21,68	176,23		46,87	178,63		35,76
8	21,0	99,31		20,60	170,82		45,43	172,35		34,50
9	19,5	92,79		19,25	162,06		43,10	163,77		32,79
10	18,0	83,40		17,30	155,65		41,40	156,16		31,26
11	16,5	74,26		15,41	147,12		39,13	142,92		28,61
12	15,0	71,63		14,86	139,17		37,01	141,22		28,27
13	13,5	63,78		13,23	128,89		34,28	129,64		25,95
14	12,0	56,46		11,71	116,38		30,95	118,22		23,67

15	10,5	50,28		10,43	111,18		29,57	110,07		22,04
16	9,0	46,25		9,60	99,54		26,47	100,45		20,11
17	7,5	39,69		8,23	90,53		24,08	91,80		18,38
18	6,0	30,31		6,29	77,01		20,48	77,18		15,45
19	4,5	21,74		4,51	59,80		15,90	64,94		13,00
20	3,0	12,33		2,56	47,06		12,52	46,92		9,39
21	1,5	1,415		0,29	23,12		6,15	25,54		5,11
	Average		4,818			3,757			4,995	

Table 2
The calculating results of SNR value on applying Anode Heel Effect

Step (mm)	Thickness (mm)	Image I			Image II			Image III		
		Mean Sign (Is)	*SD Noise* (σ)	*SNR*	*Mean Sign* (Is)	*SD Noise* (σ)	*SNR*	*Mean Sign* (Is)	*SD Noise* (σ)	*SNR*
1	31,5	225,53	2,605	96,30	228,42	2,291	100,18	227,97	2,370	101,32
2	30,0	211,32	2,258	90,23	210,18	2,112	92,18	211,15	2,083	93,84
3	28,5	201,87	2,402	86,20	200,34	2,525	87,87	201,58	2,386	89,59
4	27,0	195,10	2,103	83,30	194,05	2,191	85,11	194,92	2,175	86,63
5	25,5	190,15		81,19	188,17		82,53	187,78		83,46
6	24,0	184,36		78,72	181,54		79,62	184,18		81,86
7	22,5	178,43		76,19	174,54		76,55	177,93		79,08
8	21,0	169,81		72,51	169,33		74,27	169,81		75,47
9	19,5	163,98		70,02	163,60		71,75	161,97		71,99
10	18,0	156,12		66,66	154,47		67,75	154,82		68,81
11	16,5	145,54		62,14	142,59		62,54	149,00		66,22
12	15,0	136,04		58,09	136,14		59,71	136,84		60,82
13	13,5	125,48		53,58	127,27		55,82	126,18		56,08
14	12,0	119,58		51,06	119,03		52,21	119,61		53,16
15	10,5	110,63		47,24	108,57		47,62	110,24		49,00
16	9,0	100,89		43,08	98,82		43,34	101,37		45,05
17	7,5	88,32		37,71	91,60		40,18	90,36		40,16
18	6,0	77,11		32,92	78,36		34,37	78,39		34,84
19	4,5	61,70		26,35	63,75		27,96	62,91		27,96
20	3,0	45,74		19,53	45,80		20,09	44,64		19,84
21	1,5	23,82		10,17	27,24		11,95	27,13		12,06
	Average		2,342			2,279			2,253	

From the results of the table above, it can be shown in the form of a graph of thickness variations to the average SNR value (without and with the application of AHE) shown in Figure 2.

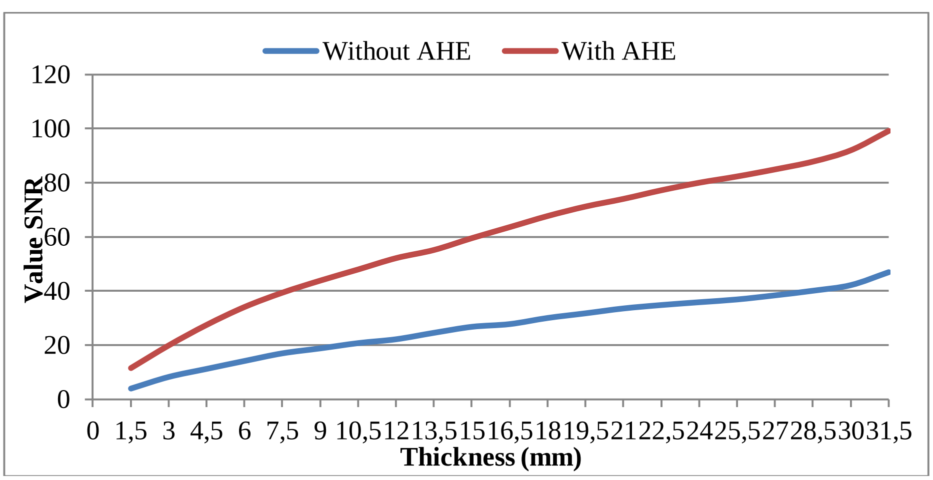

Figure 2.Thickness variations on SNR value average (without and with AHE)

The results of the SNR value average with the application of AHE showed a higher result, namely 60.54 compared to without the application of AHE, namely 26.89. AHE is applied by placing the anode on the thinner object and the cathode on the thicker object. The difference in the X-ray intensity distribution is caused by the angular tilt formed by the anode ranging from 7º to 20º in the X-ray tube (Kenneth, 2014; Gede et al., 2020). The intensity formed on the cathode side will be greater than the intensity on the anode side so that the intensity of the X-rays produced at the anode end will be smaller (Fauber, 2016). X-rays emitted from the anode experience attenuation before penetrating the object material of different thicknesses so that it can affect the quality of the radiograph or SNR so that the SNR value is generated after AHE application is better or higher than not applying AHE. Analysis of statistical tests (Dahlan, 2011) on the step wedge with the application of AHE and without the application of AHE to the SNR, the data from the SNR calculation is then performed the descriptive test shown in Table 3

Table 3
The descriptive test results of SNR value data

Image *Stepwedge*	Min	Max	Mean + SD
SNR without AHE	0,29	61,47	26,89 + 1.85
SNR with AHE	10,17	101,32	60,54 + 3,06

To determine whether the data distribution is normal or not, the normality test is carried out with SPSS. The normality test used is the Kolmogorov-Smirnov test because the processed data is greater than 50 data shown in Table 4.

Table 4
The normality test results of SNR value data using SPSS

Image step wedge	*Kolmogorov-Smirnov*	
	p-value	Gloss
SNR without AHE	0,059	*p value* > 0,05 (data normal)
SNR with AHE	0,090	*p value* > 0,05 (data normal)

Based on Table 4 above, the SNR p-value in the step wedge image without the application of AHE and with the application of AHE is greater than 0.05, it can be concluded that the SNR value data on the step wedge image without the application of AHE and with the application of AHE is normally distributed. Then, the data were analyzed statistically with a correlation test (Pearson correlation test) between the SNR values in the step wedge image without the application of AHE and with the application of AHE, the results were:

Table 5
The Pearson Correlation Test Results of SNR

P-value	R	Explanation
<0,001	0,645	there is an effect of *AHE* application on *step wedge* to SNR absorb in *computed radiography* (CR)

With a P-value <0.001 and an R-value ranging from 0.600 to 0.799, it means that there is a significant and very strong effect of the application of AHE on the step wedge of SNR absorption on computed radiography (CR). The positive sign shows the same direction, meaning that with the application of AHE, a higher SNR is generated in the image. So it can be concluded that H0 is rejected and Ha is accepted, meaning that there is an effect of the application of the anode heel effect on the step-wedge on the SNR on computed radiography (CR).

The SNR value indicates the quality of the digital image or the ability to visualize body organs (Gede et al., 2020). Increased SNR value means that the signal strength is higher, which means that the signal strength is higher than the amount of noise, so that, the image quality also increases. The higher the SNR value, the better the image quality and the easier the noise to distinguish (Fauber, 2016; Louk & Suparta, 2014).

4 Conclusion

From the research results that have been done, it can be concluded that: the SNR value on the step wedge image without the application of anode heel effect has an average of 26.89, while the SNR value on the step wedge image with the application of anode heel effect has an average of 60.54. The results of the correlation test (Pearson correlation test) SNR showed p-value <0.001 and the R-value ranged from 0.600 to 0.799, meaning that there was a significant and very strong effect of the application of the anode heel effect on the step wedge on absorption SNR in CR.

Acknowledgments
The author expresses high gratitude for funding support on this research from the DIPA PNBP Universitas Udayana for the 2020 Fiscal Year.

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Biography of Authors

	Ni Nyoman Ratini is a Physics lecturer with a concentration in the field of Medical Physics expertise. Born in Sibetan, on April 1, 1967, he worked in the Department of Physics at the Faculty of Mathematics and Natural Sciences, Udayana University, Bali since 1993. *Email: nymratini@unud.ac.id*
	I Made Yuliara lives at Jalan Kedondong No. 8 Denpasar, Bali. Phone: (+62)8123644116. He was born on July 18, 1964. He graduated with a Bachelor's degree in the Physics Program at Airlangga University in Surabaya, 1994. He finished his Master's degree in the Remote Sensing Program at the Institute of Technology at Surabaya, November 10, 2000. *Email: imdyuliara@unud.ac.id*
	Windarjoto is a Physics lecturer with a concentration in the field of Instrument Physics. Born in Surabaya on January 08, 1957, he worked in the Department of Physics at the Faculty of Mathematics and Natural Sciences, Udayana University, Bali since 1989. *Email: windaryoto@unud.ac.id*