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Determination of the Half-Value Layer by Using Filter Aluminum Sheets for Digital Mammography

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ABSTRACT

A method of determining the half-value layers (HVL) with or without using an aluminum (Al) filter sheet for digital mammography has been developed. HVL measurements using a single exposure method are performed without the addition of an aluminium filter. This study was conducted to evaluate the accuracy of measurements of HVL values in a single exposure method using a RaySave ion space detector. a standard method with a variation in aluminium filter thickness from 0.110 to 0.980 mm. The HVL measurement values were performed with the distance between the focus of the detector 60.5 cm, and the current 80 mAs at a voltage of 23 kVp, 25 kVp, 27 kVp, 29 kVp and 32 kVp. The HVL value is determined by using the interpolation formula. The results showed that the HVL value using aluminium filter was 0.03 mm higher than the standard method by using multiple exposures for the same thickness of the aluminium filter.

Keywords: HVL, Ion chamber, detector, RaySave.

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1. INTRODUCTION

Mammography is a special X-Ray examination to assess a person's breast tissue. breast examination process using low-dose X-rays that generally range from 0.7mSv. Mammography is used to detect early or screening in diagnosing breast cancer as early as possible. This tool is able to show abnormalities in the breast in the smallest form less than 5 mm (stadium zero). At this stage, a mammogram may indicate the presence of microcalcification, a lump that can not be felt by the woman himself or even the doctor [1], until a lump is 1 cm or more in size. Therefore, it is important to perform quality control tests (QC) from mammography equipment. QC tests include evaluation of image quality and meaningful dose of the gland that depends on the HVL (the beam quality), breast thickness, and tissue type. In Indonesia, exposure to medical radiation is regulated by the Nuclear Energy Regulatory Agency (BAPETEN), which comes from the Ionizing Radiation Protection Act. Quality assurance requirements (QA) for digital mammography are included in the BAPETEN Standard since October 2011.

HVL determination is an important part of the American College of Radiology (ACR) Mammography Quality Control Manual [2].

A diagnostic X-ray beam is characterized by the X-ray output and the beam quality. The X-ray output is expressed in terms of the air kerma (K) per unit tube loading (mAs) at a specified distance from the tube focus whereas the beam quality is expressed in terms of HVL. The HVL is the thickness of the aluminium absorber that is required to reduce the output to half of its initial value [3].

The determination of these two parameters is very important for quality control of the X-ray equipment and patient dose estimation. X-ray output and beam quality are dependent on the tube voltage settings and the total filtration of the tube. With increasing tube voltage settings both output and HVL increase, while with increasing total filtration the HVL increases but the output decreases. The impact of increased filtration on image quality, tube loading, and patient effective dose have been reported by Behrman et al [4].

The ionization chamber and a set of pure aluminum sheets are needed for the measurement of HVL, Aluminium with a purity > 99.9% should be used. Type 1100 aluminium (> 99% pure) may have up to 1% impurities and could introduce an error of up to 10% in HVL measurements. Since most hospitals do not have this equipment, a compact, inexpensive device is sought to help hospitals to perform this measurement [5].

2. METHODOLOGY

The digital mammographic used in this study consisted of an inverter-type high voltage generator (Type-06438506, Siemens Co., Ltd.), and X-ray tube (Mammomat 1000, Siemens Co., Ltd.) and a collimator (Type-06483692, Siemens Co., Ltd).The digital dosemeter is an ionization chamber with an electrometer (X2 R/F, Raysafe), Aluminium filters (RMI Co., Ltd.) of thickness ranging from 0.055 mm to 0.98 mm with a purity > 99.9% [5][6].

The experimental setups for HVL measurements followed the ACR standard operation protocols [5,2]. as illustrated in Figure 1. The distance between the focal spot and the image receptor was 65 cm. The compression paddle was raised as close as possible to the X-ray tube. The device was centered in the X-ray field and aligned with the chest-wall edge of the image receptor, shown in Figure 1a. The orientation of the cathode-anode axis was from the chest wall to the nipple. A mammographic ionization chamber (Ray save) was calibrated in the National Radiation Standard Laboratory. The ionization chamber was also centered in the field with the chamber center positioned at 4 cm from the chest-wall edge of the image receptor, shown in Fig.1b. The device or the chamber was full within the X-ray field of 9 x 9 cm2, which was the smallest collimation of the mammographic unit [7].

The HVL was determined for tube voltages from 23 – 35 kVp with a molybdenum target/molybdenum filter (Mo/Mo), a molybdenum target/rhodium filter (Mo/Rh), a rhodium target/rhodium filter (Rh/Rh) in a digital mammographic unit (Siemens Co., Ltd).

The ACR protocol for HVL measurements without any aluminium sheet is as follows. First, Manually select the exposure factors to be used but use an exposure time > 0.1 s. For compliance with the regulations, determine the HVL without the compression device at the maximum tube voltage used in clinical practice, and then make an exposure of the detector without any aluminium sheet and record the reading [8][9]. The ACR protocol for HVL measurements with an aluminum sheet is as follows; an aluminium sheet placed on the top of the compression paddle and makes another exposure to record a new reading. Repeated this step by increasing the aluminum thickness until the new reading is less than one-half of the original reading. The HVL can then be calculated by the following formula [9]:

$$H = \frac{t_b \ln(2D_a/D_0) - t_a \ln(2D_b/D_0)}{\ln(D_a/D_b)} \quad (1)$$

Where : HVL is half value layer (mm), D_0 is dose without any filtration, Da and D_b are dose for higher and lower than that of $D_0/2$, respectively, t_a and t_b are thickness of aluminum before and after exposure.

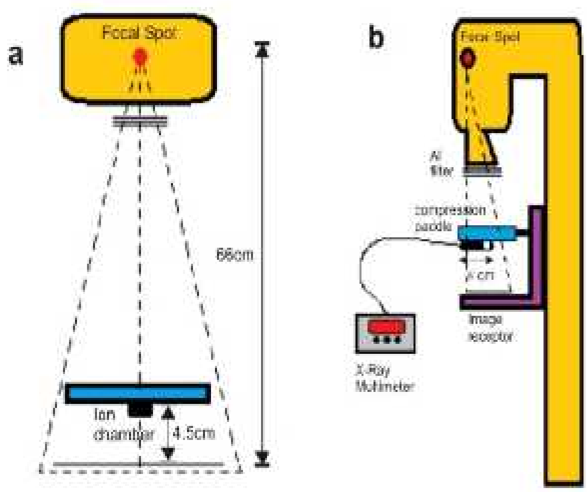

Fig 1. The experimental setup for the HVL measurement by using Aluminum as a filter in this study based on Ref. [9].

3. RESULT AND DISCUSSION

Result HVL value using single method exposure is shown by figure 2 and its numerical value is shown in table 1. Figure 2 shows that the rise in tube voltages leads to an increase in the measured HVL. This is due to an increase in the voltage of the tube affecting the wavelength produced, the higher tube voltages value that shorter the wavelength, so that higher the X-ray energy.

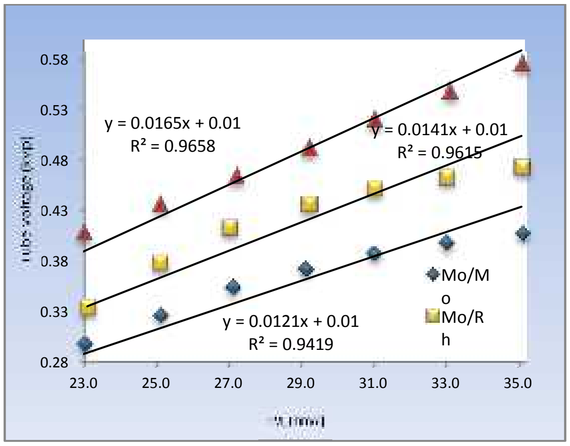

Fig. 2. HVL distribution for X-ray beams with several tube voltages using single method exposure.

Higher X-ray energy causes the penetrating power also increases, so the HVL also increased. It can be seen from figure 2 that the rise of HVL is relatively linear with the chart equation for target/filter Mo/Mo $y = 0.0121x + 0.01$; for target/filter Mo/Rh $y = 0.0141x + 0.01$; and for target/filter Rh/Rh $y = 0.0165x + 0.01$.

Table 1. HVL determined from the ACR protocol using single method exposure.

Target / filter	kVp	HVL Measure (mmAl)			
		I	II	III	Average
Mo/Mo	23	0.298	0.297	0.299	0.298
	25	0.326	0.326	0.326	0.326
	27	0.354	0.355	0.353	0.354
	29	0.373	0.371	0.372	0.372
	31	0.387	0.387	0.387	0.387
	33	0.398	0.398	0.398	0.398
	35	0.408	0.407	0.406	0.407
Mo/Rh	23	0.334	0.334	0.334	0.334
	25	0.378	0.378	0.378	0.363
	27	0.412	0.413	0.414	0.391
	29	0.436	0.436	0.436	0.419
	31	0.452	0.452	0.452	0.447
	33	0.463	0.463	0.463	0.475
	35	0.472	0.473	0.474	0.504
Rh/Rh	23	0.409	0.408	0.407	0.390
	25	0.436	0.436	0.436	0.423
	27	0.464	0.464	0.464	0.456
	29	0.491	0.492	0.493	0.489
	31	0.519	0.520	0.521	0.522
	33	0.548	0.548	0.548	0.555
	35	0.576	0.576	0.576	0.588

Result HVL value using multiple method exposures is shown in figure 3 and its numerical value is shown in table 2, the HVL is measured using aluminum sheets thickness and then HVL is calculated by interpolation formula, then plotted into the equation of the regression curve. It also shows from figure 3 that the HVL values between the two methods do not have a large percent deviation it's between 0.00% - 1.19% on all tube voltage settings from 23 kVp – 35 kVp. From the above data, the use of single method exposure other than their practical use its also shows a small deviation compared to the frequently used standard method. But it should also be noted that this method can also provide an optimal result if measurements were made using the ionization chamber detector and then the results obtained are made into regression curve equation.

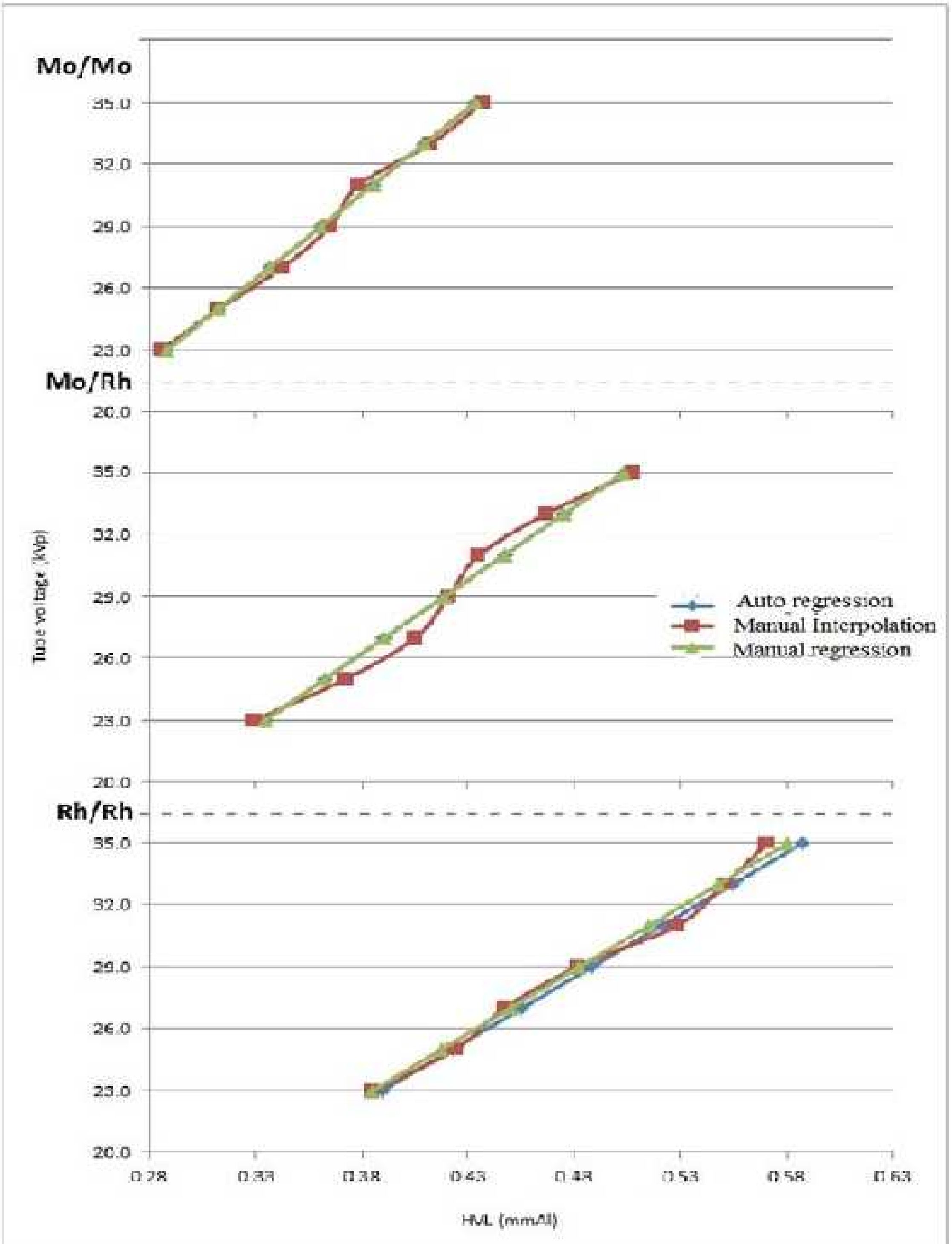

Fig. 3. HVL distribution for X-ray beams with several tube voltages using multiple method exposures and a filtration of aluminium sheets

Table 2. HVL determined from the ACR protocol using multiple method exposures

Target/filter	kVp set	Single method exposure	Multiple method exposures			
		HVL (mmAl)	Interpolation HVL (mmAl)	Δ (%)	Regression HVL (mmAl)	Δ (%)
Mo/Mo	23.0	0.288	0.286	0.83	0.288	0.00
	25.0	0.313	0.313	0.05	0.313	0.00
	27.0	0.337	0.342	1.67	0.337	0.00
	29.0	0.361	0.365	1.15	0.361	0.00
	31.0	0.385	0.378	1.73	0.385	0.00
	33.0	0.409	0.412	0.73	0.409	0.00
	35.0	0.434	0.437	0.82	0.434	0.00
Mo/Rh	23.0	0.334	0.329	1.57	0.334	0.00
	25.0	0.363	0.372	2.65	0.363	0.00
	27.0	0.391	0.405	3.72	0.391	0.00
	29.0	0.419	0.421	0.46	0.419	0.00
	31.0	0.447	0.435	2.66	0.447	0.00
	33.0	0.475	0.467	1.77	0.475	0.00
	35.0	0.504	0.508	0.94	0.504	0.00
Rh/Rh	23.0	0.390	0.385	1.17	0.385	1.18
	25.0	0.423	0.424	0.36	0.418	1.18
	27.0	0.456	0.447	1.77	0.450	1.19
	29.0	0.489	0.482	1.38	0.483	1.19
	31.0	0.522	0.528	1.32	0.515	1.19
	33.0	0.555	0.551	0.67	0.548	1.19
	35.0	0.588	0.571	2.85	0.581	1.19

4. CONCLUSIONS

A method for determining HVL of digital mammography using the ionization chamber detector RaySave and single method exposure was developed. The HVL from 0.288 to 0.588 mm can be determined within a deviation between 0.00% and 1.19 % by using the regression curve equation. The accuracy of this method is comparable to that of traditional method using multiple method exposures. This method can be applied for the purposes of the quality control digital mammography unit, where based on the above data that shows small deviation compared to the frequently used standard method.

REFERENCES

[1] Johns, H. E. (1983). The quality of X-ray (half value layer. In: The Physics of Radiology, fourth ed. Charlies C Thomas Publisher, Illinois, p. 278)

[2] ACR, (1999). Mammography Quality Control Manual. American College of Radiology, pp 225 – 315.

[3] American Association of Physicists in Medicine Report No. 74. (2002). Quality control in diagnostic radiology. Madison: Medical Physics Publishing; 1 – 19.

[4] Behrman RH. (2003). The impact of increased Al filtration on X-ray tube

loading and image quality in diagnostic radiology. Med Phys; 30: 69 – 78.
[5] Radiological Council of Western Australia, (2006). Diagnostic X-ray Equipment Compliance Testing, Workbook 2 Mammographic Equipment, pp 25 – 28.
[6] Unfors (2010). RaySafe and X2 view reference manual. USA.
[7] C.J. Tung et al. (2010). Half-value layer determination using thermoluminescent dosimeters for digital mammography. Radiation measurements 45, 729 – 732
[8] Eiji Ariga and Shigeki Ito (2012). Determination of Half value layers of X-ray equipment using computed radiography imaging plates. Physica Medica 28, 71 – 7.
[9] M. T. Lin et al. (2011). Scatter and energy dependence of thermoluminescent dosimeter to determine half-value layer in digital mammography: Monte Carlo Results. Radiation measurements 46, 2090 – 2093.