E ISSN : 2776-6764
P ISSN : 2774-2032

Compliance Test of X-Ray Beam Quality Using HVL Parameter on Digital Mammography

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Abstract

The compliance test of X-ray beam quality using HVL parameter on digital mammography was determined at a hospital in Makassar in 2019-2021. This measurement uses a ruler, X-ray multimeter, and aluminum filter. The exposure process is carried out at certain kVp and mAs conditions after placing the detector on the examination table. The HVL test to determine the X-ray beam quality is carried out by placing the detector 4 cm from the edge of the chest wall on the patient's table in an upright position facing the tube. The resulting HVL values are 0.37, 0.37, and 0.38. This study resulted in a p-value of 0.000 ($p < 0.05$). Statistically, there is a significant difference in HVL values in 2019-2021. The resulting HVL value is by the tolerance limit recommended by the IAEA, which is $0.31 \leq HVL \leq 0.58$. These values indicate that mammography works well, and it is safe for the patient.

Keywords: *HVL*, *Mammography*, *X-ray*

1. Introduction

The rapid development of technology has had a good impact on human life. The incredible impact of developing technology can be applied to the health sector and industry. Applications in the health sector include the use of technology in clinics and hospitals. While the industrial sector such as the manufacture of electronic equipment, tools for measurement, sensor systems, and others [1–4]. In addition, various kinds of tools can be made and used in the health industry. These tools are used to detect various diseases, such as CT-scan to detect Covid-19 disease, mammography to detect breast cancer, and others. Globally, breast cancer is a type of disease found in women with the second-highest mortality rate after uterine cervical cancer. The most practical examination is early screening for breast cancer using mammography. A mammography is an X-ray machine that produces images (mammograms). X-rays produce electromagnetic waves capable of detecting human anatomy [5–9].

The benefits of X-rays to obtain anatomical information in the body in medical diagnosis. The diagnosed body part receives light from the X-ray tube through the body part captured by the film to form an image. Besides these benefits, X-ray can cause harm due to excessive radiation doses. Exposure to very high doses can cause damage to body cells. So it is necessary to reduce and minimize the dose of X-ray radiation. The quality of the X-ray

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P ISSN : 2774-2032

beam is one of the parameters that must control on a mammography machine. The quality of an X-ray beam is characterized numerically in terms of the Half Value Layer (HVL), which measures the adequate energy of X-rays that penetrate an object. HVL is the thickness of the filter capable of reducing exposure to half of its initial value. The greater the HVL value, the greater the penetrating power, and vice versa [10–15].

Controlling mammography is carried out through compliance test activities by implementing a quality assurance program for diagnostic radiology. The importance of the compliance test is to control the X-ray radiation dose so that the patient does not get excessive exposure. The compliance test ensures that the equipment used functions correctly according to diagnostic radiology procedures. One of the compliance test parameters is to control the HVL value generated on the X-ray machine. The HVL value generated by the X-ray machine shows the quality of the X-ray beam on mammography. The compliance test of mammography is one of the licensing requirements for the use of ionizing radiation to the Badan Pengawas Tenaga Nuklir (BAPETEN) in Indonesia. This compliance test is expected to be within tolerance values recommended by the International Atomic Energy Agency (IAEA)[16–18].

2. Methodology

This study used a GE digital mammography machine, the Senographe Crystal type on the tube housing, and the generator/control panel SHF-0510-M with a maximum capacity of 35 kVp and 320 mAs. The compliance test using the HVL parameter was carried out at the Radiology Installation of one of the leading hospitals in Makassar in 2019-2021. This measurement's tools and materials are a ruler, X-ray multimeter, and aluminum filter. The scheme for testing the suitability of the quality of the X-ray beam is shown in Figure 1.

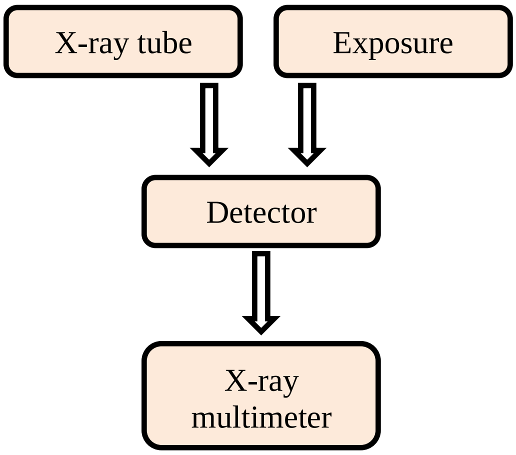

Figure 1. Schematic of compliance test on digital mammography.

The exposure process is carried out at certain kVp and mAs conditions after the detector is placed on the examination table to measure the X-ray beam quality parameters, as shown in Figure 2.

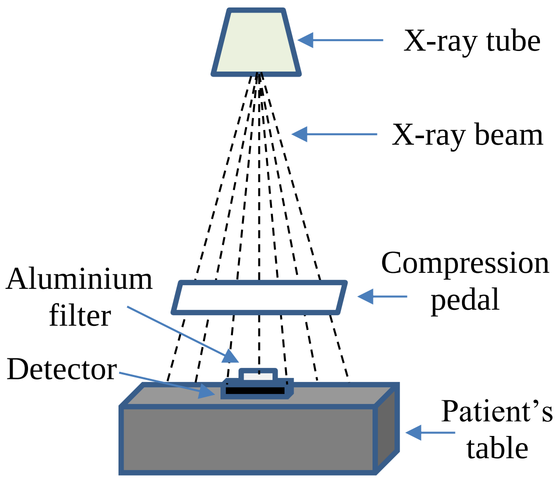

Figure 2. Measurement of X-ray beam quality.

The HVL test to determine the quality of the X-ray was carried out by placing the detector 4 cm from the edge of the chest wall on the patient's table in an upright position facing the tube (Figure 2). The exposure process was carried out at fixed mAs and kVp. The air kerma value is measured without an additional filter (*Do*). An aluminum filter was added to the exposure process, which resulted in more than half the *Do* dose being carried out without the filter. Calculation of HVL value using equation 1.

$$HVL = \frac{tb.Ln\left(2\frac{Da}{Do}\right) - ta.Ln\left(2\frac{Db}{Do}\right)}{Ln\left(\frac{Da}{Db}\right)} \quad (1)$$

Equation (1) is the thickness of the absorbent material/HVL. *Do* is the initial/unfiltered dose (mGy). Da is the dose that depends on the thickness of the material *ta* (mGy). *Db* is the dose that depends on the thickness of the material tb (mGy), *ta* is the thickness of the material when the dose is read *Da* (mm), and *tb* is the thickness of the material when the dose is read *Db* (mm).

SPSS version 23.0 bit is used to analyze the HVL parameter calculation results. This calculation aims to determine the Pearson correlation and determine the significance of the data. Determination of the significance of the data using a statistical test one-sample T-test on the SPSS application.

3. Result and Discussion

The HVL parameter compliance test results using 2019-2021 data are shown in Figure 3.

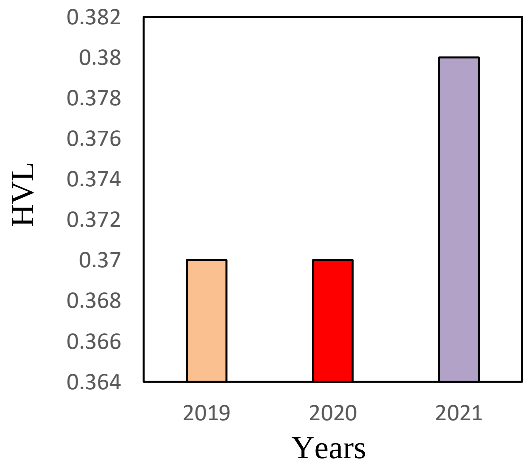

Figure 3. Graph of HVL parameter compliance test from 2019-2021.

Figure 3 shows the HVL values 2019-2021, resulting in values between 0.37, 0.37, and 0.38. These values indicate the quality of the X-ray beam expressed in terms of HVL. The penetrating power of X-rays measures the quality of the X-ray beam through which the object is passing through. The quality of X-ray is influenced by the tube voltage [17]. The HVL values 2019-2021 can be seen in Table 1.

Table 1. Values of HVL parameter compliance test for 2019-2021.

Years	HVL
2019	0.37
2020	0.37
2021	0.38

The HVL test results were processed in the SPSS application using a one-sample test to determine the significance of the test results. This test is marked from the resulting p-value. This study resulted in a p-value of 0.000 ($p < 0.05$). Statistically, there is a significant difference in HVL values in 2019-2021. Table 1 shows the HVL values of 0.37, 0.37, and 0.38. This value is close to the value reported by Pwamang, et al [15]. In addition, these HVL values are by the tolerance limit recommended by the IAEA, which is $0.31 \leq HVL \leq 0.58$ [18]. The values in Table 1 show that mammography works well, and it is safe for the patient.

4. Conclusion

This compliance test study shows the quality of X-rays, which are expressed in terms of HVL. The penetrating power of X-rays measures the quality of the X-ray beam through which the object is passing through. This compliance test resulted in a p-value of 0.000 ($p < 0.05$). Statistically, there is a significant difference in HVL values in 2019-2021. The HVL parameter compliance test results on mammography had values of 0.37, 0.37, and 0.38. These HVL values correspond to the tolerance limits recommended by the IAEA, which is $0.31 \leq HVL \leq 0.58$. This mammography works well, and it is safe for the patient.

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