Deviation Value for Conventional X-ray in Hospitals in South Sulawesi Province from 2014 to 2016

Ilham Bachtiar, Bualkar Abdullah, Dahlan Tahir
Postgraduate Student of Physic Department Hasanuddin University, Department of Physic of Hasanuddin University.
Jl. Perintis Kemerdekaan KM. 10 Makassar, Sulawesi Selatan, 90245, Indonesia
E-mail: liseilham@gmail.com

Abstract. This paper describes the conventional X-ray machine parameters tested in the region of South Sulawesi from 2014 to 2016. The objective of this research is to know deviation of every parameter of conventional X-ray machine. The testing parameters were analyzed by using quantitative methods with participatory observational approach. Data collection was performed by testing the output of conventional X-ray plane using non-invasive x-ray multimeter. The test parameters include tube voltage (kV) accuracy, radiation output linearity, reproducibility and radiation beam value (HVL) quality. The results of the analysis show four conventional X-ray test parameters have varying deviation spans, where the tube voltage (kV) accuracy has an average value of 4.12%, the average radiation output linearity is 4.47% of the average reproducibility of 0.62% and the averaged of the radiation beam (HVL) is 3.00 mm.

1. Introduction
Radiological services related to radiation protection aim to obtain a timely diagnosis and the lowest possible treatment for patients [1]. The achievement of these objectives is determined by two determinants of radiology equipment quality factors and their support systems and human resource factors. Human resource factors include installation procedures, operational procedures, maintenance procedures and improvements and procedures Quality Assurance (QA) and Quality Control (QC) [2], [3]. The procedure of carrying QA / QC therein is the implementation of the test or the so-called X-ray suitability test [4].

Quality Assurance (QA) is a quality assurance of all management programs organized to achieve excellent radiology health services by means of data collection and systematic evaluation. Quality Control (QC) is the quality control of a quality assurance program that focuses its program activities on the techniques necessary for monitoring, maintaining and maintaining technical elements of a radiographic equipment system that may affect the quality of a radiograph. One form of quality control program is an X-ray plane matching test [2]. The X-ray suitability test is a test to ensure the X-ray is in a reliable condition, both for diagnostic and interventional radiology activities and to comply with legislation [4].

Head of BAPETEN Rules No. 9 of 2011 about Compliance Testing X-ray Diagnostic and Interventional Radiology states that the purpose of X-ray plane suitability test is to realize reliable and safe operation of X-ray machine for patients, workers and the public. One X-ray plane tested for conformity is a conventional X-ray machine. Conventional X-ray is a permanently fixed X-ray machine in a room used for routine general inspection [5]. This type of this plane is most widely
owned by both government-owned and private hospitals and clinics doctors and clinical laboratories, especially in the province of South Sulawesi. The plane is declared reliable if all test parameters are within the specified tolerable range. The tolerance limit is established by both national and international nuclear inspectors. In Perka BAPETEN number 9 of 2011, the test parameters for conventional X-ray plane are tube voltage accuracy (kV), irradiation time accuracy (s), radiation output linearity, kV reproducibility, time, and radiation output and radiation beam quality value (HVL). The maximum deviation value (maximum deviation) of tube voltage accuracy (kV) and irradiation time accuracy (s) is not allowed from 10%, the linearity coefficient of the radiation output and the reproducibility variation coefficient shall not exceed 10%, while the radiation beam quality value (HVL) is more than or equal to 2.1 mm HVL [4, 6, 7].

The purpose of this study is to analyze several factors that affect the conventional X-ray plane quality assurance as well as the distribution of data of deviation test results of X-ray plane in South Sulawesi province. These factors include tube voltage (kV) accuracy, radiation output linearity, radiation output reproducibility (mGy) and radiation beam quality (HVL) value [8].

2. Research Methodology

Conventional X-ray testing was performed using a non-invasive x-ray multimeter [9]. This tool can measure tube voltage (kV), radiation output linearity, tube voltage reproducibility and radiation output along with radiation beam quality values. The measurement accuracy is the proximity level of the quantity measurement produced by the actual value. Tubular voltage accuracy measurements and time accuracy are performed for each X-ray plane. The value of deviation (Rx) tube voltage accuracy is obtained by the equation:

$$R_x = \frac{X_m - X_n}{X_n} \times 100\%$$

(1)

Where: Xm is the measured value of the tube voltage (kV) and Xn is the value of tube voltage regulation (kV) on a conventional X-ray plane [1].

The linearity test of the radiation output is performed to know the radiation output at some radiation conditions and the linearity of the current generated by the X-ray tube at a certain distance. The value of irradiance linearity of radiation output is coefficient of linearity (CL). This CL value is obtained by the equation:

$$CL = \frac{X_{max} - X_{min}}{|X_{max} - X_{min}|} \times 100\%$$

(2)

Xmax and Xmin are the calculations of the distribution of radiation dose measurements (mGy) and the milliampere second (mAs) setting values on the largest and smallest conventional X-ray plane [8].

The reproducibility distortion value is the coefficient of variety (CV) of the tube voltage (kV), and the radiation output (mGy) is obtained by the equation:

$$CV = \frac{SD}{Z_{av}} \times 100\%$$

(3)

Where SD is the standard deviation estimate of a series of voltage measurements (kVp), time (s) and dose (mGy), Zav is the mean value of the measured parameters (kVp), time (s) and dose (mGy) [8].

The value of the quality of the radiation beam (HVL) in a conventional X-ray plane can be obtained in two ways: direct and indirect measurement [10]. This measurement uses direct measurement as an estimate of HVL values in millimeters (mm).
3. Study Case
The study case in this study was to analyze the value of deviation of conventional X-ray test results conducted on 24 hospitals located in South Sulawesi Province from 2014 to 2016 with the number of conventional X-ray plane tested by 27 units of equipment.

The test parameters use four parameters: kV accuracy, radiation output linearity, reproducibility of radiation output and HVL value [10, 11], each of which will be tested for deviation value and compared to the allowable tolerance limit i.e. kV accuracy and radiation output linearity equal to 10%, reproducibility of radiation output of 5% and HVL value must be greater than or equal to 2.1 mmAl [4].

4. Results and Discussion
The study used four parameters namely tube voltage accuracy (kV), radiation output linearity, reproducibility and radiation beam quality value (HVL) to be evaluated using a quantitative method approach where the results will be described below:

![Figure 1](image_url)

**Figure 1.** Data distribution of kV accuracy deviation value.

From figure 1 it can be seen that kV accuracy deviation values from 2014 to 2016 are still within the permissible tolerable range of 10%. The red line indicates the allowable tolerance threshold. The results of the highest deviation occurred in 2015 is 11% with the highest deviation value is at 16.06% while the lowest occurred in 2016 with the value deviation 7% with the highest deviation value is at the value of 15.76%. For the year 2014 the value of deviation is at 4% with deviation value of reading result of highest tool is at value 11.4%. Thaha's research results kilo-voltage accuracy percentage was ranged from 1.5 to 3.5 % and time accuracy percentage was ranged from 0.5 to 4.1 % respectively. This study concluded that as the kilo-voltage increases by one, the dose increases by 28%[1].

From figure 1 it can be seen that overall from 2014 to 2016 the conventional x-ray device under test is still within the permitted tolerance limit of 10% from Indonesia National Standard (SNI), where in 2014 the distribution of 96% of the tools is eligible for tolerance, by 2015 93% and 2016 as many as 89% of the categorized tools are eligible.
Table 1. Deviation Values of kV accuracy from 2014 to 2016.

| Year | Accuracy Mean (%) | SD | SNI (%) |
|------|-------------------|----|---------|
| 2014 | 4.20              | 2.86 | 10      |
| 2015 | 4.35              | 4.36 | 10      |
| 2016 | 3.81              | 3.97 | 10      |

For analysis purposes, the participation factor used to determine the bus and generator weakly damped and most affected by instability. From the analysis found that the generator 2, 6, 7, 12 and 13 represents the weakest bus with eigenvalue levels approaching critical value. There are 111 state and 31 pairs resulting complex to be initialized and observed.

From table 1 kV accuracy it can be seen that the highest kV accuracy deviation value is in 2015 of 4.35% and the lowest deviation value of kV accuracy is in 2016 with 3.81%.

Figure 2. Data distribution of irradiance value of radiation output irregularities.

From the figure above it can be seen that the irregularity value of the radiation output from 2014 to 2016 is largely within the allowable tolerance limit of 10%. The red line indicates the allowable tolerance threshold. The results of the highest deviation occurred in 2015 is 11% with the highest deviation value is at 28.99% while the lowest occurred in 2016 with a value of deviation of 4% with the highest deviation value is at the value of 18.95%. For the year 2014 value deviation is at 7% with deviation value of the highest reading result of the instrument is at value 17.58%.

From the figures it can be seen that overall from 2014 to 2016 the conventional x-ray device under test is still within the permitted tolerance limit of 10% from Indonesia National Standard (SNI), where in 2014 the percentage of 93% of equipment is eligible for tolerance, by 2015 by 89% and in 2016 96% of the tools categorized as eligible are permitted.

Table 2. The value of linearity irregularities from 2014 to 2016

| Year | Radiation Output Linearity Mean (%) | SD | SNI (%) |
|------|------------------------------------|----|---------|
| 2014 | 4.04                               | 4.61 | 10      |
| 2015 | 5.18                               | 6.83 | 10      |
| 2016 | 4.19                               | 4.34 | 10      |
From table 2, Linearity of Radiation Output can be seen that the average deviation value of Radiation Output Linearity is highest in 2015 of 5.18% and the lowest average deviation value Linearity Radiation output is in 2016 with value of 4.47%.

From figure 3 shows the reproducibility value of the radiation output tested from 2014 to 2016 is within the tolerable range of 5% from Indonesia National Standard (SNI).

| Year | Reproducibility (mGy) | Mean (%) | SD  | SNI (%) |
|------|------------------------|----------|-----|---------|
| 2014 | 0.64                   | 0.56     | 5   |
| 2015 | 0.76                   | 1.10     | 5   |
| 2016 | 0.45                   | 0.68     | 5   |

Table 3 shows the highest reproducibility rate of radiation output in 2015 of 0.76%, while the lowest was in 2016 and 2014 at 0.45% and 0.64%, respectively.

From figure 4, the data distribution of deviation value of HVL radiation beam quality value.
Figure 4 shows the results of radiation beam quality (HVL) quality measurement from 2014 to 2016. From the chart it can be seen that HVL values that are below the allowable tolerance limit of 2.1 mm from Indonesia National Standard (SNI) are in 2016 and 2014. The deviation rate in 2016 is 7% and 2014 by 4%.

From figure 4 we can also see that HVL values are largely within the allowable tolerance range of above or equal to 2.1 mm from 2014 to 2016. In 2014 96%, 2015 by 100% and by 2016 by 93% of HVL values entering at the allowed tolerance limit.

| Table 4. Deviation value of HVL from 2014 to 2016. |
|-----------------------------------------------|
| **Year** | **Radiation Beam Quality (HVL)** | **Mean (%)** | **SD** | **SNI (%)** |
|---------|---------------------------------|--------------|--------|------------|
| 2014    | 3.11                           | 0.49         |        | 5          |
| 2015    | 2.98                           | 0.38         |        | 5          |
| 2016    | 2.91                           | 0.40         |        | 5          |

Table 4 shows the quality of the radiation beam (HVL) from 2014 to 2016 which in 2014 showed the highest average HVL value of 3.11 HVL at 2.91%.

5. Conclusions

From the results of data analysis deviation values of four test parameters ie kV accuracy, radiation output linearity, reproducibility of radiation output and HVL values largely meet the allowable tolerance limits. By 2015 the largest deviation value for kV accuracy, linearity and reproducibility is given, for the HVL value which is out of the maximum allowable tolerance limit in 2014. While for the average deviation, the value for kV accuracy is 4.12%, linearity of 4.47%, reproducibility of 0.62% and HVL of 3.00 mm. For further research, it can use more complete data and the latest method by using computation process or Artificial Intelligence such as Firefly Algorithm (FA) and others.

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