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Quality Control of X-rays with Collimator and the Beam Alignment Test Tool

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collimator similarity;
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gap efficiency;
quality control;
X-rays;

Abstract

This test aims to determine and analyze the accuracy of the collimator beam with an X-ray beam, to perform two test methods, namely the suitability of the alignment test tool with an X-ray beam and the suitability of the x-ray beam area using the beam alignment test tool. Collimator tests such as the Illuminance Test, Shutter Efficiency and Collimator Similarity or the suitability of the collimator field area to the X-ray beam field area within a tolerance of ≤ 2% Focus Film Distance (FFD) which has been determined by the Minister of Health Decree No. 1250/SK/XII/2009. This was carried out using FFD at a distance of 100 cm and a variation of the exposure factor which was distinguished by the voltage ranging from 50, 60, 70, 80, and 90 kV. The collimator gap efficiency test still functions efficiently/effectively, which is shown in the film there is no radiation leakage/blackening effect on the film. The results of the suitability test beam deviations that occur on the x-axis and the y-axis are still below 2 cm and the circle (C1) the average value is 0.18 cm or 1.8 mm is the value below 2 mm and the circle (C2) is the average value.

Contents

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1 Introduction

The health development that has been implemented to date has grown rapidly, but there are still many things that need to be addressed, especially in the face of current decentralization and globalization. One of the main priority efforts is to improve the quality of health services. By increasing the quality of health services continuously will increase the efficiency of health services, which in turn will have an impact on improving the quality of life of individuals and the degree of public health (Adler et al., 1992; Martina et al., 2015). The health service quality assurance policy will serve as a guideline for all parties in the implementation of quality health services. Health services that are meant are health services in general and health support services in particular especially radiology services. Although radiology services have been provided by health services at various levels of service, both government and private, the ability and quality of services are still very varied and have not fully met the demands of service user satisfaction. Then a quality control test is carried out to meet the demands of these service users, who are customers consisting of patients, families, communities, and other interested parties and the community.

Compliance Testing is a test to ensure that X-ray meets radiation safety requirements and provide accurate and accurate diagnostic information or radiology implementation (Chadidjah, 2012). The conformity test is the basis of a diagnostic radiology quality assurance program which includes a portion of the quality assurance program tests, in particular the parameters concerning radiation safety (Jha & Sharma, 1991; Kelsey et al., 1991; van Rijn et al., 2000). The main objective of the Quality Assurance Program at the Radiology Installation is a precise and accurate patient diagnosis. This goal will be related to a comprehensive quality assurance program tailored to the needs of the facility which includes 3 (three) things, namely: reducing radiation exposure, improving diagnostic images, and reducing cost strategies (Sedyaningsih, 2009; Shepard & Pei-Jan, 2002).

Referring to ISO 2000, quality is defined as the guarantor of achieving objectives or the expected output and quality must always follow the latest developments in professional knowledge. For that quality must be measured by the degree of achievement of objectives and must meet various standards or specifications. To ensure the quality of health services, the various components of input, process, and output must be defined clearly and in detail, including management and technical aspects based on the achievement of the vision and the realization of the mission that has been set together. One of the quality assurance activities is quality control activities.

2 Materials and Methods

The research was conducted at the Radiology Unit of the Kasih Ibu Hospital Kedonganan Badung-Bali. Meanwhile, data analysis was carried out at the Biophysics and Medical Physics Laboratory at Bukit Jimbaran Campus (Strauss & Rae, 2012; Susilo et al., 2012). The tools used in this study were X-ray, Collimator tool and beam alignment test tool, CR (Computer Radiography), Lux meter, Humidity meter, thermometer, and 24 x 24 cm X-ray cassette with imaging plate.

Research procedure

(1) Test the Collimator Lamp Illuminance

The test step starts from adjusting the distance between the X-ray focus and the patient's bed at a distance of 100 cm as shown in Figure 4 below,

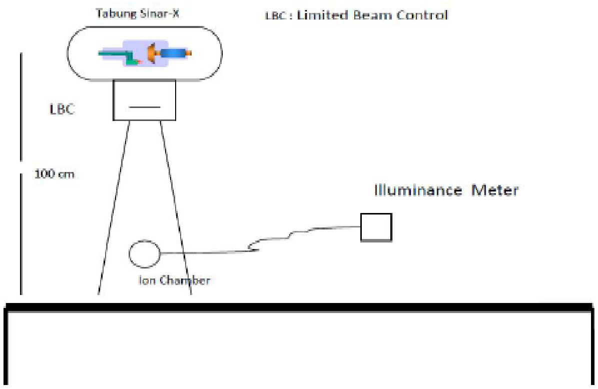

Figure 1. Schematic of illuminance testing.

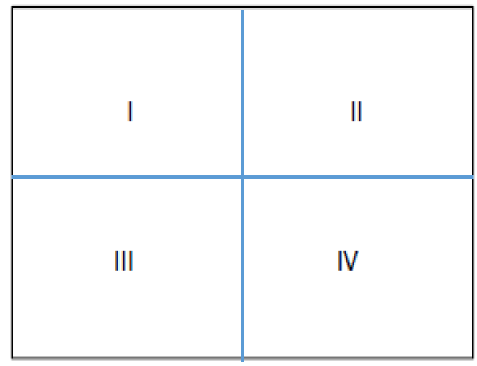

Figure 2. Area of measurement field collimator lamp

Measurements were made on an irradiation field area of 25 x 25 cm consisting of areas I, II, III, and IV as shown in Figure 2. Lux meters are placed in each quadrant and all room lighting is reduced to a dark, then readings of the lighting level are carried out on the Lux meter. The frequency of testing is carried out once a month or if the collimator lighting is indicated to be reduced. The average reading value of the four measuring areas should exceed 100 Lux at a distance of 1 meter.

(2) Collimator Shutter Efficiency Test

The shutter that is fully closed on the collimator must be able to prevent radiation from hitting the film. The purpose of this test is for radiation safety when discharging capacitors on the mobile unit or when heating the aircraft by exposure. The steps taken are as follows:

a) Before the test is carried out, the X-ray warms up has been carried out.
b) Place the cassette on the examination table at a distance of 1 m from the focus of the X-ray tube
c) Set the exposure at 80 kVp and 40 mAs, and do the first exposure by setting one side of the shutter (x) collimator tightly closed and setting the shutter (y) of the other collimator fully open.
d) Perform the same procedure as in the above item but adjust the collimator shutter side which was closed, on the contrary, is fully opened, and so on, then the film that has received 2 exposures is processed.

The schematic of the Collimator Shutter efficiency test can be shown in Figure 3.

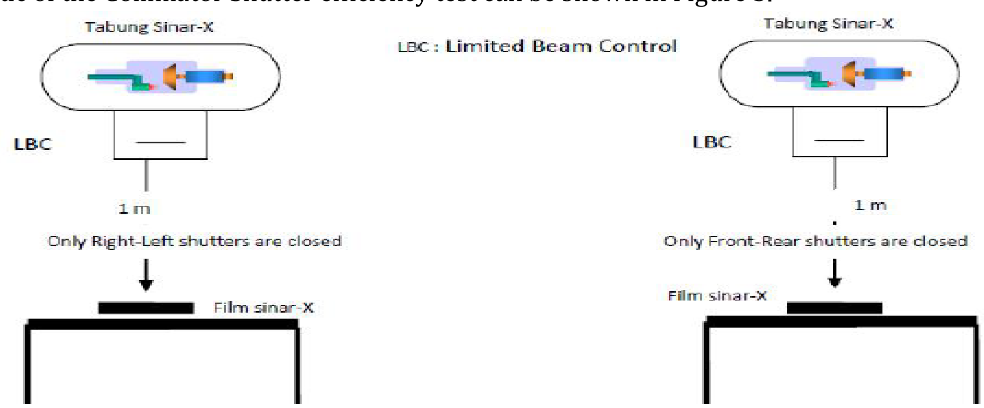

Figure 3. Schematic of the collimator gap efficiency test

Furthermore, a careful examination is carried out on the film that has been processed using the CR program, if the shutter functions efficiently/effectively, then the film will have no effect of radiation leakage or blackening on film.

(3) Test the Similarity/Straightness of the Collimator Light Beams
Determining the accuracy of the similarity between an X-ray beam and a light beam and evaluating the accuracy of the X-ray beam with the center of the light beam, using a worksheet and a test tool plate can be shown in Figure 4.

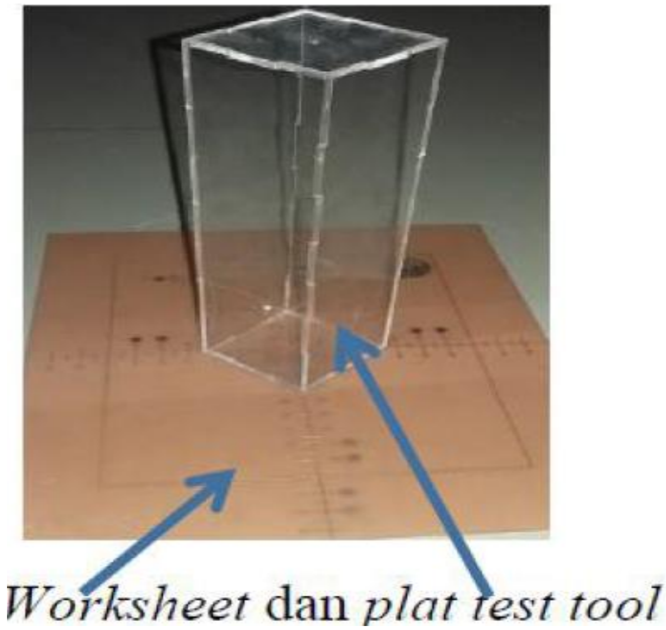

Figure 4. Photo worksheet and test tool plate

The steps taken in this measurement are to place the cassette measuring 24 x 24 cm on a flat surface. Concentrate the X-ray tube centered on the cassette and adjust the distance between focus and film (FFD) as high as 100 cm. Place the test tool collimator in the middle of the cassette. The collimator light is adjusted exactly within the rectangular area of the test tool plate. Place the beam alignment test tool in the center of the lighting area. Turn on the collimator light, adjust the area of the light field according to the rectangular line on the plate surface. Perform radiographic exposures to obtain an optical density on the film that can be observed by the evaluator (Wu & Sun, 2013; Brodsky & McCracken, 1999). Process the film with a CR program and check the suitability of the beam/X-ray beam and X-ray beam alignment.

For the collimator, note the changes in the X and Y collimator beam field scale and the radiation field scale X 'and Y' in the worksheet. Comparison of measurement results with the National Council on Radiation Protection (NCRP; ≤ 2% of FFD) standards. For the beam, pay attention to the shift in the image of the two steel balls in the film, and compare it with the NCRP standard ($\leq 3^{o}$).

3 Results and Discussions

3.1 Test the collimator lamp illuminance

The results of the X-ray plane collimator lamp illuminance test following the test procedure as in Figure 1 and Figure 2. are shown in Table 1.

Table 1
The results of the collimator lamp illuminance test

Repeat measurement	Luminance (Lux)			
	I	II	III	IV
1	99	105	100	102

2	110	105	105	106
3	105	99	100	99
4	99	100	110	105
5	100	110	105	110
Average	102,6 ± 4,83	103,8 ± 4,44	104,0 ± 4,18	104,4 ± 4,16

From the measurement results of the collimator lamp illuminance test above, the four regions have an average value of 102.6 to 104.4 so that the X-ray aircraft collimator lamp illuminance test is still within the permitted limits. Where the provisions issued by the Minister of Health of the Republic of Indonesia No. 1250 / Menkes / SK / XII / 2009 regarding quality control guidelines, that the average reading value of the four measuring areas must exceed 100 Lux at a distance of 1 meter. The frequency of testing is carried out once a month or if the collimator lighting is indicated to be reduced.

3.2 Test the collimator shutter efficiency

The shutter that is fully closed on the collimator must be able to prevent radiation from hitting the film. This test is carried out for radiation safety when discharging the capacitor charge on the mobile unit or when heating the aircraft with exposure. The results of the collimator gap efficiency test can be shown from the results of radiographic films that have been exposed at 80 kVp and 40 mAs, on the x-axis and y-axis directions as follows:

Figure 5. Radiographic Film Collimator Gap Efficiency Test Results

Notes: 1, 2, and 3 are radiographic films of the x-axis slit efficiency test
4, 5, and 6 are radiographic films of the y-axis slit efficiency test

Examination of the processed film is as shown in Figure 5., if the shutter functions efficiently / effectively, then the film will have no effect of radiation leakage or blackening on the film. As a comparison to the test results in this study, it is shown that one of the radiography films with an inefficient/effective shutter condition is shown in Figure 6. as follows:

Close the x-axis shutter Close the y-axis shutter

Figure 6. Radiographic film at shutter conditions that are less efficient/effective

3.3 Test the accuracy/straightness of the light beam

To determine the accuracy of the similarity between the X-ray beam and the light beam and evaluate the accuracy of the X-ray beam to the center of the light beam, a beam alignment test can be performed. The results of the beam similarity/straightness test from the X-ray plane can be shown in Figure 7. The radiographic film image and measurement data are shown in Table 2.

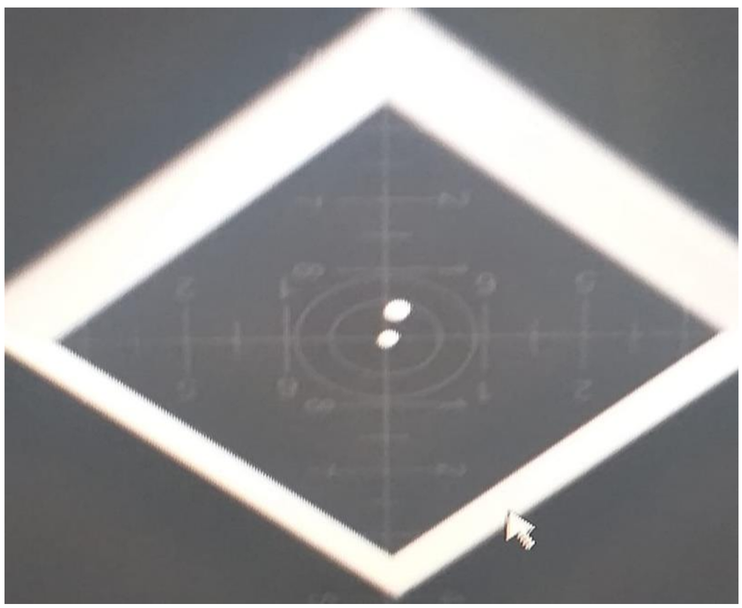

Figure 7. Radiographic film image

Table 2
Measurement results of the beam similarity/straightness test

Repeat measurement	Measurement of the beam similarity/straightness test (cm)					
	X1	X2	Y1	Y2	C1	C2
1	8,7	8,91	7,2	7,12	0,17	0,48
2	8,76	8,89	7,18	7,09	0,2	0,49
3	8,72	8,9	7,12	7,1	0,18	0,47
4	8,71	8,9	7,19	7,11	0,16	0,45
5	8,74	8,88	7,14	7,09	0,19	0,48
Average	8,73±0,02	8,89±0,01	7,16±0,03	7,10±0,01	0,18±0,02	0,47±0,02

The measurement results are as in Table 2. then the deviation of the x-axis and y-axis directions can be determined as follows:

$$X_1 + X_2 = 8.73 + 8.89 = 17.62 \text{ cm}$$
$$Y_1 + Y_2 = 7.16 + 7.10 = 14.26 \text{ cm}$$

Where X is 18.00 cm and Y is 14.00 cm, so that the deviation can be determined (ΔX) = 18.00 - 17.62 = 0.374 cm and ΔY = 14.26 - 14.00 = 0.26 cm, while the maximum allowable deviation is 2 cm. Thus, the deviation that occurs on the x-axis and y-axis is still below 2 cm. In the circle (C1) the average value of 0.18 cm or 1.8 mm is a value below 2 mm and in the circle (C2) the average value is 0.47 cm or 4.7 mm is the value still under 5 mm. So that fully testing the suitability of the collimator lamp beam is still in compliance with the provisions.

According to Sari & Hartati (2017), the accuracy of the center point of the X-ray beam is an important factor for determining partial resolution in radiographic images. Partial resolution is the ability of a device to display two small objects that are close to each other. Deviations in the accuracy of the center point of the X-ray beam can cause magnification and distortion in the radiographic image so that a diagnosis cannot be made (Moradi et al., 2020; Molinier et al., 2013). This beam similarity/straightness test parameter is performed to determine the feasibility of X-ray operation. The feasibility of an X-ray plane can be known and ascertained within accepted limits or it is appropriate that the X-ray beam plane is congruent with the collimator beam plane (Khadijah, 2012).

4 Conclusion

From the three test results conducted, it showed that the Rongen plane at the Kasih Ibu Hospital Kedonganna was still functioning well where the aircraft illumination was still above 100 Lux on average, the efficiency of the collimator gap was still very good, it was shown that there were no good X and Y axis lines on the radiographic film. and the similarity/alignment of the radiation beam is still following the NCRP standard.

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References

Adler, A., Carlton, R., & Wold, B. (1992). A comparison of student radiographic reject rates. *Radiologic Technology*, *64*(1), 26-32.

Brodsky, J. L., & McCracken, A. A. (1999, October). ER protein quality control and proteasome-mediated protein degradation. In *Seminars in cell & developmental biology* (Vol. 10, No. 5, pp. 507-513). Academic Press. https://doi.org/10.1006/scdb.1999.0321

Jha, A. N., & Sharma, T. (1991). Enhanced frequency of chromosome aberrations in workers occupationally exposed to diagnostic X-rays. *Mutation Research/Genetic Toxicology*, *260*(4), 343-348. https://doi.org/10.1016/0165-1218(91)90020-M

Kelsey, K. T., Memisoglu, A., Frenkel, D., & Liber, H. L. (1991). Human lymphocytes exposed to low doses of X-rays are less susceptible to radiation-induced mutagenesis. *Mutation Research Letters*, *263*(4), 197-201. https://doi.org/10.1016/0165-7992(91)90001-K

Khadijah. (2012). *Determination of the Accuracy of the Center Point of the Beam on the Mobile X-Ray Aircraft as a Control Quality Parameter at Prof. Dr. Hm. Anwar Makkatutu Bantaeng,* Physics, Hasunudin Makassar University.

Martina D., Susilo, Sunarno. (2015). Collimator Test on Mednif / SF-100BY X-ray Aircraft in the Medical Physics Laboratory Using the RMI Unit, *Semarang State University MIPA Journal*, *38*(2), 121-126

Molinier, J., Martinez, P., Bodez, V., Khamphan, C., Jaegle, E., Badey, A., ... & Ferrand, R. (2013). Dosimetric impact of multileaf collimator position errors during prostatic treatment by dynamic arctherapy. *Physica Medica*, *29*, e22. https://doi.org/10.1016/j.ejmp.2013.08.070

Moradi, F., Khandaker, M. U., Sani, S. A., Uguru, E. H., Sulieman, A., & Bradley, D. A. (2020). Feasibility study of a minibeam collimator design for a 60Co gamma irradiator. *Radiation Physics and Chemistry*, 109026. https://doi.org/10.1016/j.radphyschem.2020.109026

Sari, A.W., & Hartina, S. (2017). Correspondence Test of Collimator Beam with X-Ray Beams on Raico Aircraft at Raden Mattaher Radiology Installation, Jambi, *Proceedings of Meetings and Scientific Presentations of Basic Research in Nuclear Science and Technology Accelerator Science And Technology Center*, 29-34.

Sedyaningsih, E.R. (2009), Decree of the Minister of Health of the Republic of Indonesia Number 1250 / Menkes / SK / XII / 2009 concerning Guidelines for Quality Control of Radiodiagnostic Equipment, Ministry of Health of the Republic of Indonesia.

Shepard, S.J., Pei-Jan, P.L. (2002). Quality Control In Diagnostic Radiologymembers. *AAPM Report No. 74*, Published For The American Association Of Physicists In Medicine By Medical Physics Publishing.

Strauss, L. J., & Rae, W. I. (2012). Image quality dependence on image processing software in computed radiography. *SA Journal of Radiology*, *16*(2).

Susilo, Sunarno, Setiowati, Lestari. (2012). Application of Digital Radiography Tools in Photorontgen Service Development, *Journal of Mathematics and Natural Sciences*, State University of Semarang, *35*(2), 145-150.

van Rijn, J., Heimans, J. J., van den Berg, J., van der Valk, P., & Slotman, B. J. (2000). Survival of human glioma cells treated with various combination of temozolomide and X-rays. *International Journal of Radiation Oncology* Biology* Physics*, *47*(3), 779-784. https://doi.org/10.1016/S0360-3016(99)00539-8

Wu, D., & Sun, D. W. (2013). Colour measurements by computer vision for food quality control–A review. *Trends in Food Science & Technology*, *29*(1), 5-20. https://doi.org/10.1016/j.tifs.2012.08.004

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