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EVALUATION OF COLLIMATOR LAMP ILLUMINANCE ON AN X-RAY UNIT

I Made Lana Prasetya*, I Gusti Ayu Putu Puriya Maharani
Akademi Teknik Radiodiagnostik dan Radioterapi Bali, Jl. Tukad Batanghari VII No. 21, Panjer / Renon, Denpasar Selatan, Denpasar, Bali 80225, Indonesia
*lanaprasetya182@gmail.com

ABSTRACT

Collimator lamp illuminance is an important parameter in the quality control of X-ray equipment because it provides a light field for determining the irradiation field before exposure. Adequate illuminance supports accurate collimation and helps ensure that the irradiation field is appropriate for the examination. According to the applicable quality control standard, collimator lamp illuminance should be at least 100 lux at a distance of 100 cm. The goals of study is evaluation of Collimator lamp illuminance on an X-Ray unit. This study used a quantitative method with a descriptive observational approach. Illuminance measurements were performed using a lux meter at a focus-film distance (FFD) of 100 cm with a field size of 25 cm × 25 cm. The light field was divided into four quadrants, namely Quadrants I, II, III, and IV. Each quadrant was measured three times. Background illuminance was also measured three times with the room lighting on and the collimator lamp off. The mean background illuminance was then used to correct the measurement results of each quadrant. The corrected illuminance values were analyzed descriptively and compared with the minimum quality control standard. The corrected mean illuminance values were 148.27 lux in Quadrant I, 175.27 lux in Quadrant II, 166.27 lux in Quadrant III, and 174.94 lux in Quadrant IV, with an overall mean of 166.19 lux. All measurement points exceeded the minimum standard of 100 lux at a distance of 100 cm. Therefore, the collimator lamp illuminance on the tested X-ray unit met the applicable quality control requirements and was considered adequate to support accurate visualization of the irradiation field and radiological diagnostic services.

Keywords: collimator; illuminance test; quality control

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INTRODUCTION

Every hospital is required to meet established service standards to ensure quality and patient safety while providing optimal healthcare services. To achieve these standards, a structured and continuous quality control system is essential. One form of quality control implemented in healthcare facilities is the *Quality Control* (QC) program. Quality Control plays an important role in improving the quality of radiodiagnostic services and serves as a reference for the operation and evaluation of radiodiagnostic equipment (Andriani & Tsania, 2024). The *Quality Control* (QC) program aims to maintain and evaluate medical equipment to ensure that its performance complies with established standards (Satria et al., 2025).

The collimator is one of the components of an X-ray unit that requires testing as part of the *Quality Control* (QC) program (Putry Vita Dela, 2022). The collimator lamp produces a light field that serves as a visual reference for determining the boundaries of the radiation field before exposure. A clearly visible light field is essential to assist radiographers in performing accurate collimation, thereby ensuring that the irradiated area corresponds appropriately to the anatomical region being examined. Therefore, the collimator lighting system must be maintained in optimal condition to support the delivery of diagnostic radiology services (Putra & Sudarsana, 2025).

Testing of the collimator is part of the X-ray equipment conformity testing program, which aims to ensure that the collimation system continues to function in accordance with established standards, thereby supporting the quality of radiodiagnostic services and optimizing radiation safety (Badan

Pengawas Tenaga Nuklir, 2018; Rubiyanto & Janjane, 2026). The collimator lamp is used to visualize the boundaries of the radiation field, allowing the collimation process to be performed accurately. The clarity of the light field is an important factor in determining the size of the radiation field before exposure (Fajar et al., 2023; Won & Jung, 2024).

Based on the guidelines for quality control and clinical radiology services, one of the tests performed on X-ray equipment is the collimator lamp illuminance test (Kementerian Kesehatan, 2020). This test aims to assess the level of illumination produced by the collimator lamp in indicating the boundaries of the radiation field. The collimator lamp is considered to meet the established standard when it produces a minimum illuminance of 100 lux at a distance of 100 cm. The test is performed using a radiation field size of 25 cm × 25 cm (Fajar et al., 2023; Putra & Sudarsana, 2025). Therefore, illuminance testing should be conducted periodically to ensure that the performance of the collimator lamp remains compliant with applicable quality control standards (Gauntt et al., 2024; Rubiyanto & Janjane, 2026).

RSUP Prof. dr. I.G.N.G. Ngoerah is a national referral hospital that provides a wide range of healthcare services, including diagnostic radiology services that utilize X-ray equipment to support diagnosis. The high frequency of X-ray equipment use necessitates the implementation of periodic *Quality Control* (QC) programs to ensure that all equipment components function in accordance with applicable standards. One of the components that requires evaluation is the collimator lamp, as it plays an important role in visualizing the radiation field before exposure. Therefore, this study aims to conducted at the Radiology Department of RSUP Prof. dr. I.G.N.G. Ngoerah to evaluate the illuminance of collimator lamps on X-ray equipment and assess their compliance with applicable quality control standards.

METHOD

This study employed a case study with quantitative research design and an observational approach to assess the implementation of illuminance testing on radiographic collimators at the Radiology Department of RSUP Prof. dr. I.G.N.G. Ngoerah. The study was conducted through direct observation, with a lux meter used as the measuring instrument to evaluate the illuminance level of the collimator lamp. The population and sample were 1 case related to the stationary radiography X-ray unit of the Philips brand, model SR033100. The instruments used in this case study were a Lux meter to measure illuminance and an observational sheet to record the results of the instrument illumination test. Data analysis used quantitative descriptive analysis to calculate the average, correct for backlight, and compare the results with the applicable standard, which is a minimum of 100 lux.

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RESULT

The author conducted a test of the collimator on a general radiographic X-ray unit at the Radiology Department of RSUP Prof. dr. I.G.N.G. Ngoerah. The results obtained are as follows:

Specifications of the Stationary Radiographic X-ray Unit

Brand: PHILIPS
Model: SR033100
Maximum kV: 150 kVp
Serial No.: 264557

Testing Procedure

a. Equipment Preparation
   1) Prepare the lux meter as shown in Figure 1 below.



Figure 1. Lux Meter

2) Set the focus-to-film distance (FFD) to 100 cm, as shown in Figure 2.



Figure 2. FFD Setting at a Distance of 100 cm

3) Ensure that the detector is aligned with the anode-cathode axis.
4) Measure the background illuminance using a lux meter at the center of the collimation field, with the room lights switched on and the collimator light switched off.
5) Turn on the collimator light and set the field size to approximately 25 × 25 cm.
6) Divide the field into four quadrants: I, II, III, and IV, as shown in Figure 3 below.

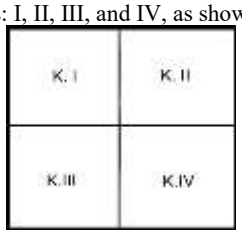

Figure 3. Division of the Field into Four Quadrants

7) Turn off the room lights and turn on the collimator light.
8) Measure each quadrant three times, as shown in Figure 4 below.



Figure 4. Measurement of Each Quadrant

b. Measurement Process
   1) Record the measurement results directly from the lux meter.
   2) Calculate the average background illuminance from the three repeated measurements. Then, subtract the average background illuminance from each illuminance measurement obtained for each quadrant. Calculate the average illuminance for each quadrant based on the three repeated measurements, and then calculate the overall average illuminance across the four quadrants.

The results of the X-ray beam collimation test using the collimator light field are presented in Table 1 below:

Table 1.
Results of the Collimator Lamp Illuminance Test

Alat ukur					SID (cm)	100	
Lapangan		25 cm ×25 cm					
	Titik ukur	Pengukuran (lux)	Rerata (lux)	Cahaya latar (lux)	FK	Hasil Uji	Nilai lolos uji
	K.I X1 = 316 X2 = 309 X3 = 320	315,00	332,92	166,73	1.00	166,19	≥100 lux
	K.II X1 = 342 X2 = 342 X3 = 342	342,00					
	K.III X1 = 332 X2 = 335 X3 = 332	333,00					
	K.IV X1 = 346 X2 = 334 X3 = 345	341,67					
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Notes:
Q.I = Quadrant I
Q.II = Quadrant II
Q.III = Quadrant III
Q.IV = Quadrant IV
BL = Background Light
X1 = First measurement
X2 = Second measurement
X3 = Third measurement
Mean = Average measurement value for each quadrant
Background Light = Average room illumination measured when the collimator lamp is switched off
CF = Correction factor
Test Result = Illuminance value after background-light correction
The mean background illuminance was calculated using the following equation:

$$\overline{E_L} = \frac{X_{L1} + X_{L2} + X_{L3}}{n}$$

$$\overline{E_L} = \frac{164{,}9 + 170{,}8 + 164{,}5}{3}$$

$$\overline{E_L} = 166{,}73 \text{ lux}$$

The mean background illuminance of 166.73 lux was used as the correction factor for all collimator lamp illuminance measurements. The corrected illuminance was calculated using the following equation: $E_k - \bar{X} \quad \overline{E_L}$

Notes:
E_k = Corrected illuminance value (lux)
[Equation symbol] = Collimator lamp illuminance measurement result (lux)
$\bar{E}L$ = Mean background illuminance (lux)
Based on the calculations, the mean illuminance values were 148.27 lux for Quadrant I, 175.27 lux for Quadrant II, 166.27 lux for Quadrant III, and 174.94 lux for Quadrant IV.
The overall mean illuminance was calculated using the following equation:

$$\overline{E_{total}} = \frac{\overline{E_{KI}} + \overline{E_{KII}} + \overline{E_{KIII}} + \overline{E_{KIV}}}{4}$$

$$\overline{E_{total}} - \frac{148{,}27 + 175{,}27 + 166{,}27 + 174{,}94}{4}$$

$$\overline{E_{total}} - \frac{664{,}75}{4}$$

$$\overline{E_{total}} - 166{,}19 \text{ lux}$$

The calculation results showed that the overall mean illuminance of the collimator lamp was 166.19 lux.

DISCUSSION

Empirical Measurement & Compliance Analysis

Quality control testing of the stationary radiographic X-ray unit at the Radiology Department of RSUP Prof. dr. I.G.N.G. Ngoerah demonstrated a mean net illuminance of 166.19 lux at a Source-to-Image Distance (SID) of 100 cm with a radiation field size of 25 cm × 25 cm, after correcting for ambient background lighting. Individual quadrant illuminance values ranged from 148.27 lux (Quadrant I) to 175.27 lux (Quadrant II), with Quadrant III and Quadrant IV recording 169.27 lux and 171.94 lux, respectively. Under national regulatory standards (Kementerian Kesehatan, 2020), the acceptable performance baseline for collimator lamp illuminance is a minimum of 100 lux at 100 cm SID. Furthermore, the Nuclear Energy Regulatory Agency enforces identical compliance criteria to ensure operational radiation safety and image quality (Badan Pengawas Tenaga Nuklir, 2018). Because all measured quadrant values (148.27–175.27 lux) and the overall average (166.19 lux) exceed the 100 lux statutory threshold by 48.27 to 75.27 lux, the collimator lighting assembly at RSUP Prof. dr. I.G.N.G. Ngoerah fully complies with established quality control regulations (Badan Pengawas Tenaga Nuklir, 2018; Kementerian Kesehatan, 2020).

Comparative Regulatory Framework: National vs. International Benchmarks

While the tested unit comfortably meets Indonesian statutory standards (≥100 lux), evaluating the results against international benchmarks reveals deeper clinical insights. The American Association of Physicists in Medicine (AAPM) Task Group 150 Report (Gauntt et al., 2024) and the United States Food and Drug Administration (Food and Drug Administration, 2019) under 21 CFR 1020.31(d)(2)(ii) establish a higher minimum illuminance threshold of 160 lux at 100 cm SID. This elevated requirement compensates for bright ambient lighting in modern digital radiography suites, where low-intensity light fields can become washed out, leading to improper patient positioning. The mean illuminance of 166.19 lux recorded at RSUP Prof. dr. I.G.N.G. Ngoerah successfully surpasses both the national baseline of 100 lux (Kementerian Kesehatan, 2009) and the stringent international AAPM/FDA benchmark of 160 lux (Food and Drug Administration, 2019; Gauntt et al., 2024). This demonstrates that the collimator system delivers superior visual field definition capable of maintaining high visibility under clinical ambient lighting conditions.

Spatial Light Anisotropy and Uniformity Evaluation

An analysis of intra-field light distribution reveals a variance of 27.00 lux between the maximum illumination in Quadrant II (175.27 lux) and the minimum in Quadrant I (148.27 lux). Light distribution anisotropy within collimator fields is caused by physical factors, including: 1) Lamp Filament Geometry and Orientation: Incandescent halogen or LED filaments emit non-isotropic light patterns relative to the internal reflector assembly. 2) Mirror Surface Quality and Angle: Minor physical tilting, aging, or micro-debris on the internal silvered mirror alters light reflection paths toward the secondary shutters. 3)Collimator Window Translucency: Dust accumulation or acrylic yellowing on the exit window creates localized light attenuation across specific quadrants. To evaluate spatial consistency, light field uniformity can be quantified as the ratio of minimum illuminance to mean illuminance ($U = [E_{\text{min}} / E_{\text{mean}}] \times 100\%$). For this unit, the calculated uniformity ratio is 89.22% ($148.27 / 166.19 \times 100\%$). This exceeds baseline uniformity performance reported in similar diagnostic evaluations (83%–92%), confirming that the 27.00 lux inter-quadrant variance is physically minor and does not compromise visual field boundary delineation (Fajar et al., 2023; Rubiyanto & Janjane, 2026).

Synthesis with Contemporary Empirical Literature

These findings align with recent empirical studies on X-ray collimator illumination and compliance: 1) Distance Dependence (Inverse-Square Law): Putra and Sudarsana (2025) evaluated an MIS brand X-ray unit, observing that collimator illuminance measured 271.6 lux at 100 cm SID, but dropped sharply to 109.5 lux at 150 cm and 0.55 lux at 180 cm. This exponential decay ($E \propto 1/d^2$) underscores why maintaining a strict 100 cm SID protocol during quality control measurements is essential for standardized performance evaluation (Putra & Sudarsana, 2025). 2) Inter-System Variability: Rubiyanto and Janjane (2026) evaluated mobile X-ray units at Hospital XYZ, recording a net illuminance of 284 lux for a Shimadzu unit and 135.5 lux for a Siemens unit, noting intra-field light dominance in specific quadrants due to bulb alignment while confirming overall compliance (Rubiyanto & Janjane, 2026). 3) Methodological Precision: Fajar et al. (2023) validated automated 4-point lux sensing systems, demonstrating that correcting for background illumination ($E_{\text{net}} = E_{\text{measured}} - E_{\text{background}}$) yields accurate, reproducible illuminance profiles (Fajar et al., 2023). 3) Field Congruence Integrity: Won and Jung (2024) emphasized that maintaining collimator lamp illuminance above regulatory limits directly impacts the accuracy of X-ray/light field congruence testing, preventing visual alignment errors during patient setup (Won & Jung, 2024).

Clinical Safety and Radiation Protection (ALARA Principle)

Sufficient collimator lamp illuminance plays a vital role in radiation protection and diagnostic efficiency: Anatomy-Specific Beam Restricting: A clear light field allows radiographers to restrict the primary X-ray beam precisely to the anatomical region of interest (ROI), preventing unnecessary radiation exposure to adjacent non-target tissue (Food and Drug Administration, 2019; Gauntt et al., 2024). Protection of Radiosensitive Organs: Accurate collimation reduces scatter radiation and limits primary beam exposure to sensitive structures such as the thyroid, gonads, and active bone marrow. Prevention of Repeat Exposures: High visual clarity eliminates positioning trial-and-error, reducing image retakes caused by anatomical cutoff or off-center alignment. This directly upholds the ALARA (As Low As Reasonably Achievable) principle in radiodiagnostic practice (Badan Pengawas Tenaga Nuklir, 2018; Won & Jung, 2024).

Recommendations for Ongoing Quality Control (QC)

To preserve this performance standard, the radiology department should implement a routine Quality Control (QC) program: 1) Periodic Testing Schedule: Perform monthly technologist illuminance checks and annual comprehensive acceptance testing by a Qualified Medical Physicist (Gauntt et al., 2024). 2) Preventive Optics Maintenance: Regularly inspect and clean the collimator translucent exit window and internal mirror to prevent dust accumulation that degrades lux output.

3) Threshold-Based Lamp Replacement: Proactively replace collimator bulbs when mean illuminance approaches 120 lux, well before reaching the statutory failure threshold (Kementerian Kesehatan, 2009).

CONCLUSION

Based on the results of the collimator lamp illuminance test conducted on the stationary radiographic X-ray unit at the Radiology Department of RSUP Prof. dr. I.G.N.G. Ngoerah, the mean illuminance was 166.19 lux after correction for background light. This value exceeded the minimum requirement of 100 lux at a distance of 100 cm, as stipulated in the Decree of the Minister of Health of the Republic of Indonesia Number 1250/MENKES/SK/XII/2009. All measurement points across the four quadrants showed illuminance values ranging from 148.27 to 175.27 lux. These findings indicate that the collimator lamp illuminance parameter met the applicable radiodiagnostic quality control requirements. Therefore, the collimator lighting system of the tested X-ray unit was in good working condition and suitable for supporting diagnostic radiology services.

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