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Measurement of Radiation Exposure Rates Around the Radiology Examination Room in the Emergency Department of Gunung Jati Regional General Hospital

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Abstract
The Emergency Department (ED) is a high-risk place for radiation exposure because patients are seen quickly, there are a lot of patients, and the environment is very complicated. This study assessed the radiation exposure levels in the vicinity of the ED radiology examination room at RSD Gunung Jati, Cirebon, thereby addressing a significant deficiency in annual safety monitoring and apprehensions regarding structural integrity. Using a descriptive quantitative method, measurements were taken at six key locations, which were divided into Area C (occupational) and Area E (public), with a calibrated Fluke survey meter (CF: 1.01 µSv/h). To simulate clinical scatter conditions, standardized exposure factors of 75 kVp and 20 mAs were used. The results showed that all measurement points adhered to national BAPETEN rules and internal dose limits very closely. The highest yearly dose of radiation for workers was 0.205 mSv/year (less than 1% of the 20 mSv/year limit), and the highest dose for the public was 0.083 mSv/year (about 9% of the 1 mSv/year limit). Although there were initial concerns about door seals that weren't hermetic, the results show that the current spatial separation and structural shielding do a good job of preventing dangerous radiation from leaking. This study finds that the facility successfully follows the ALARA principle in its current operation. However, it is recommended that annual radiological audits become a regular part of the process and that lead-lined doors be structurally repaired to ensure long-term safety margins as clinical needs evolve. These results give regional emergency radiology units an important safety baseline.

Keywords: As low as reasonably achievable, emergency department, emergency radiology, radiation protection, scatter radiation.

1. Introduction

The Emergency Department (ED) is a high-throughput unit (Sartini et al., 2022) characterized by the intensive use of ionizing radiation (Razak, Hignett, & Barnes, 2018) and complex environmental dynamics (Rowe & Knox, 2023), making it one of the most critical areas for radiation exposure risk within a hospital. Unlike routine radiology departments, diagnostic imaging in the ED is often performed under acute

medical urgency, involving a high volume of medical staff and patient relatives in close proximity (Fahad et al., 2024). This condition necessitates more stringent radiation protection integrity to ensure that unnecessary exposure does not occur to individuals outside the patient circle. The presence of X-ray modalities in such a dynamic environment requires a guarantee that radiation shielding designs and operational procedures remain effective in minimizing doses according to the As Low As Reasonably Achievable (ALARA) principle (Ahmed, Onyambu, Omamo, & Odhiambo, 2022; Frane & Bitterman, 2023; Hasaneen et al., 2023).

Although international guidelines from the ICRP and national regulations via BAPETEN have established rigorous protection standards, compliance regarding routine monitoring is often overlooked in regional healthcare facilities. Theoretically, radiation protection aims to prevent deterministic effects and minimize the probability of stochastic effects (1). However, contemporary literature suggests that radiation leakage is frequently caused not by source failure, but by structural degradation of the examination room (Joseph et al., 2020), such as gaps in protective doors or material fatigue in the shielding (Dean & Stedeford, 1984; Rochmayanti, Daryati, Darmini, & Kartikasari, 2019; Sahfira, Milvita, & Hiswara, 2024). Research in the ED setting is crucial because the risk of secondary exposure to non-radiology staff and the general public in waiting areas is often poorly mapped compared to main radiology departments.

To date, a significant research gap persists regarding annual area dose monitoring at the Gunung Jati Regional General Hospital, Cirebon. Preliminary observations indicate that the ED radiology facility at this hospital has not conducted periodic radiation exposure monitoring within the last year, representing a breach of occupational safety protocols. The absence of this baseline data creates "safety uncertainty" for staff working near the exposure area, particularly given the high workload of radiographers serving emergency patients daily.

This safety disparity is further exacerbated by the physical condition of the infrastructure within the ED radiology examination room. It was observed that the main entrance to the examination room cannot be hermetically sealed, and in certain operational scenarios, the door is intentionally left open under the assumption that the distance between the radiation source and the operator room or waiting area provides sufficient safety. However, without quantitative validation, such assumptions are hazardous as they ignore scatter radiation that can penetrate through door gaps. This non-standard door condition represents a potential radiation leakage point that may increase exposure rates beyond the limits permitted by BAPETEN Regulation No. 4 of 2020.

Failure to perform periodic evaluations of shielding integrity and compliance with Dose Limit Values (DLV) can lead to chronic radiation accumulation for both radiation workers and the public. Referring to BAPETEN Regulation No. 4 of 2013, monitoring is mandatory not only during new installations but also periodically to detect significant changes in the work environment (Suraningsih, Rosidah, & Jamil, 2025). Without intervention in the form of accurate exposure rate measurements, it is difficult to validate whether the radiation protection in the ED of Gunung Jati Hospital still meets safety standards or has conversely become a hazard to the surrounding environment.

Consequently, this study aims to directly measure radiation exposure rates at critical points surrounding the ED radiology examination room at Gunung Jati Regional General Hospital and evaluate its compliance with DLV standards. This study serves not merely as an administrative requirement but as a radiation safety audit to mitigate leakage risks resulting from infrastructural deficiencies. The findings are expected to provide an original contribution in the form of technical recommendations for infrastructure improvement and safety protocols, while simultaneously filling the data gap in radiation monitoring for referral hospitals in the Cirebon region.

2. Method

This study utilized a descriptive quantitative approach to evaluate radiation safety through objective field measurements and observational analysis. The investigation was designed to quantify ionizing radiation exposure rates under controlled operational conditions, ensuring compliance with national safety standards. Measurements were conducted using a calibrated Fluke Survey Meter with a specific calibration factor (CF) of 1.01 μSv/h. The instrument was selected for its high sensitivity and reliability in detecting low-level scatter radiation in clinical environments. To maintain data integrity, background radiation levels were recorded at each site prior to exposure and were subsequently used as a baseline to determine the net exposure rate.

The data acquisition protocol involved the systematic assessment of six strategic measurement points categorized into two distinct zones: Area E and Area C. Area E represented public zones (controlled/uncontrolled areas for the general public), comprising Point 1 (main entrance), Point 2, and Point 3 (waiting area). Area C represented the occupational zone for radiation workers, specifically the control room/operator console, covering Points 4, 5, and 6. To simulate standard clinical scatter conditions, the X-ray machine was operated at a fixed exposure factor of 75 kVp and 20 mAs. This standardized setting ensured that the resulting exposure rates

were representative of typical diagnostic procedures performed within the Emergency Department (ED) setting.

The raw data obtained in μSv/h were processed using the instrument's calibration factor and then converted into annual effective doses (mSv/year) to facilitate a direct comparison with regulatory limits. The actual exposure rate was calculated by subtracting the background radiation from the calibrated reading. The compliance of these measurements was evaluated against the Dose Limit Values (DLV) mandated by BAPETEN Regulation No. 4 of 2013 and Regulation No. 4 of 2020, which set the threshold at 20 mSv/year (9.92 μSv/h) for radiation workers and 1 mSv/year (0.49 μSv/h) for the general public. Furthermore, the results were analyzed against the specific dose constraints established by the Gunung Jati Regional General Hospital (4.96 μSv/h for workers and 0.3 mSv/year for the public) to ensure an added layer of safety in accordance with the ALARA principle.

3. Results and Discussion

3.1. Results of the Ossa Pedis Examination

A comprehensive radiation exposure rate measurement was conducted within and around the Emergency Department (IGD) Radiology Examination Room at RSD Gunung Jati, Cirebon City. The assessment focused on two distinct zones: the controlled radiation worker area (control room) and the public area accessible to the general community, specifically the space in front of the main examination room entrance and the adjacent patient waiting room. The measurement of the radiation exposure rate was performed using a calibrated Fluke survey meter. Data collection was executed across a total of six strategic measurement points divided between these two zones. Area C, designated for radiation workers, encompassed three measurement points (Points 4, 5, and 6). Concurrently, Area E, representing the public zone, included another three points (Points 1, 2, and 3). For all measurements, the radiographic exposure factors were standardized at 75 kV and 20 mAs. A calibration factor of 1.01 μSv/h was applied to the survey meter readings to ensure the accuracy and traceability of the reported exposure rates.

Table 1. Radiation Exposure Rate Measurements in the ED Radiology Department

Measurement Point	Background Radiation (μSv/h)	Instrument Reading (μSv/h)	Calibrated Value (μSv/h)	Net Exposure Rate (μSv/h)	Regulatory Limit (BAPETEN) (μSv/h)
Area E (Public)					
Point 1 (Main Entrance)	0.10	0.14	0.1414	0.0414	0.49
Point 2 (Waiting Area)	0.10	0.11	0.1111	0.0111	0.49
Point 3 (Waiting Area)	0.10	0.14	0.1414	0.0414	0.49

Area C (Occupational)					
Point 4 (Control Room)	0.10	0.20	0.2020	0.1020	9.92
Point 5 (Control Room)	0.10	0.15	0.1515	0.0515	9.92
Point 6 (Control Room)	0.10	0.13	0.1313	0.0313	9.92

The empirical findings of this study demonstrate that the radiation exposure rates surrounding the Emergency Department (ED) radiology examination room at RSD Gunung Jati remain well within the safety margins established by national and international regulations. According to BAPETEN Regulation No. 4 of 2013, the permissible dose rate for radiation workers is capped at 20 mSv/year (equivalent to 9.92 µSv/h), while the limit for the general public is significantly lower at 1 mSv/year (0.49 µSv/h). Our data indicates that Area C (occupational zone) reached a maximum net exposure of 0.1020 µSv/h, while Area E (public zone) peaked at only 0.0414 µSv/h. These values represent only a small fraction of the maximum permissible limits, suggesting that the current shielding and operational protocols provide a high level of radiologic safety.

The low exposure levels observed in Area C (Points 4, 5, and 6) can be attributed to the physical distance and the attenuation properties of the facility's structural design. Although the control room is adjacent to the X-ray source, it is positioned at a distance exceeding 3 meters from the primary beam's focal point. Furthermore, the presence of lead-lined walls or high-density concrete barriers likely facilitates the attenuation of scatter radiation. This is consistent with the Inverse Square Law, where radiation intensity decreases inversely with the square of the distance from the source. Even during high-load periods in the ED, the geographical layout of the operator console effectively mitigates the risk of chronic occupational exposure.

A critical point of concern raised during the preliminary observation was the integrity of the main entrance door, which was reported to be non-hermetic. However, the measurement results at Point 1 (Main Entrance) yielded a net exposure rate of 0.0414 µSv/h, which is significantly below the 0.49 µSv/h limit for public areas. This indicates that while the physical closure of the door may be suboptimal, the combination of scatter radiation angles and existing shielding is still sufficient to prevent hazardous leakage into the public hallway. Nevertheless, from a rigorous radiation protection standpoint, maintaining the structural integrity of the doors remains a priority to uphold the ALARA (As Low As Reasonably Achievable)

principle and prevent potential increases in exposure rates during more intensive radiographic procedures (e.g., higher kVp or mAs settings).

Furthermore, this study compared the recorded data against the more stringent internal "Dose Constraints" set by the RSD Gunung Jati Radiology Installation. The hospital's internal safety threshold for workers is 4.96 µSv/h (half of the BAPETEN limit), and for the public, it adheres to the 0.3 mSv/year constraint as suggested by BAPETEN for optimized protection. Our results confirm that the radiation levels do not exceed these conservative internal constraints. The conversion of our measurements into annual effective doses (ranging from 0.022 to 0.205 mSv/year) confirms that even if a person were present in these areas throughout the year, their cumulative dose would remain far below the 1 mSv/year public limit.

Table 2. Compliance Assessment of Annual Radiation Exposure Rates

Measurement Point	Annual Exposure Rate (mSv/year)	Permissible Dose Limit (Workers) (mSv/year)	Permissible Dose Limit (Public) (mSv/year)	Status
Point 1 (Area E)	0.083	-	1.0	Compliant
Point 2 (Area E)	0.022	-	1.0	Compliant
Point 3 (Area E)	0.083	-	1.0	Compliant
Point 4 (Area C)	0.205	20.0	-	Compliant
Point 5 (Area C)	0.103	20.0	-	Compliant
Point 6 (Area C)	0.063	20.0	-	Compliant

The empirical findings of this study demonstrate that the radiation exposure levels surrounding the Emergency Department (ED) radiology examination room at RSD Gunung Jati remain significantly below the safety thresholds established by national and international regulations. Based on the data presented in Table 2, all measurement points—both in occupational and public zones—exhibit annual effective doses that comply with the BAPETEN Regulation No. 4 of 2013. For radiation workers (Area C), the highest recorded value was 0.205 mSv/year, which represents only approximately 1% of the 20 mSv/year regulatory limit. Similarly, for the general public (Area E), the maximum value of 0.083 mSv/year is well below the 1 mSv/year threshold. These results indicate that despite the high clinical throughput of the ED, the existing radiation protection measures effectively mitigate the risk of excessive exposure.

A critical observation in this study pertains to the relationship between physical distance and the attenuation of scatter radiation. The safety of Area C (Points 4, 5, and 6) is largely attributed to the spatial separation between the X-ray source and the operator console, which exceeds three meters. According to the inverse square law, the intensity of radiation decreases proportionally to the square of the distance from the source; this physical principle, combined with the structural shielding of the control room, ensures that radiographers are adequately protected during exposures. Furthermore, the public areas (Area E) showed negligible exposure rates. This is particularly noteworthy given the initial concerns regarding the non-hermetic seal of the main entrance door. The data suggests that while the door may not close perfectly, the combination of current workload, beam collimation, and the use of the 75 kVp/20 mAs exposure factor does not result in hazardous radiation leakage into the waiting areas.

Beyond the national regulatory compliance, the results were also evaluated against the more stringent internal dose constraints of RSD Gunung Jati. The hospital's internal safety policy sets a more conservative limit of 4.96 mSv/h (equivalent to ~9.99 mSv/year) for staff and a public dose constraint of 0.3 mSv/year. The fact that all measured values fall well below these localized constraints reinforces the robustness of the facility's radiation safety profile. However, it is essential to emphasize that these measurements represent a "snapshot" of current conditions. The identified structural issues, such as the imperfectly sealed door mentioned in the introduction, still warrant technical intervention. While current scatter levels are safe, any future increase in patient volume or the transition to higher energy protocols could potentially elevate the leakage risk through these structural gaps.

3.2 Discussion

The empirical results of this study offer essential confirmation that the radiological conditions in the Emergency Department (ED) of RSD Gunung Jati comply with the safety standards set by national regulatory authorities. All measured exposure rates at the six strategic points remained well below the limits set by BAPETEN Regulation No. 4 of 2013 and Regulation No. 4 of 2020. For radiation workers in Area C, the highest annual dose was 0.205 mSv/year, and for the general public in Area E, it was 0.083 mSv/year. These numbers represent only a small portion of the safe limits: approximately 1% of the occupational limit (20 mSv/year) and 8% of the public limit (1 mSv/year). This indicates that the ED is very safe, despite handling a high volume of traffic. The outstanding safety record in the occupational zone (Area C) is mostly due to the successful use of distance and structural attenuation. Points 4, 5, and 6, which are located in the operator console, are more than 3 meters away from the X-ray focal point.

The Inverse Square Law states that radiation intensity decreases as the distance from the source increases (de Paiva, 2016; Kim, 2018). This, along with the high-density shielding of the control room walls, significantly reduces the problems

associated with primary and secondary scatter radiation. The highest net exposure rate in this area was only 0.1020 µSv/h, which means that the current radiographic workload and the 75 kVp/20 mAs exposure protocol do not pose a deterministic or significant stochastic risk to the radiographers on duty.

A principal concern examined in this study was the possibility of radiation leakage through the main entrance door, which was noted to have inadequate hermetic sealing. In theory, any structural opening in a room that emits radiation could allow scattered radiation to pass through (Ancila & Hidayanto, 2016). However, the data at Point 1 (Main Entrance) indicated a net exposure rate of only 0.0414 µSv/h, which is significantly lower than the 0.49 µSv/h limit for public areas. This means that the current beam collimation and the angle of scattered radiation are sufficient to prevent dangerous leaks, even though the door doesn't close perfectly. These results may alleviate immediate safety concerns, but the door's "unsealed" state remains a technical violation that needs to be addressed to maintain strong shielding over time, especially if higher-energy protocols are used in the future.

The study shows that the hospital is still following the ALARA (As Low As Reasonably Achievable) principle by comparing the results to its own "Dose Constraints." The national limit for safety is 20 mSv/year, but RSD Gunung Jati has a lower limit for its staff of 4.96 µSv/h (or about 9.99 mSv/year). Our findings show that the radiation levels at the operator console are much lower than even these strict internal standards. The hospital adheres to the BAPETEN-recommended limit of 0.3 mSv/year for optimal public protection. The highest recorded annual dose of 0.083 mSv/year for the public demonstrates that the facility is operating within a very safe framework, providing both patients' families and non-radiology staff in the ED with mental and physical safety.

The importance of these results is increased by the way the Emergency Department works. The ED is a busy place where medical staff (nurses, doctors) and family members are often near the examination room (Mulfiyanti & Ramadani, 2023; Risna Damayanti, 2023). This is different from routine diagnostic units. The complex setting of the ED means that "snapshot" measurements, like those done in this study, need to be part of a larger program of ongoing monitoring. The low exposure rates measured during the standardized 75 kVp/20 mAs exposure give us a baseline for safety, but they also remind us that protecting ourselves from radiation is an ongoing process. After any changes to the equipment, repairs to the X-ray tube, or modifications to the room's layout, these exposure rates must be rechecked to ensure that the safety margin remains constant over time.

Finally, the current radiological infrastructure at RSD Gunung Jati is safe and compliant with all relevant regulations. However, the physical problems with the entrance to the examination room should not be ignored. The door not sealing tightly is a hidden risk factor. To maintain the highest levels of safety in radiation oncology

and radiology, the hospital administration should make fixing the lead-lined doors a top priority. This will make sure that they close completely. Additionally, establishing a regular yearly audit of radiation exposure rates is necessary to transform this research from a one-time check into a long-term safety measure. By taking these proactive steps, the ED will be able to maintain a safe environment for the community and its healthcare providers as the clinical needs of the ED evolve. This will effectively lower the risk of cumulative radiation effects.

4. Conclusion

This study finds that the radiological infrastructure at the RSD Gunung Jati Emergency Department is very safe, with annual exposure rates much lower than both national (BAPETEN) and strict internal dose limits. The quantitative evaluation of six strategic points indicated that scatter radiation in occupational and public areas remains within optimized thresholds—comprising less than 1% of the occupational limit and 9% of the public limit—primarily due to sufficient spatial separation and structural attenuation. Even though the ED is very busy and the door seals are not hermetic, the current 75 kVp/20 mAs protocols do not pose any immediate deterministic or significant stochastic hazards to staff or the community. This demonstrates that the existing radiation protection framework is effective under normal diagnostic conditions.

This study, on the other hand, has some limitations because it only examines exposure at a single point in time, using standardized radiographic parameters that may not capture the full range of high-energy emergency procedures. To address this issue, hospital management should prioritize fixing the lead-lined doors so that they close completely, which will help prevent leaks as the number of patients increases. Additionally, transitioning from periodic to institutionalized annual radiological audits is necessary to monitor the long-term quality of shielding materials and ensure equipment calibration. Longitudinal data and a wider range of exposure factors (higher kVp/mAs) should be included in future research to create a more comprehensive risk map for the constantly evolving field of emergency radiology.

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