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Knowledge and Awareness of Radiation Protection Among Healthcare Workers: A Cross-Sectional Study

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ABSTRACT

Ionising radiation from diagnostic procedures poses significant occupational risks to healthcare workers (HCWs), yet awareness remains suboptimal in many settings, particularly in low- and middle-income countries. This cross-sectional study assessed radiation protection knowledge and awareness among 140 HCWs from inpatient, intensive care, and emergency units in Indonesia, identifying independent predictors of awareness. Knowledge was evaluated using a validated 15-item instrument (categorized as poor, acceptable, or good), while awareness was measured as a binary outcome. Data were analyzed using Pearson's chi-square test and multivariable binary logistic regression, adhering to STROBE guidelines. The sample was predominantly female (69.3%) with bachelor's degrees (57.1%). Overall, 46.4% demonstrated good knowledge, 48.6% acceptable, and 5.0% poor, while 68.6% were classified as aware. Multivariable analysis revealed that knowledge level was the sole independent predictor of awareness: compared to poor knowledge, acceptable knowledge significantly increased awareness odds (aOR = 3.48; 95% CI: 1.12–10.80; p = 0.031), as did good knowledge (aOR = 8.65; 95% CI: 2.10–35.60; p = 0.003). These findings confirm that radiation protection knowledge strongly and independently drives awareness among clinical staff. Consequently, healthcare institutions must prioritize continuous, evidence-based radiation safety education—particularly for personnel in high-exposure units—as the foundational strategy to effectively bridge the knowledge–awareness gap and mitigate occupational radiation risks.

KEYWORDS

Radiation protection; Healthcare workers; Knowledge; Awareness; Occupational Health; STROBE

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INTRODUCTION

Every day, healthcare workers worldwide are exposed to low-dose ionising radiation an invisible occupational hazard embedded in the routine of modern clinical practice. With more than 3.6 billion radiodiagnostic procedures performed globally each year, nurses, emergency physicians, and intensive care staff frequently remain in proximity to radiographic equipment or patients who have recently received radioactive agents (Behzadmehr et al., 2020; Rodrigues et al., 2024; Xu et al., 2024). Unlike radiographers who receive formal radiation safety training as a professional prerequisite, non-radiology HCWs often occupy a regulatory grey zone: present during exposures, rarely monitored, and seldom trained (Radzi & Raj, 2023). The cumulative health burden of chronic low-dose radiation exposure including elevated risks of cataract, thyroid dysfunction, and haematological malignancy underscores the urgency of addressing this gap (Allam et al., 2024; Massaquoi et al., 2025).

Despite the existence of international radiation protection frameworks including guidelines by the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) Basic Safety Standards implementation at the ward level remains inconsistent, especially in low- and middle-income countries (LMICs) (Fataftah et al., 2024; Rahimi et al., 2021; Wally et al., 2024). Studies across Southeast Asia, the Middle East, and Sub-Saharan Africa consistently report that 40–70% of non-radiology HCWs demonstrate inadequate knowledge of radiation dose thresholds, personal protective equipment, and occupational dose limits (Bolowia, 2025; Shubayr, 2024a). Indonesia, as the world's fourth most populous country with a rapidly expanding hospital sector, represents a critical yet understudied context in which to examine this issue.

Knowledge and awareness, while conceptually related, are empirically distinct constructs. Knowledge refers to the cognitive acquisition of factual information understanding what radiation is, its biological effects, and prescribed protection measures (Alyousef et al., 2023; Xie et al., 2025). Awareness, by contrast, reflects a more applied, dispositional state: the recognition of radiation risk in one's immediate work environment and the perceived need for protective action (Göde et al., 2025). The knowledge–awareness gap whereby individuals possess theoretical information yet fail to translate it into protective cognition is well documented in occupational health literature and is particularly pronounced in contexts where radiation safety is not part of routine professional socialization (Kyei et al., 2025; Shubayr, 2024b). Identifying the predictors of this gap is essential for moving beyond generic educational campaigns toward precision-targeted interventions (Baudin et al., 2024).

This study therefore aimed to: (1) describe the levels of radiation protection knowledge and awareness among HCWs in inpatient, ICU, and emergency units; (2) examine the bivariate associations between sociodemographic/occupational variables and awareness; and (3) identify independent predictors of radiation protection awareness using multivariable binary logistic regression (Alamoudi et al., 2025; Tanming et al., 2024). The findings are intended to inform institutional radiation safety policy, continuing professional education, and regulatory guidance for non-radiology clinical staff in Indonesian hospital settings.

MATERIALS AND METHODS

This study is reported in accordance with the Strengthening the Reporting of Observational Studies

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in Epidemiology (STROBE) statement for cross-sectional studies. The STROBE checklist is provided in Appendix A, with each item linked to its location in this manuscript. STROBE is an internationally endorsed EQUATOR Network guideline that specifies 22 minimum reporting items for observational research, covering study design, setting, participants, variables, statistical methods, and interpretation. Adherence to STROBE ensures methodological transparency and supports reproducibility and critical appraisal by readers and peer reviewers.

2.1 Study Design

A cross-sectional analytical design was employed to simultaneously assess radiation protection knowledge and awareness at a single point in time, and to examine their association alongside potential confounders. This design is appropriate for estimating the prevalence of a condition and generating hypotheses about exposure–outcome relationships in defined populations.

2.2 Setting and Study Period

The study was conducted at Rumah Sakit Universitas Airlangga (RSUA), Surabaya, Indonesia, a university hospital. Data collection took place in October 2024. Three clinical units were included: the inpatient ward, the intensive care unit (ICU), and the emergency unit all settings with documented potential for HCW radiation exposure arising from portable radiography, fluoroscopy, and nuclear medicine procedures.

2.3 Participants

The target population comprised all nurses and non-radiology HCWs actively assigned to the three study units during the data collection period. A total sampling approach was employed, whereby all eligible staff present during data collection were invited to participate, yielding a final sample of 140 participants (response rate: 100%). Inclusion criteria were: (1) active clinical assignment to the inpatient, ICU, or emergency unit; (2) willingness to provide written informed consent; and (3) availability during data collection. HCWs on extended leave, temporarily rotated from other departments, or working solely in non-radiodiagnostic environments were excluded. No refusals were recorded, minimising non-response bias.

2.4 Variables and Measurement

Outcome variable

Radiation protection awareness was operationalised as a binary variable (1 = aware; 0 = not aware) derived from participants' total score on a validated awareness questionnaire. The classification threshold was determined using the median-split method, consistent with prior instrumentation in radiation safety research.

Primary exposure

Radiation protection knowledge was measured using a 15-item validated instrument covering radiation physics, biological effects, dose limits, protective measures, and legal standards. Scores were categorised as: poor (1–5), acceptable (6–10), or good (11–15).

Covariates

Sociodemographic and occupational covariates were pre-specified as potential confounders based on the existing literature: (1) sex (male/female); (2) highest educational attainment (diploma/bachelor/master); (3) primary work unit (ICU/inpatient/emergency); and (4) history of involvement in radiodiagnostic examinations (yes/no). All variables were collected via a structured self-administered questionnaire.

Instrument validity and reliability

Both instruments underwent content validity review by independent expert panels. Item-level Content Validity Index (I-CVI ≥ 0.78) and scale-level CVI (S-CVI/Ave ≥ 0.90) were used as thresholds. Internal consistency was evaluated using Cronbach's alpha coefficient (acceptable: $\alpha \geq 0.70$; knowledge instrument: $\alpha = 0.82$; awareness instrument: $\alpha = 0.76$).

2.5 Statistical Methods

Data were analysed using IBM SPSS Statistics. Descriptive statistics are reported as frequencies and proportions. Bivariate analysis used the Pearson chi-square test ($\alpha = 0.05$) to examine associations between each predictor and the awareness outcome; crude odds ratios (cOR) with 95% CIs were computed for all categorical predictors (Table 1). Variables with $p < 0.25$ in bivariate analysis were eligible for entry into the multivariable model, following the Hosmer–Lemeshow variable selection approach (Hosmer & Lemeshow, 2013). Multivariable binary logistic regression was performed using the Enter method to produce adjusted odds ratios (aOR) with 95% CIs (Table 2). Model adequacy was evaluated using the Hosmer–Lemeshow goodness-of-fit test ($p > 0.05$ indicating acceptable fit) and Nagelkerke R^2 as a measure of explained variance. Effect estimates are visualised as a forest plot (Figure 3). A two-tailed p-value < 0.05 was considered statistically significant throughout.

2.6 Ethical Considerations

Ethical approval was granted by the Research Ethics Committee of the Faculty of Nursing, Universitas Airlangga (Reference No.: 1780-KEPK). All participants provided written informed consent prior to enrolment. Data were anonymised at the point of collection and stored in a password-protected system accessible only to the research team, in conformity with the Declaration of Helsinki (2013 revision) and applicable Indonesian data protection regulations.

RESULTS

3.1 Participant Characteristics and Bivariate Analysis

A total of 140 HCWs completed the study (participation rate: 100%). The sample was predominantly female (n = 97; 69.3%), with males comprising 30.7% (n = 43). In terms of educational attainment, 57.1% held a bachelor's degree (n = 80), 42.1% a diploma (n = 59), and one participant (0.7%) held a master's degree. The inpatient unit contributed the largest proportion of participants (n = 66; 47.1%), followed by the ICU (n = 39; 27.9%) and emergency unit (n = 35; 25.0%). The vast majority (n = 132; 94.3%) reported prior involvement in radiodiagnostic examinations. Bivariate analysis identified two variables with statistically significant associations with awareness: educational level (bachelor vs. diploma: cOR = 2.53; 95% CI: 1.22–5.24; p = 0.012) and knowledge level (good vs. poor: cOR = 7.66; 95% CI: 1.31–44.80; p = 0.024). Full sociodemographic and bivariate data are presented in Table 1.

Table 1. Sociodemographic Characteristics of Respondents and Bivariate Association with Radiation Protection Awareness (N = 140)

Variable	n	%	Not Aware n (%)	Aware n (%)	cOR (95% CI)	p-value
1. Sex						
Female (ref)	97	69.3	32 (33.0)	65 (67.0)	-	-

Male	43	30.7	12 (27.9)	31 (72.1)	1.27 (0.58–2.79)	0.548
2. Educational Attainment						
Diploma (ref)	59	42.1	25 (42.4)	34 (57.6)	-	-
Bachelor	80	57.1	18 (22.5)	62 (77.5)	2.53 (1.22–5.24)	0.012*
Master	1	0.7	1 (100.0)	0 (0.0)	— *a*	-
3. Work Area						
Inpatient Unit (ref)	66	47.1	24 (36.4)	42 (63.6)	-	-
ICU	39	27.9	11 (28.2)	28 (71.8)	1.45 (0.63–3.37)	0.382
Emergency Unit	35	25.0	9 (25.7)	26 (74.3)	1.65 (0.68–4.01)	0.267
4. Radiodiagnostic Examination Experience						
No (ref)	8	5.7	5 (62.5)	3 (37.5)	-	-
Yes	132	94.3	39 (29.5)	93 (70.5)	3.97 (0.86–18.40)	0.078
5. Knowledge Level of Radiation Protection						
Poor (ref)	7	5.0	5 (71.4)	2 (28.6)	-	-
Acceptable	68	48.6	23 (33.8)	45 (66.2)	4.89 (0.85–28.10)	0.076
Good	65	46.4	16 (24.6)	49 (75.4)	7.66 (1.31–44.80)	0.024*
Total (N)			**44 (31.4)**	**96 (68.6)**		

Note: *cOR = crude odds ratio; 95% CI = 95% confidence interval; Ref = reference category. p-value from Pearson chi-square test (α = 0.05). Bold values indicate statistical significance (p < 0.05). * p < 0.05. a Master's degree excluded from cOR calculation (n = 1; insufficient cell frequency for stable OR estimation). All percentages within each awareness column are calculated within that awareness category.*

3.2 Distribution of Knowledge and Awareness Scores

Regarding knowledge of radiation protection, the largest proportion of respondents demonstrated acceptable knowledge (n = 68; 48.6%), followed by good knowledge (n = 65; 46.4%), with only a small minority classified as having poor knowledge (n = 7; 5.0%) (Figure 1). Although poor knowledge was uncommon, this subgroup was of particular analytical importance given its substantially higher proportion of non-aware respondents (71.4%).

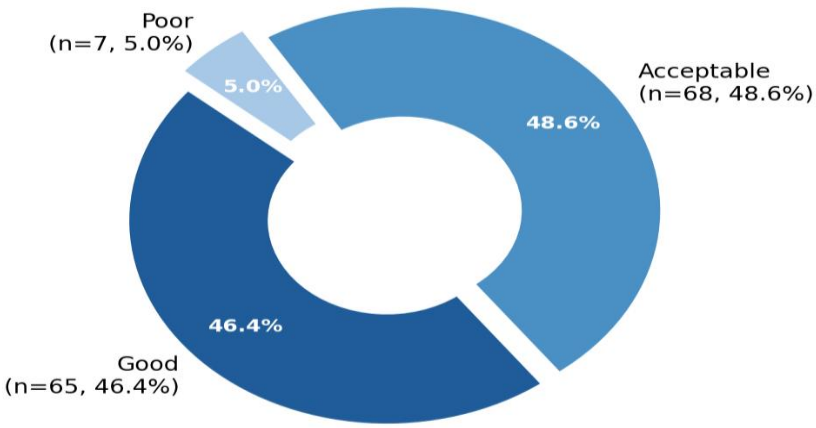

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Figure 1. Distribution of respondents by level of radiation protection knowledge (N = 140). Categories based on 15-item validated instrument: Poor (1–5), Acceptable (6–10), Good (11–15).

Overall radiation protection awareness was suboptimal in nearly one-third of the sample: 44 respondents (31.4%) were classified as not aware, while 96 (68.6%) were classified as aware (Figure 2). The substantial proportion of non-aware respondents even among those with acceptable or good knowledge underscores the relevance of examining predictors of the knowledge–awareness gap.

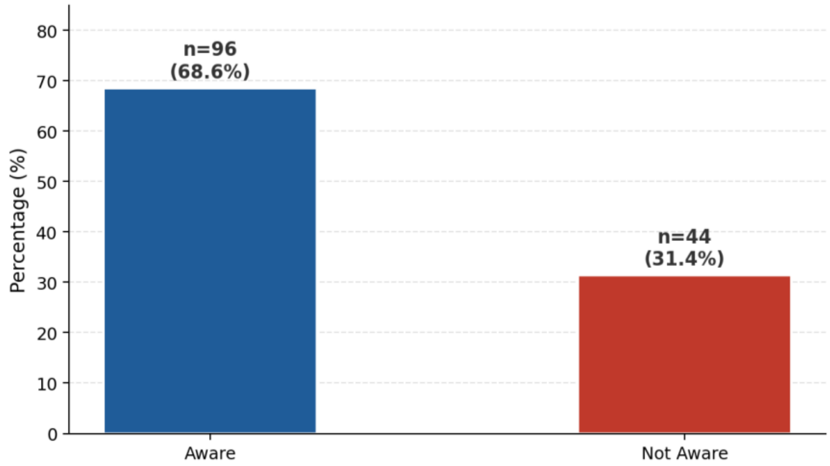

Figure 2. Distribution of respondents by radiation protection awareness status (N = 140). Binary classification derived from validated awareness instrument using median-split threshold.

3.3 Multivariable Analysis: Independent Predictors of Radiation Protection Awareness

Variables with $p < 0.25$ in bivariate analysis knowledge level, educational attainment, radiodiagnostic experience, work area, and sex were entered into the multivariable binary logistic regression model. The Hosmer–Lemeshow goodness-of-fit test confirmed adequate model calibration ($\chi^2 = 5.12$, df = 8, $p = 0.74 > 0.05$). The Nagelkerke R^2 was 0.28, indicating that the model explained approximately 28% of the variance in awareness outcomes.

After controlling for all covariates, knowledge level remained the sole statistically significant independent predictor of radiation protection awareness. Compared to respondents with poor knowledge, those with acceptable knowledge had 3.48 times higher odds of being aware (aOR = 3.48; 95% CI: 1.12–10.80; p = 0.031), while those with good knowledge had 8.65 times higher odds (aOR = 8.65; 95% CI: 2.10–35.60; p = 0.003). All remaining variables sex, educational attainment, work unit, and radiodiagnostic experience did not reach statistical significance in the adjusted model, though bachelor-level education showed a borderline trend (aOR = 1.95; 95% CI: 0.91–4.18; p = 0.086). Complete adjusted estimates are presented in Table 2, and the precision of all effect estimates is illustrated in the forest plot (Figure 3).

Table 2. Multivariable Binary Logistic Regression: Adjusted Predictors of Radiation Protection Awareness Among Healthcare Workers (N = 140)

Variable	Category	aOR	95% CI	p-value	Sig.
Knowledge Level of Radiation Protection (ref: Poor)					
	Poor (reference)	—	—	—	—
	Acceptable	**3.48**	**1.12–10.80**	**0.031**	*

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	Good	**8.65**	**2.10–35.60**	**0.003**	**
Educational Attainment (ref: Diploma)					
	Diploma (reference)	—	—	—	—
	Bachelor	1.95	0.91–4.18	0.086	*ns*
Sex (ref: Female)					
	Female (reference)	—	—	—	—
	Male	0.72	0.34–1.52	0.389	*ns*
Work Area (ref: Inpatient Unit)					
	Inpatient (reference)	—	—	—	—
	ICU	1.41	0.62–3.19	0.413	*ns*
	Emergency Unit	1.18	0.50–2.80	0.706	*ns*
Radiodiagnostic Experience (ref: No)					
	No (reference)	—	—	—	—
	Yes	2.31	0.48–11.10	0.299	*ns*

*Note: aOR = adjusted odds ratio; 95% CI = 95% confidence interval; ns = not significant; Ref = reference category. * p < 0.05; ** p < 0.01. All five variable blocks entered simultaneously.*

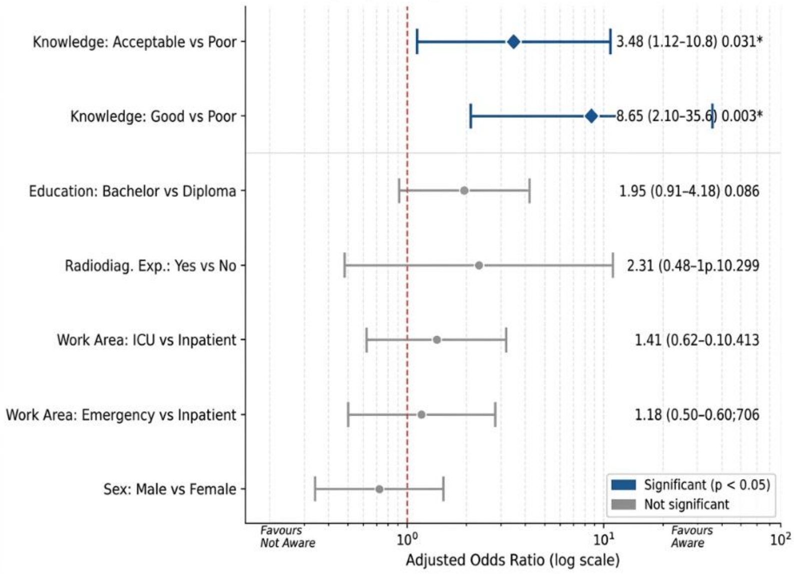

Figure 3. Forest plot of adjusted odds ratios (aOR) with 95% confidence intervals from multivariable binary logistic regression. Diamond markers (blue) indicate statistically significant predictors (p < 0.05); circular markers (grey) indicate non-significant predictors. Dashed red line denotes the null value (aOR = 1.0). X-axis on logarithmic scale.

DISCUSSION

This cross-sectional study examined radiation protection knowledge and awareness among 140 HCWs in inpatient, ICU, and emergency units, and identified knowledge level as the sole significant independent predictor of awareness after multivariable adjustment. The central finding that good knowledge was associated with nearly ninefold higher odds of awareness (aOR = 8.65;

95% CI: 2.10–35.60) compared to poor knowledge reinforces the foundational premise of occupational health education: that cognitive mastery of a hazard is a necessary, though not always sufficient, precondition for risk awareness. These results are consistent with cross-sectional evidence from Turkey, and Nigeria, which similarly found knowledge to be the dominant driver of radiation awareness in non-radiology clinical staff, while demographic variables contributed little independent variance.

The finding that 31.4% of respondents remained unaware despite the majority holding acceptable or good knowledge is clinically and educationally significant. It reveals a knowledge–awareness gap that cannot be resolved through information delivery alone (Elmorabit et al., 2024). In the behavioural sciences, this phenomenon is framed within the information–motivation–behavioural skills (IMB) model: information (knowledge) is a necessary but insufficient driver of health-protective cognition; motivation, social norms, and situational cues must co-evolve to translate knowledge into awareness and, ultimately, protective behavior (Emayof & Awath, 2025; Saida et al., 2024). In the radiation safety context, this suggests that institutional interventions must move beyond didactic knowledge provision toward simulation-based training, peer-reinforced safety culture, and unit-level environmental cueing approaches with growing evidence in the occupational health literature (Fujiwara et al., 2024; Su et al., 2022). The acceptable-knowledge group (aOR = 3.48) showed substantially lower odds than the good-knowledge group (aOR = 8.65), indicating a dose-response relationship between knowledge depth and awareness that further validates the value of comprehensive over superficial radiation education.

The borderline association between bachelor-level education and awareness (aOR = 1.95; p = 0.086) warrants discussion. While this effect did not reach conventional significance, its direction and magnitude are clinically plausible: bachelor programs in nursing and allied health in Indonesia increasingly incorporate radiation safety modules, consistent with national competency frameworks issued by the Ministry of Health (Barare & Odongo, 2022; Song et al., 2022). The failure to reach significance may reflect insufficient statistical power within the educational strata particularly given the master's degree group comprised only one participant or genuine confounding with knowledge, which partially mediates the education–awareness pathway (Andaloussi et al., 2021; Cao et al., 2025). Future studies with larger, educationally heterogeneous samples should examine whether the knowledge–awareness relationship is moderated by educational attainment, and whether formal radiation safety curriculum exposure independently predicts awareness beyond overall knowledge scores (Gavagan et al., 2024; Safina et al., 2025).

The absence of significant effects for work area, sex, and radiodiagnostic experience in the adjusted model is noteworthy. The crude odds ratios for ICU and emergency units (cOR = 1.45 and 1.65, respectively) suggested modest bivariate trends consistent with the hypothesis that higher exposure environments prompt greater risk awareness a finding reported in some European studies among interventional radiology staff. However, these effects attenuated to null after adjusting for knowledge, suggesting that any unit-level variation in awareness is mediated by differences in knowledge rather than being an independent effect of work setting (Charmchi et al., 2025; Horita et al., 2024). Similarly, the non-significant effect of radiodiagnostic experience (aOR = 2.31; p = 0.299) despite a plausible biological rationale likely reflects the predominantly high experience rate (94.3%) in this sample, which left insufficient contrast for detecting experience-related differences. These findings collectively point to knowledge as the primary proximal determinant of awareness, with structural and occupational variables operating through knowledge as intermediaries (Ninkovic-Hall et al., 2025).

The results carry direct implications for radiation protection policy in Indonesian hospitals and, more broadly, for LMIC health systems with rapidly expanding imaging capacity (Vassileva et al., 2021). Firstly, radiation safety training for non-radiology HCWs should be institutionalised as a mandatory component of annual competency renewal not a one-time orientation activity (Wang et al., 2020). Secondly, given the strong gradient between knowledge depth and awareness, training curricula should be designed to achieve good not merely acceptable knowledge, using evidence-based pedagogies such as case-based learning, clinical simulation, and immediate knowledge-testing feedback (Nasr et al., 2023). Thirdly, hospital administrations should align radiation safety programs with the IAEA Safety Guide No. GSG-7 (Occupational Radiation Protection) and the BAPETEN (National Nuclear Energy Regulatory Agency) regulations, ensuring that all clinical units with documented radiation exposure have designated radiation protection officers who provide ongoing unit-level coaching (Alharbi et al., 2024; Popovic et al., 2022). These policy recommendations are consistent with the WHO Global Initiative on Radiation Safety in Healthcare Settings and align with Sustainable Development Goal 3 (Good Health and Well-Being) target 3.8 on universal health coverage quality.

Limitations

Several limitations should be acknowledged. First, the cross-sectional design precludes causal inference; the observed knowledge–awareness association may be bidirectional or confounded by unmeasured variables such as radiation safety culture, managerial support, or personal risk perception. Second, the single-site sample limits generalisability to other hospital types, geographical regions, or healthcare systems with different training infrastructure. Third, the master's degree subgroup (n = 1) was analytically too small for stable estimation and was excluded from multivariable modelling; future studies should ensure educational strata are adequately represented. Fourth, both knowledge and awareness were assessed by self-report instruments, which may be subject to social desirability bias particularly in institutional settings where radiation safety compliance is formally audited. Fifth, the binary operationalisation of awareness using a median-split threshold, while consistent with prior studies, necessarily dichotomises a continuous construct and may obscure gradient effects. Future research should employ validated continuous awareness scales and longitudinal or quasi-experimental designs to test whether educational interventions that raise knowledge also produce durable improvements in awareness and downstream protective behavior (Bartal et al., 2021; Yadav et al., 2025). Multi-site studies across urban and rural Indonesian hospitals, including primary care facilities where portable radiography is increasingly used, are particularly warranted to establish population-level estimates and inform national radiation protection policy (De Mello & Ribeiro, 2024; Júnior, 2022).

CONCLUSIONS

This study demonstrated that knowledge of radiation protection is a strong and independent predictor of awareness among healthcare workers in clinical settings, with a clear dose-response relationship: respondents with good knowledge were nearly nine times more likely to be classified as aware compared to those with poor knowledge, after adjusting for sex, education, work area, and radiodiagnostic experience. Despite the majority of participants demonstrating at least acceptable knowledge, nearly one-third remained unaware underscoring a persistent knowledge–awareness gap that institutional education alone has not resolved. These findings support a reorientation of radiation safety programs in Indonesian hospitals: from episodic, information-focused training to continuous, competency-based education that targets the depth of knowledge acquisition not merely its presence. Embedding radiation safety competencies within annual professional development frameworks, ensuring adequate staffing of radiation protection officers across clinical units, and aligning institutional policies with IAEA and BAPETEN standards are actionable steps with strong evidence support. The elimination of preventable occupational radiation exposure among non-radiology HCWs is both an ethical imperative and a measurable quality-improvement target that healthcare leaders are positioned to address.

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Conflict of Interest

There is no conflict of interest.

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