

Effective Mobile Application for Reducing Optically Stimulated Luminescent Placement Errors and Enhancing Safety at Songklanagarind Hospital Cardiac Catheterization Laboratory, Thailand

Kanchana Saeheng, R.N., Chantana Charoensin, R.N.

Registered Nurse, Naradhiwas Rajanagarindra Heart Center, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand.

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Abstract:

Objective: To develop a mobile application within the “App Smart Med PSU” platform for real-time radiation dose reporting and Optically Stimulated Luminescent (OSL) guidance, and to evaluate its effectiveness in reducing placement errors, enhancing safety awareness, and improving user satisfaction among Healthcare Personnel (HCP).

Material and Methods: A pre-post intervention study involved 30 HCP at Songklanagarind Hospital, selected via purposive sampling based on Cardiac Catheterization Laboratory (CCL) experience. The application was developed over six months, guided by the Technology Acceptance Model (TAM) and Health Belief Model (HBM). Data were collected over 12 months post-implementation (June 2024–May 2025), with baseline data from the prior year (June 2023–May 2024). Outcomes included OSL placement audits and a 17-item satisfaction questionnaire (Cronbach’s Alpha=0.83).

Results: The application reduced improper OSL placements from 199 to 31 incidents (84.42% reduction, p -value<0.001, Wilcoxon Signed-Rank Test). User satisfaction was high (mean=4.27/5), with top scores for ease of use (4.31) and data security (4.32). Ninety percent of HCP reported heightened safety awareness.

Conclusion: The application significantly reduced OSL placement errors and enhanced safety practices. Its integration into nursing workflows suggests potential for broader adoption in Thai CCLs.

Keywords: healthcare personnel, mobile application, OSL dosimeter, radiation safety, Thailand

Contact: Chantana Charoensin, R.N.
Naradhiwas Rajanagarindra Heart Center, Faculty of Medicine, Prince of Songkla University,
Hat Yai, Songkhla 90110, Thailand.
E-mail: sachantana@gmail.com

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Introduction

Cardiovascular diseases remain a leading cause of morbidity and mortality worldwide and in Thailand, resulting in an increasing volume of diagnostic and interventional procedures performed in cardiac catheterization laboratories (CCLs)¹. These procedures expose healthcare personnel (HCP), particularly cardiologists and nurses, to ionizing radiation, which is associated with both deterministic and stochastic health effects, including cataracts, skin injury, and malignancy^{2,3}. Consequently, effective radiation monitoring and safety management are essential components of occupational health practices in high-volume Cardiac Catheterization Laboratory (CCL) environments⁴.

Optically Stimulated Luminescent (OSL) dosimeters are widely adopted as standard personal radiation monitoring devices in CCLs to ensure regulatory compliance and long-term dose surveillance⁵. At Songklanagarind Hospital, radiation data are provided monthly by the National Nuclear Technology Service Center. However, the traditional paper-based reporting system has been associated with multiple challenges, including delayed feedback, duplicate documentation, and errors related to improper OSL placement. These issues can lead to inaccurate dose readings and may compromise both individual safety awareness and institutional radiation protection efforts^{4,6}.

Previous studies have extensively investigated the physical and dosimetric properties of OSL technology across various applications. Sholom et al. demonstrated that optically stimulated luminescence signals derived from mobile phone protective glass exhibited linear dose-response relationships and stable signal characteristics, highlighting the adaptability of OSL technology to diverse detector materials that require systematic data interpretation⁷. Similarly, McKeever et al. reviewed advancements in the use of thermoluminescence and OSL signals obtained from components of personal electronic devices for emergency dosimetry, emphasizing the importance of digital processing

and structured data handling for reliable dose assessment⁸. In clinical contexts, OSL systems have also been validated for in vivo dosimetry in radiotherapy, showing reproducible dose measurements and acceptable uncertainty levels suitable for routine clinical use⁹.

Collectively, these studies confirm the reliability and versatility of OSL technology across different settings; however, they primarily focus on detector performance and physical measurement characteristics. Limited attention has been given to the integration of OSL-related data into user-centered digital reporting systems that support real-time interpretation, individualized feedback, and practical application in routine clinical workflows for healthcare personnel.

Prior research has emphasized that radiation safety awareness and protective behaviors among HCP play a critical role in reducing occupational exposure in interventional environments^{10,11}. Educational interventions, including simulation-based and virtual reality training, have been shown to improve knowledge and safety practices related to radiation protection^{12,13}. Nevertheless, such approaches often rely on periodic training sessions and do not provide continuous, personalized feedback regarding individual radiation exposure. In Thailand, existing hospital information systems rarely offer intuitive, user-friendly interfaces that allow HCP to access their own radiation dose data in a timely and comprehensible manner, thereby limiting proactive self-monitoring and engagement in radiation safety behaviors¹⁴.

To address these gaps, this study developed a mobile application integrated within the “App Smart Med PSU” platform to support radiation dose reporting and OSL dosimeter guidance for HCP working in the CCL at Songklanagarind Hospital. The application provides individualized graphical dose reports, color-coded risk alerts, and visual guidance on proper OSL placement. Its design is informed by the Technology Acceptance

Model (TAM), which emphasizes perceived ease of use and usefulness to promote technology adoption¹⁵, and the Health Belief Model (HBM), highlighting the role of perceived risk and perceived benefits in motivating preventive health behaviors¹⁶. By combining validated OSL data with a user-centered digital interface, the application aims to reduce OSL placement errors, enhance radiation safety awareness, and improve efficiency in nursing and multidisciplinary CCL workflows.

Objective

This study aimed to:

Develop a mobile application within the “App Smart Med PSU” platform for HCP in the CCL at Songklanagarind Hospital, Thailand, to provide real-time radiation dose reports and OSL dosimeter guidance.

Evaluate its effectiveness in reducing OSL placement errors, enhancing radiation safety awareness, and improving user satisfaction among HCP.

Research framework

The mobile application, integrated into the “App Smart Med PSU” platform, was designed for HCP at Songklanagarind Hospital. It provides real-time radiation dose reports, graphical displays, color-coded alerts, and

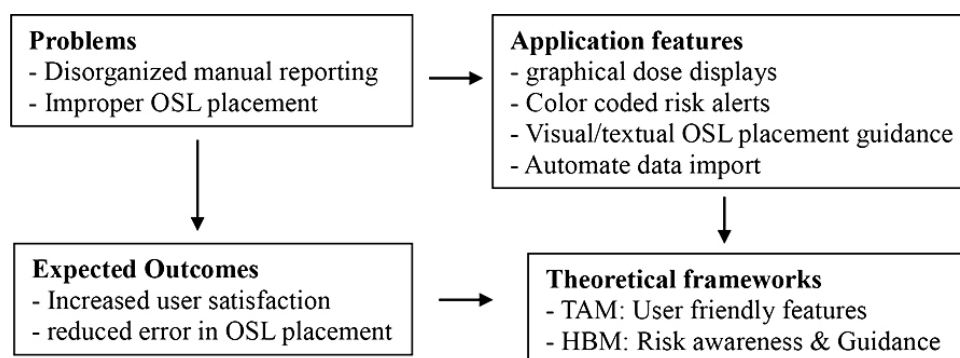
OSL usage guidance. The design is informed by the Technology Acceptance Model (TAM)¹⁵ and Health Belief Model (HBM)¹⁶.

TAM emphasizes perceived ease of use and usefulness to drive technology adoption, guiding the application’s intuitive interface to enhance user satisfaction and address manual reporting inefficiencies¹⁵. HBM posits that perceived risk susceptibility and preventive action benefits promote behavior change, supporting alerts and guidance to increase radiation risk awareness and reduce OSL errors¹⁶.

Figure 1 illustrates how application features (real-time reports, graphical displays, alerts, OSL guidance) align with TAM and HBM to achieve improved user satisfaction and reduced OSL placement errors.

Material and Methods

This pre-post intervention study was conducted in the CCL at Songklanagarind Hospital, Thailand, to develop and evaluate a mobile application for radiation dose reporting. The study was approved by the Institutional Review Board (IRB) of the Faculty of Medicine, Prince of Songkla University (REC.64-384-9-1).



TAM=the technology acceptance model, HBM=health belief model, OSL=optically stimulated luminescent

Figure 1 Research framework flowchart

Participants

The cardiac catheterization laboratory at Songklanagarind Hospital employed a total of 49 healthcare personnel (HCPs) during the study period. Of these, 30 HCPs were recruited using purposive sampling based on predefined inclusion criteria. Eligible participants were required to (1) be actively working in the CCL, (2) have at least one year of experience in the CCL, and (3) routinely use an OSL dosimeter as part of occupational radiation monitoring.

The selected sample included nurses, nurse assistants, and physicians with a range of professional experience spanning from 2 to 20 years. The sample size was considered appropriate for this single-center pilot and pre-post intervention study, which aimed to evaluate the feasibility, usability, and preliminary effectiveness of the application rather than to generate population-level estimates.

Furthermore, the sample represented over 60% of the total CCL workforce, ensuring adequate representation across professional roles and experience levels. This approach is consistent with studies in applied health technology and nursing informatics conducted in specialized clinical settings.

Application development

The application was developed over six months in three phases, based on HCP needs and existing CCL reports:

Requirement analysis (2 months): Requirement analysis was conducted during the initial phase of application development to identify user needs, workflow challenges, and expectations regarding radiation dose reporting in the cardiac catheterization laboratory. This phase involved semi-structured interviews with 15 healthcare personnel who were actively working in the CCL but were not included in the 30 participants recruited for the intervention study.

Participants for the interviews were selected to represent different professional roles within the CCL, including nurses, nurse assistants, and physicians. All interviews were conducted individually to allow participants to freely express their experiences and perspectives without peer influence. The interviews were conducted by a nurse researcher with experience in qualitative research and familiarity with the CCL working environment.

An interview guide was developed based on the existing literature on radiation safety practices and digital health applications. The interviews focused on the challenges associated with manual radiation dose reporting, awareness of personal radiation exposure, difficulties related to OSL dosimeter usage, and expectations for a digital reporting system. Each interview lasted approximately 30–45 minutes and was documented using written notes.

Qualitative data obtained from the interviews were analyzed using thematic analysis. The researcher independently reviewed the interview notes, performed initial coding, and grouped codes into themes that reflected key user needs and system requirements. The identified themes informed the functional design of the application, including graphical dose visualization, automated data integration, alert features, and OSL placement guidance.

Design and development (3 months): An interdisciplinary team of nurses, IT specialists, and radiation safety officers developed the application within the “App Smart Med PSU” platform.

Features included:

Graphical dose displays for monthly and yearly exposure.

Color-coded alerts (green=low risk, yellow=moderate risk, red=high risk) based on international guidelines⁵.

OSL placement guidance with visual and textual instructions.

Automated data import from Excel reports provided by the National Nuclear Technology Service Center,

reducing manual entry errors by 95% and streamlining integration with existing systems¹³. TAM ensured usability¹⁵, while HBM informed risk-awareness features¹⁶.

Testing and refinement (1 month): The application was pilot tested with 10 HCP, selected for their diverse roles to capture varied feedback. Structured surveys assessed usability, leading to two refinement cycles that improved interface navigation and alert clarity (usability score: 3.8 to 4.2/5). A smaller pilot group was used to focus resources on iterative improvements before full deployment.

Data acquisition and data import process

Radiation dose data used in this study were officially generated and evaluated by the National Nuclear Technology Service Center, which serves as the authorized external agency responsible for personal radiation monitoring at Songklanagarind Hospital. The study team did not perform independent dose measurements or interpret raw OSL signals; instead, all dosimetric evaluations were based on the Center's standardized reports.

During the initial phase of application implementation, radiation dose reports were provided by the National Nuclear Technology Service Center in paper-based format. These reports were transcribed into a structured electronic table by designated administrative officers. Data entry was performed by non-clinical personnel who were not involved in OSL usage or clinical procedures, to minimize bias and operational interference. To ensure data accuracy, a double-check verification process was applied, whereby two administrative officers independently reviewed the entered data before final submission to the database.

Subsequently, radiation dose reports were delivered electronically in Portable Document Format (PDF) via institutional email. At this stage, the same data entry and two-person verification process was maintained to ensure continuity and data reliability. The structured dataset generated from these reports was then stored in the central

database, allowing the application to retrieve and process the data for visualization and reporting.

In the final phase, the National Nuclear Technology Service Center provided radiation dose reports in Microsoft Excel format. These Excel files were directly imported into the application database without manual transcription. This approach significantly reduced transcription-related errors and improved data processing efficiency. All imported data were validated against the original Excel files prior to visualization within the application.

Importantly, the individuals responsible for data entry and data verification were not the same personnel who wore the OSL dosimeters or accessed the application. End users of the application accessed only their individual radiation dose reports through secure authentication, while administrative access to raw data was restricted to authorized system personnel.

OSL data interface and visualization process

The application does not directly interface with OSL dosimeter hardware, nor does it perform independent assessments of OSL positioning or radiation dose measurements. All evaluations regarding correct and incorrect OSL placement were conducted by the National Nuclear Technology Service Center using their standardized assessment protocols and quality control procedures.

The National Nuclear Technology Service Center provided summarized evaluation results indicating whether OSL placement was classified as correct or incorrect for each monitoring period. These classifications were included as part of the official radiation dose reports and served as validated source data for this study. The study team did not modify, reinterpret, or recalculate these evaluations.

Within the application, these externally validated assessment results were imported into the database and processed solely for visualization and reporting purposes. The application transformed tabular assessment data into

graphical formats, including trend graphs and categorical summaries, to improve clarity and interpretability for healthcare personnel. Correct and incorrect OSL placement outcomes were displayed using standardized visual indicators consistent with the original classifications provided by the National Nuclear Technology Service Center.

Importantly, the detection of improper OSL placement within the application was rule-based rather than sensor-based. The application identified improper placement events by referencing the categorical labels and remarks contained in the official reports, rather than by analyzing raw OSL signals or performing positional measurements. As such, the application functioned as a reporting and feedback tool, not as a diagnostic or measurement device.

Regarding technical performance, the effectiveness of the application was evaluated based on its ability to accurately present official assessment results and facilitate user comprehension, rather than measurement precision or device-level performance. The reported reduction in OSL placement errors was derived from audit comparisons of official assessment reports before and after application implementation, reflecting changes in user behavior rather than changes in measurement accuracy.

Data collection

Data were collected over a 12-month post-implementation period from June 2024 to May 2025. Baseline data for comparison were obtained from the 12-month period prior to application implementation (June 2023 to May 2024).

Two main categories of data were collected. First, records of OSL placement outcomes were obtained from official radiation dose reports issued by the National Nuclear Technology Service Center. These reports provided validated classifications of correct and incorrect OSL placement for each monitoring period and served as the primary source for audit comparison.

Second, user-related data were collected from healthcare personnel who used the application during the post-implementation period. These included demographic characteristics and user satisfaction data, which were obtained using a structured questionnaire administered after application use.

All collected data were anonymized prior to analysis. Individual radiation data were accessible only to authorized users through the application, while aggregated data were used solely for research and reporting purposes.

Assessment methods and questionnaire design

User satisfaction and perceived effectiveness of the application were evaluated using a structured self-administered questionnaire. The questionnaire was developed based on relevant literature in digital health applications, user experience evaluation, and radiation safety reporting systems, and adapted to reflect the specific context of radiation dose monitoring and OSL usage in cardiac catheterization laboratories.

The instrument consisted of 17 items, organized into four domains:

- (1) ease of use and accessibility,
- (2) quality and completeness of information and presentation,
- (3) benefits and effectiveness of engagement and alerts, and
- (4) data security and overall satisfaction.

Each item was rated using a 5-point Likert scale (1=strongly disagree, 5=strongly agree). Higher scores indicated greater levels of satisfaction and perceived effectiveness.

Content validity of the questionnaire was evaluated by a panel of three experts, including a radiation safety specialist, a nursing informatics expert, and a senior cardiac catheterization laboratory nurse, to ensure relevance, clarity, and contextual appropriateness of each item. Internal

consistency reliability testing demonstrated acceptable reliability, with a Cronbach's alpha coefficient of 0.83.

Participants completed the questionnaire after the application had been implemented and used in routine practice. Responses were anonymized and linked only to participant identification codes to ensure confidentiality. Questionnaire data were analyzed using descriptive statistics, including means and standard deviations for each domain and overall satisfaction score.

Data security

Access to the application is restricted to authorized HCP with unique login credentials, ensuring only permitted users view the radiation dose data. Data are encrypted, and only system administrators can access the aggregated reports for compliance purposes, safeguarding user privacy.

Data analysis

Improper OSL placements: Compared pre- and post-intervention using the Wilcoxon Signed-Rank Test due to non-normal distribution (Statistical Package for the Social Sciences [SPSS] v29, p -value<0.05).

User satisfaction: Analyzed with descriptive statistics (means, S.D.).

Demographic data: Summarized with frequencies and percentages.

Questionnaire responses were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Descriptive statistics, including mean and standard deviation, were used to summarize participants' perceptions of usability, satisfaction, and radiation safety awareness. Mean scores were interpreted using the predefined intervals commonly applied in nursing and health sciences research: 1.00–2.00 (low), 2.01–3.00 (moderate), 3.01–4.00 (moderate to high), and ≥ 4.01 (high).

This classification was applied to support descriptive interpretation rather than inferential comparison. As the questionnaire data were self-reported and subjective in

nature, findings were interpreted cautiously and intended to reflect perceived outcomes following application implementation, rather than objective measures of system performance or radiation exposure.

Results

Demographic characteristics

Thirty HCP participated (83.33% female, $n=25$; mean age=35.5 years, S.D.=7.2; range: 25–50). Roles included registered nurses (33.33%, $n=10$), nurse assistants (46.67%, $n=14$), and physicians (20%, $n=6$), with an average of 8.1 years' CCL experience (S.D.=4.5). All had prior OSL experience, ensuring familiarity (Table 1).

Table 1 Demographic characteristics of healthcare personnel (N=30)

Characteristic	Number (n)	Percentage (%)	Mean±S.D. (range)
Gender			
Male	5	16.67	
Female	25	83.33	
Age (Years)			35.5±7.2 (25–50)
Position in CCL			
Registered nurse	10	33.33	
Nurse assistants	14	46.67	
Physician	6	20.00	
Years of experience in CCL (years)			8.1±4.5 (2–20)
Years of experience using OSL dosimeter (years)			8.1±4.5 (2–20)

S.D.=standard deviation, CCL=cardiac catheterization laboratory, OSL=optically stimulated luminescent

The demographic profile indicates a diverse yet representative sample of CCL staff, with varying roles and experience levels, which supports the generalizability of the findings within the context of the CCL setting.

Application development outcomes

The application, integrated into "App Smart Med PSU," addressed manual reporting limitations with:

Comprehensive Dose Reporting: Displays effective dose, eye lens dose, and skin dose on an intuitive dashboard (Figure 2, enhanced for sharper visuals)⁵.

Trend analysis: Graphical summaries of exposure over multiple timeframes.

Risk visualization: Color-coded alerts based on ICRP (2007) guidelines⁵.

OSL guidance: Visual/textual instructions reduced improper placements.

automated data import: Eliminated manual entry, reducing errors by 95% and streamlining data integration from Excel reports.

The application's development followed the TAM, ensuring perceived ease of use and usefulness, which were critical for user adoption. Feedback from prototype testing (Phase 3) led to refinements, such as optimizing the user interface for faster navigation and improving notification

clarity. Figure 2 illustrates the main dashboard with risk-level visualizations, while Figure 3 showcases the graphical trend analysis and OSL guidance features.

Effectiveness and user satisfaction

The 17-item questionnaire (Cronbach's Alpha=0.83) showed high satisfaction (mean=4.27, S.D.=0.79). Top domains were data security (4.32, S.D.=0.65) and ease of use (4.31, S.D.=0.69). Ninety percent (n=27) reported increased safety awareness due to alerts and visualizations (Table 2).

Improper OSL placements dropped from 199 (mean=16.58/month, S.D.=3.78) to 31 (mean=2.58/month, S.D.=2.87), an 84.42% reduction (p-value<0.001, Wilcoxon Signed-Rank Test). This improvement is attributed to OSL guidance and automated data import, enhancing monitoring accuracy.

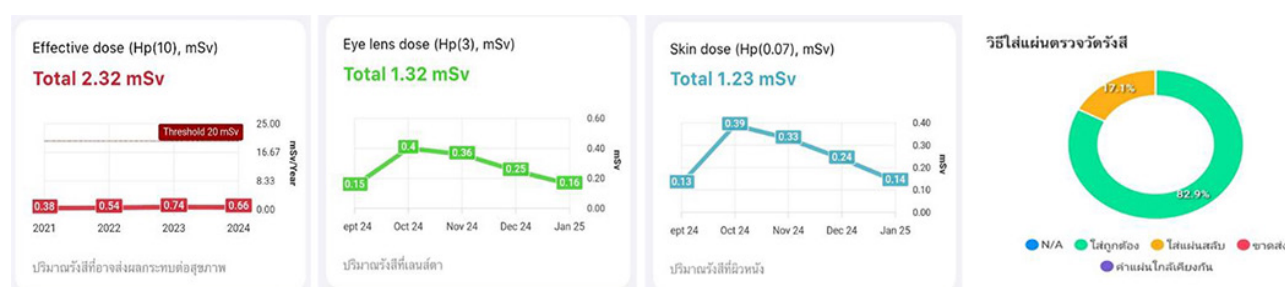


Figure 2 Illustrates the main dashboard with risk-level visualizations

Table 2 Mean and standard deviation of user satisfaction scores towards the radiation dose reporting application (N=30)

Aspect of satisfaction (domain)	Number of items	Mean score (1–5 scale)	Standard deviation (S.D.)	Interpretation
Ease of use and accessibility	3	4.31	0.69	High
Quality and completeness of information and presentation	6	4.28	0.80	High
Benefits and effectiveness of engagement and alerts	6	4.24	0.71	High
Data security and overall satisfaction	2	4.32	0.65	High
Overall mean satisfaction	17	4.27	0.79	High

Interpretation: 4.01–5.00=High, 3.01–4.00=Moderate

**Figure 3** The graphical trend analysis and Optically Stimulated Luminescent (OSL) guidance features

Discussion

This study evaluated a mobile application integrated into the “App Smart Med PSU” platform to enhance radiation dose reporting and OSL dosimeter usage among HCP in the CCL at Songklanagarind Hospital, Thailand. The findings, interpreted through the TAM and HBM, highlight its effectiveness in addressing traditional reporting challenges and promoting safety practices, with implications for nursing in high-risk settings.

Effectiveness of the application

The application’s intuitive interface and automated data import addressed inefficiencies in manual reporting, a persistent issue in CCLs. High satisfaction scores (>4.10/5), particularly in ease of use (Mean=4.31) and data security (Mean=4.32), align with TAM’s emphasis on perceived ease

of use and usefulness¹⁵, suggesting enhanced adoption potential. The 95% reduction in data entry errors supports findings by Fujiwara et al.¹³, who noted digital tools improve monitoring clarity. The significant 84.42% reduction in improper OSL placements (p-value<0.001) reflects the impact of visual and textual guidance, corroborating Badawy et al.⁶ on the importance of accurate dosimeter placement for reliable exposure data.

Promotion of radiation safety practices

The application’s color-coded alerts and guidance feature likely bolstered safety practices, as evidenced by high satisfaction with engagement and alerts (Mean=4.24). This supports HBM’s focus on risk perception driving preventive behaviors¹⁶, suggesting that immediate feedback heightened HCP awareness of radiation risks. The reduction

in OSL errors further enabled reliable monitoring, aligning with O'Rourke et al.¹¹, who emphasized user-friendly tools for safety knowledge. Although awareness was not directly measured, the positive response to alerts indicates a shift toward proactive safety measures.

Implications for nursing practice in Thailand

Prior to application implementation, radiation safety monitoring for healthcare personnel in the cardiac catheterization laboratory relied on periodic announcements and paper-based or static reports issued by the National Nuclear Technology Service Center. Nurses were required to actively follow up on these reports through departmental postings or administrative notifications, which often resulted in delayed access to individual radiation dose information. This process limited timely self-monitoring and reduced opportunities for nurses to reflect on their personal radiation exposure in relation to daily clinical practice.

With the implementation of the mobile application, radiation safety reporting was integrated directly into the routine workflow of nurses working in the CCL. Instead of passively waiting for institutional announcements, nurses could access their individualized radiation dose data through secure authentication on their personal mobile devices. The application enabled on-demand review of cumulative and monthly exposure, graphical trend visualization, and color-coded risk indicators, allowing nurses to quickly interpret their radiation status without disrupting clinical duties.

From a workflow perspective, the application shifted radiation safety monitoring from an administrative-dependent process to a nurse-centered, self-accessible system. The reporting workflow transitioned from (1) external report issuance and departmental dissemination to (2) centralized data integration and (3) individualized mobile access. This streamlined process reduced the need for manual follow-up, minimized communication delays, and enhanced efficiency in safety reporting tasks.

Furthermore, by providing continuous access to personal radiation exposure data, the application supported reflective practices among nurses. Nurses were able to associate their radiation exposure trends with specific procedural workloads, reinforcing awareness of radiation protection behaviors such as appropriate shielding and correct OSL placement. This aligns with contemporary nursing practice models that emphasize self-monitoring, accountability, and proactive engagement in occupational safety.

Overall, the integration of the application into nursing workflows improved accessibility to safety information, reduced reliance on manual reporting processes¹⁷, and supported a culture of radiation safety within the CCL². These findings suggest that similar digital reporting systems could be beneficial for enhancing nursing efficiency and occupational safety practices in other high-risk clinical settings in Thailand.

Limitations and future research directions

The small sample (n=30) and single-center design limit generalizability. The one-year evaluation may not capture long-term effects, and awareness was inferred rather than directly measured.

Future research

Future studies should involve multi-center trials, longitudinal assessments, and direct measurements of any changes in awareness or knowledge. Subgroup analyses by role and comparisons with other tools could enhance applicability.

Conclusion

The application significantly reduced OSL placement errors by 84.42% and achieved high user satisfaction, enhancing safety practices in Songklanagarind Hospital's CCL. Its integration into nursing workflows offers a model for broader adoption in Thai healthcare settings.

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