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Effect of Safety Measure Training Program on Performance of Nurses Dealing with Radioactive Iodine dean faculty of nursing may university

Hanan abdel hamid Gafer

hananabdelhamidgafer@gmail.com

Ain Shams University

Samah Faisal Fakhry

Ain Shams University

Laila Ahmed Abdel Hamid

Ain Shams University

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Abstract

Background: Radioactive Iodine (RAI / I-131) therapy is a primary and highly effective intervention for managing thyroid disorders, particularly differentiated thyroid cancer and hyperthyroidism. Despite its therapeutic benefits, handling unsealed radioactive materials poses significant occupational radiation hazards to nursing staff involved in patient care.

The medical use of nuclear medicine and radiation therapy has expanded significantly worldwide over recent decades, escalating the emphasis isolation, management, and waste disposal.

Aim: The aim of this study was to investigate the effect of a training program in safety measures applied by nurses dealing with radioactive iodine (RAI) patients on their performance. It hypothesized that the implementation of the training program will lead to a significant improvement in nurses' knowledge of RAI hazards and prevention, and to a significant improvement in nurses' safe practices when dealing with RAI patients. The methodology pursued in carrying out the study is presented under

− Technical

− Operational

− Administrative

− Statistical designs.

Methods Research Design: A one-group quasi-experimental study design featuring pre -test, immediate post-test, and 3-month follow-up assessments ($O_1 \rightarrow O_2 \rightarrow O_3$)conducted at Setting: El- Salam Oncology Center

A total coverage sample of all 60 nurses working at the center who met the inclusion criteria of directly managing RAI patients and having a minimum of one year of clinical experience. Sample size sufficiency was validated using G*Power 3.1.9.4 software.

Data Collection Tools:

1- Knowledge Self-Administered Questionnaire: Covered socio-demographic characteristics and contained 140 knowledge items (90 multiple-choice and 50 true/false questions) spanning.

2- Observational Performance Checklist: Comprised 119 items categorizing nursing care before, during, and after patient isolation, PPE donning/doffing procedures, patient discharge education, and waste management.

Results: Results revealed a substantial, statistically highly significant improvement ($p<0.001$) in nurses' overall knowledge and practices following the training program. Satisfactory knowledge levels rose from 38.3% pre-intervention to 100% immediately post-training, remaining high (95.0%) at the follow-up phase.

Significant performance improvements were also observed across all practical domains (e.g., room preparation, PPE donning/doffing, discharge instructions, and waste management).

Introduction and background

Radioactive Iodine (I-131) remains the cornerstone treatment for differentiated thyroid cancer (DTC) and severe hyperthyroidism. The clinical value of radioiodine lies in its ability to selectively target thyroid tissue while minimizing systemic exposure. However, working with unsealed radioactive sources presents inherent occupational risks to healthcare teams—especially nurses, who are on the front lines of patient care, monitoring, isolation, and radioactive waste management.

Globally, the use of nuclear medicine has expanded significantly over the past two decades, and with it, an increased focus has been placed on radiation safety measures in clinical settings. The International Atomic Energy Agency (IAEA) and World Health Organization (WHO) consistently emphasize the importance of professional training for staff handling radioactive substances to prevent unnecessary exposure, contamination incidents, and breaches of safety regulations (Volpe et al., 2024). The expansion of nuclear medicine services has increased healthcare workers' exposure to ionizing radiation (San, 2022; Volpe et al., 2024).

Radioactive iodine (RAI) therapy is an essential and widely used modality in the management of various thyroid disorders, particularly differentiated thyroid cancer, and hyperthyroidism. Its clinical value lies in its ability to selectively target thyroid tissue while minimizing systemic exposure. Despite its therapeutic benefits, the use of RAI involves handling unsealed radioactive materials, which presents inherent occupational risks to healthcare personnel, particularly nurses who are directly involved in preparation, patient care, isolation management, and waste handling (Nguyen et al., 2024).

Nurses, as front-line caregivers, are central to the safe care of RAI patients, yet multiple studies indicate gaps in their knowledge, inconsistent use of protective equipment, and variation in adherence to monitoring and documentation protocols (Volpe et al., 2024). Nurses working in RAI units are required to follow strict radiation safety protocols to protect themselves, other healthcare team members, patients, and the public. Ensuring compliance with these protocols demands adequate knowledge, practical skills, and confidence in applying safety procedures in a high-risk environment (Nguyen et al., 2024).

Nurses caring for RAI patients must be thoroughly versed in radiation physics and the three core principles of radiation protection: Time, Distance, and Shielding. Despite these critical responsibilities, national and international studies reveal notable gaps in theoretical knowledge, as well as inconsistencies in protocol adherence and personal dosimeter usage. These deficiencies often stem from a lack of specialized in-service training programs and reliance on informal, un standardized instructions.

Literature Review

Radioactive iodine (RAI) therapy is a specialized form of treatment widely used in the management of hyperthyroidism and differentiated thyroid cancer. Its increasing global use has led to a corresponding rise in the number of healthcare workers, especially nurses, who interact with patients receiving RAI. As frontline caregivers, nurses provide direct patient care before, during, and after RAI administration, making them uniquely vulnerable to occupational exposure to ionizing radiation. This review synthesizes existing research across several major domains: RAI therapy and clinical context, nurse responsibilities in RAI care, occupational radiation hazards, safety principles, gaps in knowledge and compliance, and the impact of training programs on nursing performance.

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Mechanism of Action

Radioactive iodine (RAI), primarily in the form of Iodine-131 (I-131), is a central therapeutic agent in the management of differentiated thyroid carcinoma, hyperthyroidism, and remnants of functioning thyroid tissue following thyroidectomy. Its clinical utility stems from the unique biological property of thyroid follicular cells to trap and organify iodine. Understanding the mechanism of action of RAI is essential for nurses working with RAI patients, as it explains both the therapeutic effects and the associated safety hazards. The process involves several integrated steps, including iodine uptake, intracellular transport, organification, hormonal incorporation, and subsequent emission of cytotoxic radiation that targets thyroid-derived tissue *(Donzé et al., 2024)*.

The therapeutic activity of I-131 begins with its selective uptake by thyroid follicular cells through the Sodium-Iodide Symporter (NIS), an intrinsic membrane glycoprotein located on the basolateral surface of thyrocytes. NIS functions as a secondary active transporter, co-transporting two sodium ions and one iodide ion into the cell down the gradient established by the Na?/K? ATPase pump. Because NIS selectively captures both stable and radioactive iodine, RAI accumulates primarily in thyroid tissue or metastatic lesions that retain NIS expression *(Palot Manzil and Kaur, 2025)*.

The level of NIS expression determines the efficiency of iodine uptake. Differentiated thyroid cancer cells (papillary and follicular carcinomas) typically maintain some degree of NIS activity. In contrast, poorly differentiated or anaplastic cancers often lose NIS expression, reducing the effectiveness of RAI therapy. Uptake can be significantly increased through Thyroid-Stimulating Hormone (TSH) elevation pharmacologically (recombinant human TSH) or physiologically (withdrawal of thyroid hormone). Increased TSH stimulates NIS transcription and membrane localization, resulting in higher iodine

trapping capacity. Once I-131 enters the cell, it concentrates in thyroid tissue at levels up to 20–40 times greater than plasma, enabling targeted radiation delivery while minimizing systemic exposure *(Blick et al., 2025)*.

After entering the thyroid follicular cell, iodine is transported across the apical membrane into the follicular colloid. This process is facilitated by two crucial proteins: Pendrin, a chloride/iodide exchanger on the apical membrane; and Anoctamin-1 (ANO1) and other carrier proteins contributing to iodide efflux *(Zhang et al., 2022)*.

In the colloid, iodine undergoes a process known as organification, catalyzed by the enzyme thyroid peroxidase (TPO) in the presence of hydrogen peroxide (H2O2). TPO oxidizes iodide to iodine and binds it covalently to tyrosyl residues on thyroglobulin, forming monoiodotyrosine (MIT) and diiodotyrosine (DIT). These are subsequently coupled to form the thyroid hormones thyroxine (T4) and triiodothyronine (T3) *(Yavuz and Puckett, 2025)*.

Although the organification process occurs in both normal and neoplastic thyroid cells, cancerous tissue often displays reduced or imperfect organification. Nevertheless, sufficient uptake still occurs to allow meaningful therapeutic radiation doses. The unique capacity of thyroid tissues to incorporate iodine into biological molecules explains why RAI selectively targets the thyroid gland, functioning both as a diagnostic tracer and as a therapeutic radionuclide *(Silaghi et al., 2021)*.

The mechanism of RAI allows destruction of thyroid remnants after surgery; functioning metastases in lymph nodes, lungs, or bone; and hyperfunctioning tissue in Graves' disease and toxic nodules. Cancer cells expressing NIS can internalize RAI like normal thyroid cells. Although metastatic lesions may show reduced organification, even partial uptake is sufficient to accumulate therapeutic radiation doses. The success of RAI therapy depends on adequate TSH stimulation; NIS expression levels in tumor cells; effective biological half-life; and absence of iodine contamination from diet or contrast agents. These factors guide both pre-treatment preparation and nursing protocols *(Zaletel et al., 2024)*.

OVERVIEW OF RAI THERAPY

Radioactive iodine (I-131) therapy is widely considered the gold standard for treating differentiated thyroid carcinoma and refractory hyperthyroidism due to its high efficacy, targeted uptake by thyroid tissue, and long-term therapeutic outcomes *(Ciarallo and Rivera, 2020)*.

I-131 is administered either in capsule or liquid form. Once ingested, it accumulates within thyroid remnants, where it delivers beta radiation that destroys malignant or overactive cells. Although clinically effective, the therapy's radiological consequences necessitate special handling because patients temporarily become mobile radiation sources capable of emitting gamma rays, necessitating isolation precautions for specific periods *(Taci et al., 2023)*.

The increased clinical reliance on RAI has heightened the demand for nurses trained in radiation protection. Nurses are required not only to assist in preparing patients for the therapy but also to monitor

and protect themselves from exposure during care activities. The absence of adherence to radiation protection regulations, especially concerning time, distance, and shielding, can significantly increase occupational radiation dose. For these reasons, RAI therapy cannot be delivered safely without competent nursing care that integrates clinical knowledge with radiation-protection competency *(Diawtipsukon et al., 2025)*.

Significance of the Study For Nursing Practice & Safety

Healthcare facilities are subject to stringent regulations governing the safe handling of radioactive materials. Adequate training ensures compliance with regulatory requirements, reducing the risk of legal and regulatory penalties associated with non-compliance. By understanding and implementing safety measures effectively, nurses can minimize the risk of adverse events associated with RAI therapy and can expand their expertise and advance their careers in specialized areas of healthcare, such as nuclear medicine and oncology nursing. Given the critical role of nurses in RAI therapy delivery and patient care, it is imperative to evaluate the impact of training programs focused on enhancing their knowledge, skills, and adherence to safety measuresin a highly specialized and high-risk area of nursing care.

Research aim and Hypotheses

The aim of this study was to investigate the effect of a training program in safety measures applied by nurses dealing with radioactive iodine (RAI) patients on their performance. It hypothesized that the implementation of the training program will lead to a significant improvement in nurses' knowledge of RAI hazards and prevention, and to a significant improvement in nurses' safe practices when dealing with RAI patients. The methodology pursued in carrying out the study is presented under

- Technical
- Operational
- Administrative

Statistical designs.

Methods

I. Technical Design:

This includes the details of the research design, study settings, and data collection tools.

Research design

A one-group quasi-experimental design with pre-post assessment was used in this study. This design was used because the more robust randomized design could not be applied due to logistical constraints related to disrupting regular work in the setting.

Setting

The study was conducted at El-Salam Oncology Center.

El-Salam Oncology Center is a two building has consist of

The first building	The second building
isolation rooms for RAI (1)	chemotherapy department with 37 beds
Inpatient department 36 beds with ;icu department 5 beds and operation rooms 3 beds.	Radiation department with 2 rooms and a Gamma unit and 5 outpatient rooms.

Subjects

Sample criteria: All the staff nurses working in the study setting formed the study population. Their total was 60 nurses. Of these,40are in the inpatient departments,10 are in the chemotherapy unit and gamma department ,and 10 are in the inpatient departments. The staff nurse was included in the study sample based on the following criteria:

Inclusion criteria:

Dealing with RAI patients (diagnostic or therapeutic). According to hospital policy, nurses rotate every 3 months from the incurrent department to another one. So all staff nurses deal with patients with RAI.

At least one year of experience in the setting.

Exclusion criteria: None.

Sample size: The sample size was calculated to detect an improvement in staff nurses' knowledge and practice with an Odds Ratio of 3.0, a small to moderate effect size according to *Chen et al. (2022*). Using the G*Power software package, Version 3.1.9.4 at 95% level of confidence and 80% power, the required sample size is 59.

Sampling technique: A convenience sampling technique was used in recruiting the nurses in the study sample according to the set criteria.

Data collection tools

Two tools were used in data collection, namely a self-administered questionnaire for knowledge and an observation checklist for practice.

Knowledge Self-administered questionnaire: This was developed by the researcher based on pertinent literature. It consists of the following parts:

Part 1:includednurses'personal characteristics such as age, gender, marital status, nursing qualification, experience years, previous training in radiotherapy and in occupational safety, etc., in addition to identification data such as work hospital and unit.

Part 2: This part was dedicated to assessing staff nurses' knowledge related to RAI. It involved90 multiple-choice questions (MCQ) and 50 True/False questions. They covered nurses' knowledge about RAI nature/hazards, nurse role, PPE (Personal Protective Equipment), isolation, waste management, patient education, measurement, emergencies, and support.

Scoring: For each question, a correct response was scored 1, and an incorrect zero. For each area of knowledge and for the total questionnaire, the scores of the items were summed up and the totals divided by the number of corresponding items, giving mean scores. These scores were converted into percentage scores and means and standard deviations were computed. For categorical analysis, knowledge was considered satisfactory if the percentage score was 60% or more and unsatisfactory if less than 60%.

Observation checklist: The researcher developed this tool based on*(Abdel Hamid, 2015)*. It was intended to assess staff nurses' safe practices before and after the implementation of the training program. It involved129 items to assess the staff nurse's practice in each of the following areas:

Admission/Discharge:

Admission assessment (8 items): e.g., "Orient patient to the ward"

Admission instructions (5 items): e.g., "instructed the patient about radiation precautions"

Occupational safety for:

Personnel(4 items): e.g., "Nurse is wearing radiation film badge "

Patient room(13 items): e.g., "Nurse prepared disposable cups as per protocol"

Outside room(5 items): e.g., "Warning signs"

Admission(3 items): e.g., "Wear overshoes while standing in the room"

Post admission(8 items): e.g., "Assess if nausea persists"

Discharge(6 items): e.g., "Keep signs in place"

Discharge instructions(28 items): e.g., "The nurse instructed about avoiding sharing bed for 5 days"

Personal occupational safety:

Preparation before isolation room entry(5 items): e.g., "Verifies dosimeter is worn correctly"

- *Donning PPE*(10 items): e.g., “Dons double gloves”
- *Inside room*(10 items): e.g., “Uses disposable equipment”

Doffing PPE(10 items): e.g., “Removes lead apron last”

Documentation(4 items): e.g., “Records entry/exit times”

Scoring: The items observed to be done were scored “1” and the not done were scored “0. The items checked “not applicable” were dismissed and discounted from the total items. For each area, the scores of the items were summed up and the total divided by the number of items, giving a mean score for the area. These scores were converted into percentage scores and means and standard deviations were computed. For categorical analysis, the practice was considered adequate if the percent score was 60% or more, and inadequate if less than 60%.

The data collection tools used in this study, including the questionnaire and the observation checklist, were specifically developed by the researchers for the purpose of the present study. Both tools were developed based on a comprehensive review of relevant literature and previous studies and were designed to address the study objectives and assess the required variables. To the best of the researchers’ knowledge, neither the questionnaire nor the observation checklist has been previously published or used in any other study.

II. OPERATIONAL DESIGN

In this design, a description of the preparatory phase of the study, the pilot study, and the fieldwork is presented.

Preparatory phase

This phase involved the preparation of the tools to be used in data collection. The researcher conducted thorough review of all available literature evidence relevant to the study topic. This was based on a review of the related textbooks and publications in scientific journals, in addition to an internet journal search. At this stage, the tools were prepared in their preliminary form. They were then presented to a group of experts to examine their face and content validity. Their opinions were sought for each item regarding its relevance and clarity, in addition to their overall opinion about the form. They were asked to express their views and comments, and provide suggestions for any item addition/omission. Necessary modifications were made accordingly.

Pilot study

A pilot study was conducted on 6staff nurses representing 10% of the total sample of staff nurses in the study settings, the pilot study was carried out on a sample of nurses from another setting. Its purpose was to examine the feasibility of the study and the clarity and pertinence of the data collection tools. It also helped the researcher estimate the time needed to fill outthe forms.Required modifications were

made based on the pilot study results, and the tool was finalized accordingly. The pilot nurses were not included in the main study sample to avoid any contamination bias, given the intervention nature of the study.

Validity and reliability of the tools: Upon preparation of the tools, they were presented to a panel of experts in nursing administration and radiology. They confirmed their face and content validity.

The reliability of the data collection tools was assessed through the internal consistency approach. yThey demonstrated a very high level of reliability for the knowledge tool aanc level for the practice checklist, as demonstrated below. le ceptab

Scale	N of Items	Coefficient
Knowledge	140	Spearman-Brown: 0.91
Practice	119	Spearman-Brown: 0.58

Fieldwork

The fieldwork for this study was carried out through assessment, planning, implementation, and evaluation phases.

Assessment phase

During this phase, after securing all official permissions, the researcher started the process of staffnurses' sample recruitment according to the eligibility criteria. The researcher met with the director of the hospital and the head nurses of the selected departments/units to determine the most suitable time to collect data. Then, she introduced herself to the staffnurses and obtained their verbal consent to participate in the study after explaining the aim of the study and its procedures and clearly informing them about their rights. Then, the researcher handed the knowledge questionnaire to each staff nurse along with full instructions about filling it out. The researcher was present all the time to respond to any queries.

The filled forms were then collected, and a schedule for the observation of the staff nurses' practice was set. For staff each nurse, the practice of the steps of admission/discharge and personal occupational safety was assessed by the researcher through direct observation using the related data collection form.

knowledge responses and nurses' practices obtained at this phase constituted the baseline or pretest for further comparisons and assessment of the effectiveness of the intervention. They were also used to guide the preparation of the educational program and booklet.

Planning phase:

During this phase, the researcher prepared the training program and its related questioners. This was based on the knowledge gaps and deficiencies in staff nurses' performance based on the analysis of the

collected baseline pre-intervention data. These helped identify their learning needs and develop the training program in addition to the relevant information from pertinent literature.

The researcher developed the training program and related questioners. The main goal of the program was to improve staff nurses' knowledge and performance related tothe risks of radioactive iodine(RAI) and the safety measures that should be applied in the treatment of patients undergoing RAI therapy.

The knowledge specific objectives were the nurse’s ability to define the basic principles, importance, and scope of radiation safety in the care of patients receiving RAI, describe the safe preparation and management of RAI therapy, and the nurse's role in ensuring patient safety, environmental protection, and regulatory compliance, select, use, and properly dispose of Personal Protective Equipment (PPE), explain strict adherence to institutional isolation measures to maintain a radiation-safe healthcare environment, list the practical skills and protocols needed to safely manage RAI waste and respond effectively to pollution incidents, educate patients and families about safety precautions after radioiodine therapy, mention practical skills for monitoring radiation exposure, keep accurate records, and participate in audits, respond safely to radiation-related emergencies, and appropriately report to prevent escalation, and ensure compliance with hospital radiation safety policies, explain the provision of psychological support, e effective communication, and empathy to enhance patient confidence, reduce anxiety, and ensure cooperation with radiation precautions.

The specific objectives related to practical skills included the ability to read the film badge, measure radiation exposure every 3 months, apply Gamma worker protection policies, and document and write reports. The psychometric objectives included the ability to work-in a group, manage scientific dialogue and discussion, and evaluate performance.

The program’s total duration was 17hours of theoretical and practical hours, divided into 10 sessions, with an average of one and a half to two hours per session. The venue was the lecture hall at El-Salam oncology Center. The teaching methods included mini-lectures, group discussions, small group discussions (10-15), role playing, brainstorming, and practical applications. The teaching media included the PowerPoint projector, videos, flipcharts, radiation safety labels and codes, demonstration materials for PPE, RAI Patient Care Protocol Guide, and radiation monitors (sample dosimeter). In addition, training program prepared by the researcher (Appendix I) was distributed to the attending nurses as a reference for future use.

Implementation phase:

The staff nurses in the study group were divided into small groups, each group having 8-10 nurses. The program was conducted through 10 sessions, 2-3 sessions per week for each group over a period of 4 weeks. The session duration was about one and a half to two hours. The total time for program implementation was 17 hours per group. The program implementation lasted from October 2025 to June 2026.

At the beginning of the first session, the researcher provided the attendants with an orientation to the aim and the specific objectives of the training program. Also, they were briefed about the three phases of the study and the program sessions regarding time, duration, place, and content. The researcher emphasized the importance of regular attendance and active participation.

Different teaching and learning methods were used during the sessions. These included interactive mini-lectures, group discussions, demonstration-re-demonstration, and role-playing. The instructional media included data show, pictures and posters, a whiteboard, and the educational brochure the program was presented in a clear and concise form with the application of adult learning principles.

The researcher started each session with a briefing of the previous session, followed by the objectives of the new one. She used simple language, with the use of motivation and reinforcement techniques. Direct reinforcement was in the form of a copy from thetraining program given to each nurse for use as a future reference. Nurses were encouraged to ask for any elaboration, explanation or interpretation of any item addressed in the sessions.

Evaluation phase:

After the completion of the implementation phase, an immediate posttest was undertaken using the same tools previously used in the pretest assessment to measure the improvements instaff nurses' knowledge and performance. The follow-up assessment was carried out after three months using the same data collection tools.

III. Administrative Design:

An official letter was addressed from the Dean of the Faculty of Nursing to the director of the selected study setting seeking permission to conduct the study. Copies of the study protocol and data collection forms were enclosed. Then, the researcher met with the medical and nursing directors to explain the study aim and procedures and obtain their permission and cooperation during the fieldwork.

Ethical considerations:

The study complied with principles of the declaration of Helsinki and was approved by the research ethics committee of faculty of nursing , Ain Shams University Cairo(code number 30-9-2024) . The researcher clearly explained and informed nurse mangers the goals and procedures of the study and obtained written informed consent about their right to withdraw any moment without providing any reason were guaranteed confidentiality and anonymity of the data provided only for research purposes.

IV. Statistical Design:

Descriptive statistics were used to present data as frequencies and percentages for qualitative variables, and means, standard deviations, and medians for quantitative ones. The internal consistency approach was used to assess the reliability of the tools, with estimation of Spearman-Browncoefficients for the

knowledge and practice tools. Analytic statistics included chi-square tests for comparing categorical variables, and Spearman's rank correlation for the relations among quantitative and ranked variables. Multiple regression analysis was used to identify independent predictors of the scores of knowledge and practice. The level of statistical significance was set at p-value <0.05. All analyses were carried out on the SPSS 20.0 statistical package

Results

Table 1:Personal job characteristics of nurses in the study sample (n=60)

	Frequency	Percent
Age:		
<40	23	38.3
40+	37	61.7
Range	24-55	
Mean±SD	40.6±5.7	
Median	42.0	
Sex:		
Male	1	1.7
Female	59	98.3
Marital status:		
Unmarried (single/divorced/widow)	9	15.0
Married	51	85.0
Nursing qualification:		
Diploma	54	90.0
Bachelor	6	10.0
Job position:		
Director/head nurse	12	20.0
Staff nurse	48	80.0
Experience years (total):		
<20	18	30.0
20+	42	70.0
Range	<1-28	
Mean±SD	17.8±7.2	
Median	20.0	
Experience years (RAI):		
<1	54	90.0
1+	6	10.0
Range	<1-5	

	Frequency	Percent
Mean±SD	0.2±0.8	
Median	0.0	
Had training in RAI therapy	1	1.7
Had training in safety	0	0.0

The study sample included 60 nurses whose ages ranged between 24 and 55 years, with a median of 42.0 years, as shown in Table 1. All but one were females (98.3%), with the majority married (85.0%), carrying diploma degrees in nursing (90.0%), and working as staff nurses (80.0%). The median of their years of total experience in nursing was 20.0, but their length of experience in RAI therapy was mostly less than one year (90.0%). Only one (1.7%) nurse had attended previous training in RAI therapy, and none in safety.

Figure 1: Distribution of the staff nurses in the study sample according to their nursing qualifications

Figure 1 shows that slightly more than two-thirds (68.3%) of the staff nurses in the study sample carried a secondary nursing school diploma, while 21.7% carried a technical institute diploma. Only 10.0% had a bachelor's degree in nursing.

Figure 2: Distribution of the nurses in the study sample according to their work departments/units

As Figure 2 shows, more than one-half of the nurses in the study sample were working in outpatient departments and in wards (56.7%). On the other hand, the lowest percentage was working in radiotherapy (5.0%)

Part II. Staff Nurses' knowledge throughout the intervention

Table 2: Nurses' knowledge of RAI and its hazards and related safety measures throughout the study phases

Satisfactory (60%+) Knowledge of RAI	TIME						X^2 (p-value)	X^2 (p-value)
	Pre		Post		FU			
	No.	%	No.	%	No.	%	Pre-post	Pre-FU
Nature/hazards	9	15.0	58	96.7	30	50.0	81.14 (<0.001*)	16.75 (<0.001*)
Nurse role	28	46.7	60	100.0	60	100.0	43.64 (<0.001*)	43.64 (<0.001*)
PPE	36	60.0	59	98.3	35	58.3	26.73 (<0.001*)	0.03 (<0.001*)
Isolation	16	26.7	60	100.0	52	86.7	69.47 (<0.001*)	43.98 (<0.001*)
Waste management	23	38.3	60	100.0	47	78.3	53.49 (<0.001*)	19.75 (<0.001*)
Patient education	34	56.7	60	100.0	53	88.3	33.19 (<0.001*)	15.09 (<0.001*)
Measurement	39	65.0	60	100.0	48	80.0	25.46 (<0.001*)	3.39 (0.07)
Emergencies	31	51.7	60	100.0	55	91.7	38.24 (<0.001*)	23.64 (<0.001*)
Support	24	40.0	57	95.0	36	60.0	41.37 (<0.001*)	4.80 (0.03*)

(*) Statistically significant at p<0.05

Table 2 points to generally low percentages of staff nurses having low pre-intervention satisfactory knowledge of RAI. It ranged between 15.0% for the knowledge of RAI nature and hazards, and 65.0% for its measurements. At the post-intervention phase, there were statistically significant improvements in all knowledge areas, reaching 100.0% in most areas (p<0.001). The significant improvements were maintained through the follow-up phase, with some declines in some areas. The areas with the highest declines were those of RAI nature and hazards, which dropped to 50.0%, and PPE, which dropped to 58.3%. Nonetheless, the levels were still significantly higher in comparison to the pre-intervention levels.

(*) Statistically significant at p<0.05

Figure 3: Total staff nurses' knowledge of RAI and its hazards and related safety measures throughout the study phases

As Figure 3 displays, fewer than two-fifths (38.3%) of the nurses in the study sample had satisfactory total knowledge in the pre-intervention phase. This rose to 100.0% in the post-intervention phase and slightly declined to 95.0% in the follow-up phase. These improvements were statistically significant ($p<0.001$).

Table3: Correlations between nurses' knowledge and practice overall scores and their characteristics

	Spearman's rank correlation coefficient	
	Knowledge scores	Practice scores
Practice score	.455**	
Nurse age	.070	.042
Qualification	-.114	.014
Experience (total)	.041	-.005
Experience (current)	-.001	.014
Patient age	-.083	.020

(**) Statistically significant at p<0.01

Table 3 indicates a statistically significant moderate positive correlation between nurses' overall score of knowledge and practice phase (r=0.455). Meanwhile, no significant correlations were revealed between their knowledge and practice and any of their characteristics or patient age.

Discussion

Continuing professional education is increasingly recognized as an essential strategy for strengthening radiation safety culture, minimizing occupational exposure, and promoting high-quality patient care in environments involving ionizing radiation*(Wahab &Younis, 2025)*. Research has demonstrated that innovative educational approaches, including multimedia-based learning and theory-driven behavioral interventions, produce sustained improvements in radiation safety knowledge and protective practices among nurses*(*Hemati et al., 2025)

This reinforces the importance of incorporating structured, evidence-based radiation safety education into continuing nursing education and institutional competency programs to ensure the safe management of patients receiving RAI while protecting both healthcare professionals and the public from unnecessary radiation exposure*(*Shubayr& Dailah, 2026*)*.

This study’saim was to investigate the effect of a training program onsafety measures applied by nurses dealing with radioactive iodine (RAI) patients on their performance. The present study evaluated the effectiveness of a structured educational program on nurses' knowledge and practices regarding the care of patients receiving radioactive iodine (RAI) therapy. The findings demonstrated substantial deficiencies in nurses' baseline knowledge of RAI therapy and radiation safety, accompanied by inadequate adherence to recommended safety practices. Following implementation of the training program, statistically significant improvements were observed in both knowledge and practice scores, and these gains were largely sustained during follow-up. The educational intervention thus led to significant improvements in nurses’ total knowledge and practices. Therefore, the research hypotheses set can be accepted.

The findings of this study clearly demonstrate that a structured training program grounded in adult learning principles produces a profound, statistically significant improvement ($p < 0.001$) in both the knowledge base and practical clinical performance of nurses caring for radioactive iodine (RAI / I-131) patients.

was hypothesized that the implementation of the training program would lead to a significant improvement in nurses’ knowledge of RAI hazards and prevention, and to a significant improvement in nurses’ safe practices when dealing with RAI patients.

The present study evaluated the effectiveness of a structured educational program on nurses' knowledge and practices regarding the care of patients receiving radioactive iodine (RAI) therapy. The findings demonstrated substantial deficiencies in nurses' baseline knowledge of RAI therapy and radiation safety, accompanied by inadequate adherence to recommended safety practices. Following implementation of the training program, statistically significant improvements were observed in both knowledge and practice scores, and these gains were largely sustained during follow-up. The educational intervention thus led to significant improvements in nurses’ total knowledge and practices. Therefore, the research hypotheses set can be accepted.

Similar improvements following targeted radiation safety education have been reported in previous studies, which demonstrated that structured training significantly enhances healthcare professionals' knowledge and compliance with radiation protection principles*(*International Atomic Energy Agency, 2022; *Abdel-Aziz et al., 2023)*.

Continuous professional education is therefore considered a cornerstone for promoting patient and occupational safety in environments involving ionizing radiation.

The nurses in the current study sample covered a wide range of ages, from the third to the sixth decades, which would help in identifying any effect of age on their knowledge and experience. The sample had only one male nurse, which is in contradiction with the current gender trends in the nursing profession. The predominance of female participants is consistent with the global nursing workforce, although the presence of only one male nurse limits any meaningful comparison by gender. Previous research has

similarly shown that demographic characteristics alone are poor predictors of radiation safety competence, whereas specialized education and clinical exposure are more influential determinants of nurses' preparedness for radiation-related care*(*World Health Organization, 2024*)*.

As regards the nurses' qualifications in the present study, the majority had diploma degrees.Although theyhad long experience in nursing, with a median of 20.0 years, the majority had less than one year of experience in RAI therapy. Moreover, they had almost no previous training in RAI therapy or safety. This might explain their deficient pre-intervention knowledge and practice.This finding reflects the specialized nature of nuclear medicine services, where only a limited proportion of nurses receive direct exposure to radiation-related clinical practice*(*Kim et al., 2023).

Meanwhile, according to Abo El-Magd et al. (2022) and the *International Commission on Radiological Protection(2022)*, professional competence in radiation safety depends not only on years of clinical experience but also on continuous specialty-specific education and regular competency assessment. Nurses working outside specialized nuclear medicine units may have limited opportunities to acquire practical experience in radiation protection, making continuing education essential. They demonstrated that previous radiation safety training is one of the strongest predictors of nurses' knowledge and compliance with radiation protection guidelines.

According to the present study findings, nurses' pre-intervention knowledge of RAI was mostly unsatisfactory. The knowledge areas with the least satisfactory responses were those related to RAI nature and hazards, isolation, and waste management. Conversely, the knowledge areas with the highest percentages of pre-intervention knowledge were those of PPE and measurements. These deficiencies are concerning because these topics constitute fundamental components of safe nursing care for patients receiving RAI therapy. Inadequate knowledge in these areas may increase the risk of unnecessary radiation exposure for healthcare workers, patients, family members, and the surrounding environment. Conversely, these nurses had relatively better knowledge regarding personal protective equipment (PPE) and radiation measurements, possibly because these concepts are commonly addressed during general infection prevention and occupational safety training.

Similar knowledge gaps have been identified among nurses working in oncology and nuclear medicine departments, highlighting the persistent need for specialized radiation safety education. This was reported in a study of nurses' knowledge and compliance with radiation protection precautions in nuclear medicine units in Egypt *(*El-Sayed et al., 2023). Along the same lines, *Alomairy(2024)* and *Alshamrani et al. (2026)* identified knowledge gaps among nurses in nuclear medicine departments in Saudi Arabia.

Post-intervention, there were significant improvements in all knowledge areas, reaching 100.0% in most areas. These were maintained through the follow-up phase, with some declines in some areas. The findings indicate that the implemented study intervention succeeded in improving nurses' knowledge, and this was confirmed by the results of multivariate analysis. The sustained improvement observed

during follow-up indicates that learning was not merely temporary but was consolidated into longer-term knowledge.

The effectiveness of the program could have more than one explanation. The first is that the program was structured and tailored to respond to the identified nurses' learning needs, ensuring that the educational content addressed existing knowledge and practice gaps. The second is the use of adult learning approaches in the implementation of the program, with encouragement of active participation,discussion, demonstration, and immediate feedback, which are known to enhance learners' engagement and knowledge retention. The The third is the program berchoer prepared by the researcher and distributed to the attendees. It helped them to track the training sessions, and in addition, it served as a future reference, which could explain the retention of the improvements through the follow-up phase. Also, combining theoretical instruction with practical demonstrations is consistent with contemporary educational approaches emphasizing experiential learning and competency-based training in healthcare settings *(*Cant& Cooper, 2023; *WHO, 2024)*.

Similar findings have been reported in recent quasi-experimental studies showing that structured educational programs significantly improve nurses' understanding of radiation hazards, radiation protection principles, and safe patient management, with knowledge retention persisting for several months following trainingin studies in North Korea *(*Kim et al., 2023), and in Saudi Arabia*(Alqahtani et al.,2024)*.

Although knowledge remained significantly higher than Although knowledge remained significantly higher than baseline during follow-up, modest declines were observed in specific domains, particularly regarding the nature and hazards of RAI and the appropriate use of PPE. Such declines are expected because knowledge retention naturally decreases over time when newly acquired information is not regularly reinforced or applied in clinical practice*(*Lee et al., 2022). These findings emphasize the importance of continuous professional development, periodic refresher courses, and regular competency assessments to maintain radiation safety knowledge. Reinforcement through ongoing education, simulation exercises, and workplace reminders has been shown to improve long-term retention and sustain safe clinical behaviors among healthcare professionals working with ionizing radiation*(International Atomic Energy Agency, 2023)*.

As regards the nurses' demographic and job factors significantly related to their pre-intervention knowledge, the current study identified statistically significant relations with their qualifications, with diploma degree nurses having more satisfactory knowledge. This might be explained by differences in clinical responsibilities rather than educational preparation. For instance, the diploma nurses in the study setting were more likely to provide direct bedside care for patients receiving RAI therapy, allowing them to gain practical experience through repeated exposure to radiation safety procedures. Conversely, bachelor's degree nurses may have assumed more supervisory or administrative responsibilities, resulting in less frequent, direct involvement in specialized patient care. The finding supports previous evidence suggesting that specialty-specific education and continuous professional training exert a

greater influence on radiation safety competence than demographic or educational characteristics alone*(*Kim et al., 2023).

In addition, the bivariate analyses of the current study demonstrated a statistically significant relationshipbetween nurses' pre-intervention knowledge and work departments. For instance, those nurses working in ICU/OR and chemotherapy departments had more satisfactory knowledge. This could be due to their more frequent encounters with RAI patients in these departments, with stricter adherence to safety protocols required in these highly technical clinical environments. In line with this, it has been reported that healthcare professionals working in high-risk departments are generally more familiar with hazardous material handling and multidisciplinary safety practices, which may facilitate the acquisition of radiation safety knowledge*(International Commission on Radiological Protection, 2022;* EL-Sayed et al., 2023).

Overall, the educational intervention led to statistically significant improvements in nurses' total practices inthe post-intervention phase. These improvements persisted throughout the follow-up period, indicating successful translation of theoretical knowledge into clinical practice. and follow-up phases. The multivariate analysis confirmed the positive effect of the intervention on nurses' total practice, as it was identified as its only significant independent predictor, highlighting the central role of structured continuing education in promoting safe nursing care.

The success of the current study's educational intervention could be attributed to the same three factors previously mentioned. In addition, the practical part of the session, with demonstrations using real objects and authentic equipment, simulationexercises, and hands-on training, could be of major importance in the success of the program. These likely enhanced participants' psychomotor skills, confidence, and adherence to recommended radiation protection procedures. Contemporary nursing education literature consistently demonstrates that competency-based training combining theoretical instruction with simulation is more effective than didactic teaching alone in improving clinical performance and sustaining behavioral change*(*Cant& Cooper, 2023*)*.

Conclusion

The main study findings indicate clear deficiencies in nurses' knowledge of Radioactive Iodine (RAI) and its therapy, particularly regarding its nature and hazards, isolation, and waste management. Likewise, their practices of the patient admission/discharge process and of personal radiation safety are mostly inadequate. The implementation of the educational intervention is effective in improving nurses' total knowledge and practices, and this is retained through the follow-up phase. The direct and independent positive effect of the intervention is confirmed by the multivariate analysis.These findings provide strong evidence supporting the incorporation of regular radiation safety training into nursing education and clinical practice to enhance occupational safety, improve patient care quality, and ensure compliance with international radiation protection standards.

Limitations of existing training programs

Despite their effectiveness, existing training programs often suffer from limitations such as short duration or limited follow-up; small sample sizes; focus on radiology rather than RAI nursing; lack of hands-on simulation training; and poor integration into institutional culture. These gaps demonstrate the need for comprehensive, RAI-specific training programs tailored to the unique responsibilities of nurses caring for radioactive patients (Alzahrani et al., 2024).

Identified gaps in existing training programs include lack of RAI-focused training interventions; insufficient evidence on nurse performance outcomes; limited research in Middle Eastern/Egyptian contexts; inadequate evaluation of long-term compliance; and fragmented guidelines for RAI nursing practices. There is no single, unified, comprehensive guideline specifically designed for nurses who care for radioactive iodine (RAI) patients, and instead, relevant instructions are scattered across multiple sources, disciplines, and documents (PetranovićOvčariček et al., 2025).

Fragmented guidelines refer to a situation in which recommendations related to RAI nursing care are dispersed across multiple regulatory, medical, and institutional documents; inconsistent, or incomplete, rather than being presented in one integrated, nurse-focused framework, leading to variability in practice and gaps in compliance. Nurses must rely on multiple, partially overlapping documents, often written for different professional groups, making consistent application difficult (Ling et al., 2023).

Guidelines are written for different audiences. IAEA / ICRP guidelines focus on radiation protection principles and regulatory compliance. NCRP provides technical radiation safety standards. American Thyroid Association (ATA) focuses on medical management of thyroid disease. Hospital policies address local operational procedures. None of these documents are written specifically for nursing practice, yet nurses are expected to integrate them in daily care (Rodrigues and Yu, 2025).

Nursing roles are implicit, not explicit. Most guidelines describe what should be done (e.g., maintaining distance, use shielding), but do not clearly define nursing-specific actions ,implication and recommendation

Efficacy of the Structured Educational Intervention

Immediately following the 17-hour training program, 100% of the participating nurses achieved satisfactory overall knowledge, with perfect scores across key practical domains (including PPE donning/doffing, room preparation, patient education, and waste management).

This immediate shift reinforces the recommendations of the International Atomic Energy Agency (IAEA, 2022; SSG−46), which advocate for competency-based, site-specific radiation protection training over generic orientation modules. The multiple linear regression analysis further confirmed that the training program was the single strongest independent predictor of score improvements ($\beta=20.91$ for knowledge, $\beta=38.76$ for practice; $p < 0.001$), outweighing variables like age, general nursing experience, or educational background. This confirms that specialized safety behaviors require explicit, targeted instruction rather than general clinical longevity.

. Skill Retention and Knowledge Decay Dynamics

At the 3-month follow-up, total satisfactory knowledge remained exceptionally high at 95.0%, and clinical performance retained 100% adequacy. However, a subtle decay was observed in theoretical domains—specifically regarding RAI physical characteristics/hazards (dropping from 96.7% post-test to 50.0% at follow-up) and specific PPE principles (dropping to 58.3%).

These findings directly support the decay models documented by

(Mendoza & Santos (2023), who highlighted that while motor skills and routine protocol execution (e.g., waste disposal and step-by-step donning/doffing) remain resilient due to daily workplace repetition, abstract physics concepts deteriorate rapidly without visual job aids or periodic micro-learning. Additionally, the moderate positive correlation between overall knowledge and practical compliance ($r = 0.455, p < 0.01$) underscores that while practical adherence can be driven by standardized routine, robust theoretical knowledge

RECOMMENDATIONS

Based on the main present study findings, the following recommendations are proposed.

- Recommendations for Nursing Practice:
    - Apply this competency-based training program on a wide scale to improve nurses' knowledge and skills.
    - Implement mandatory radiation safety orientation programs for all nurses newly assigned to nuclear medicine and RAI therapy units.
    - Conduct regular refresher training sessions to reinforce knowledge and maintain competency in radiation protection principles and RAI patient care.
    - Develop standardized nursing protocols and checklists for the admission, care, isolation, and discharge of patients receiving RAI therapy to promote consistent adherence to evidence-based radiation safety practices.
    - Ensure the availability of essential radiation protection resources, including PPE, dosimeters, radiation warning signs, disposable materials, and written safety guidelines.
- Recommendations for Nursing Administration:
    - Establish periodic competency assessments of nurses working in nuclear medicine units using standardized knowledge tests and observational practice checklists.
    - Appoint a radiation safety nurse in each nuclear medicine unit to monitor compliance, provide mentoring, and coordinate continuing education.
    - Periodic audits of nurses' compliance with radiation protection standards and feedback on performance.

- Recommendations for Nursing Education:
    - Incorporate comprehensive radiation safety content into undergraduate nursing curricula.
    - Expand the use of simulation-based education to allow students and staff nurses to practice radiation safety in realistic but risk-free clinical scenarios.
    - Provide accessible educational resources, including printed manuals, electronic learning modules, instructional videos, and mobile applications that support self-directed learning in radiation protection.
- Recommendations for Hospital Policy:
    - Develop institutional policies requiring annual certification or recertification in radiation safety for nurses assigned to RAI therapy units.
    - Implement regular environmental and clinical safety audits to monitor compliance with national and international radiation protection standards.
    - Ensure adequate staffing levels to reduce workload and allow nurses sufficient time to perform radiation safety procedures correctly without time pressure.
- Recommendations for Future Research:
    - Conduct multicenter studies with larger samples from different hospitals to improve generalizability.
    - Evaluate the long-term effectiveness of educational interventions with longer follow-up periods.
    - Compare different educational approaches, such as simulation-based, blended learning, e-learning, and traditional classroom, to determine the most effectiv

Provide accessible educational resources, including printed manuals, electronic learning modules, instructional videos, and mobile applications.

Abbreviations

I-131: Iodine-131, a radioactive isotope of iodine used in the diagnosis and treatment of thyroid disorders, particularly differentiated thyroid cancer. RAI: Radioactive Iodine, referring to radioactive iodine therapy using I-131. ALARA: As Low As Reasonably Achievable, a principle used to minimize radiation exposure. PPE: Personal Protective Equipment. TLD: Thermoluminescent Dosimeter, used to monitor occupational radiation exposure. WHO: World Health Organization. ICRP: International Commission on Radio logical Protection. NRC: Nuclear Regulatory Commission. CT: Computed Tomography.

Declarations

Ethical Approval and consent to participate.

study was obtained from the Research Ethics Committee of Ain Shams University 30- 9 -2024. The study was conducted in accordance with the ethical principles of research involving human participants. The purpose and procedures of the study were explained to all participating nurses, and written informed consent was obtained from each participant before enrollment. Participation was voluntary, and participants were informed that they had the right to withdraw from the study at any time without any consequences.

Consent for publication

Not applicable.

Data availability

The data that support the finding of this study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests .

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Author contributions

HA contributed to the conception and design of the study, data collection, data analysis, interpretation of the findings, and drafting and revising the manuscript. SF contributed to the supervision of the study, development and refinement of the research design, critical review of the methodology, interpretation of the findings, and critical revision of the manuscript. LAAH contributed to data collection, data analysis, interpretation of the findings, and critical revision of the manuscript. All authors read and approved the final version of the research.

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Figures

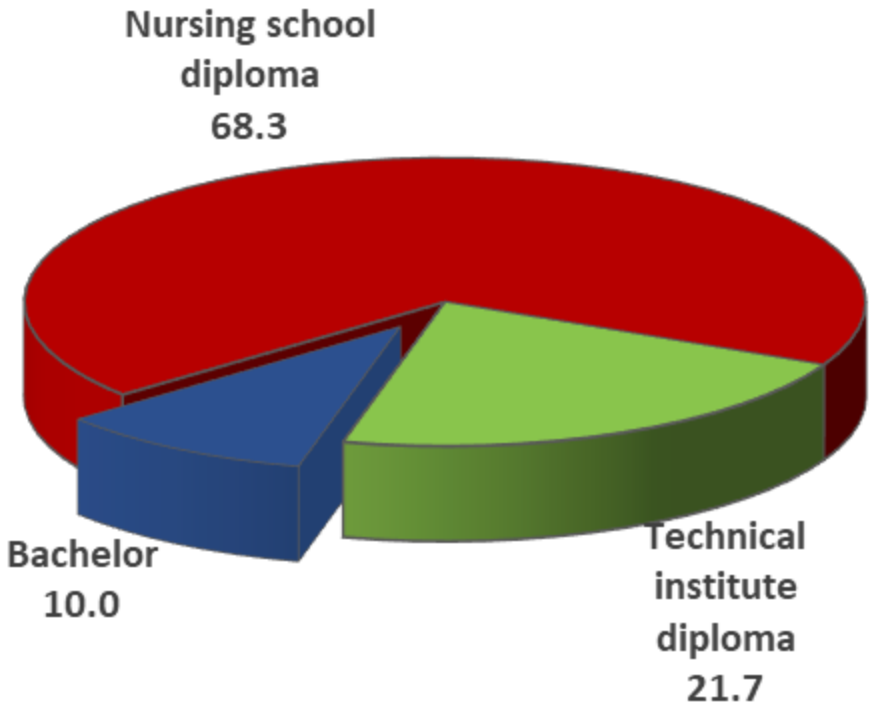


Figure 1

Distribution of the staff nurses in the study sample according to their nursing qualifications

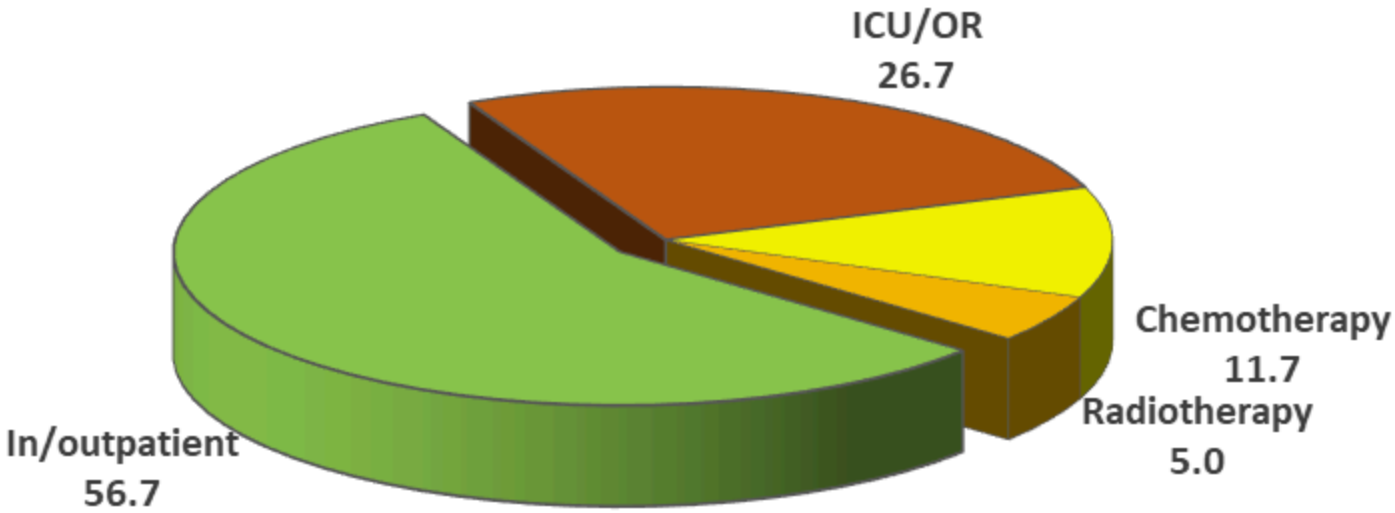


Figure 2

Distribution of the nurses in the study sample according to their work departments/units

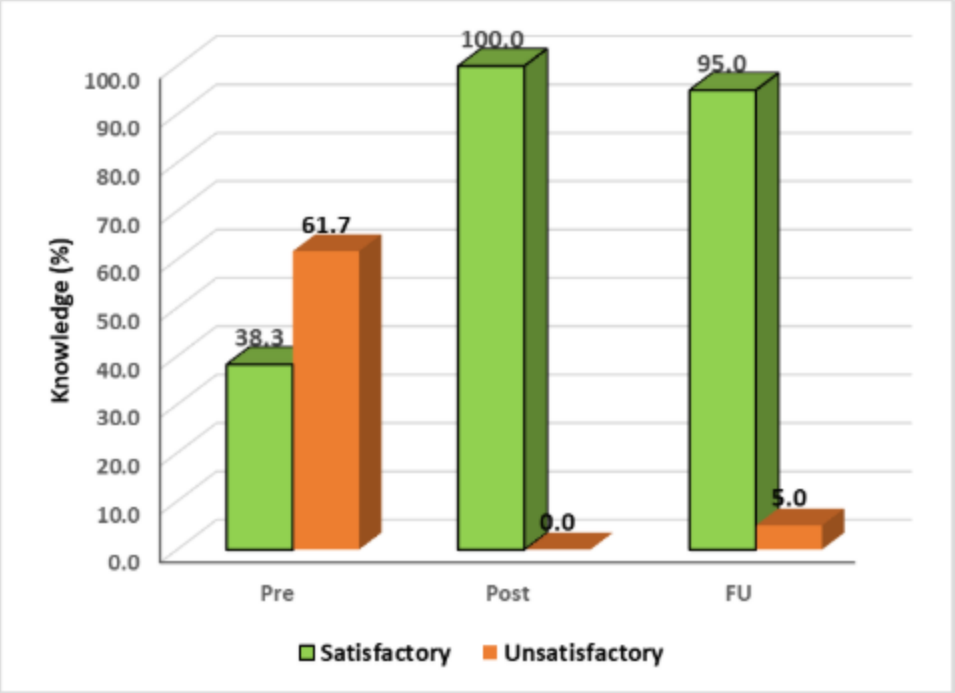


Figure 3

Total staff nurses' knowledge of RAI and its hazards and related safety measures throughout the study phases

(*) Statistically significant at p<0.05