Turk J Intensive Care 2024;22:170-9
DOI: 10.4274/tybd.galenos.2023.04909

ORIGINAL RESEARCH / *ÖZGÜN ARAŞTIRMA*

Habip Balsak,
Ayşe Beşer

Radiation Safety Practices and Improvement of Knowledge Level in Intensive Care Unit Working Conditions: An Experimental Study on Nurses

Yoğun Bakım Ünitesi Çalışma Koşullarında Radyasyon Güvenliği Uygulamaları ve Bilgi Düzeyinin Geliştirilmesi: Hemşireler Üzerinde Deneysel Bir Çalışma

Received/Geliş Tarihi : 09.07.2023
Accepted/Kabul Tarihi : 17.08.2023

Habip Balsak, Ayşe Beşer
Batman University Faculty of Health Sciences, Public Health Nursing, Batman, Turkey

Habip Balsak, Ph.D, (✉),
Batman University Faculty of Health Sciences, Public Health Nursing, Batman, Turkey

E-mail : h.balsak@gmail.com
Phone : +90 488 217 38 91
ORCID ID : orcid.org/0000-0003-4039-7439

ABSTRACT *Objective:* The aim of this study is to evaluate the effectiveness of radiation safety training developed for nurses working in intensive care units (ICUs).
Materials and Methods: This study was carried out on a total of 144 nurses working in the neonatal and pediatric ICUs of two different hospitals. The radiation safety training developed for the nurses of the ICU for the nurses in the training group (n=62) was given face-to-face in 7 sessions in groups of 8-10 people. The data were collected through the descriptive information form and the radiation safety information form, as well as the observations made by the researcher.
Results: As a result of the observations, the development of protective behaviors against ionized radiation of the nurses in the training group increased significantly both compared to the control group and pre-training case ($p<0.05$). It was determined that score averages of radiation safety knowledge levels of intensive care nurses in training group increased significantly. In the last observations, it was determined that there was a significant decrease in the use of some personal protective equipment by the nurses in the training group ($p<0.05$). Over time, a limited decrease was observed in the radiation safety knowledge levels of the nurses in the training group.
Conclusion: It has been concluded that the radiation safety training applied within the scope of the research is an effective method in ensuring the radiation safety of the nurses working in the ICUs. Correct safety practices of employees in ICU units are expected to have a positive impact on patient and employee safety.
Keywords: Nursing, radiation, intensive care unit, training, protection

ÖZ *Amaç:* Bu çalışmanın amacı, yoğun bakım ünitelerinde (YBÜ) çalışan hemşirelere yönelik geliştirilen radyasyon güvenliği eğitiminin etkinliğini değerlendirmektir.
Gereç ve Yöntem: Bu çalışma iki farklı hastanenin yenidoğan ve çocuk YBÜ'lerinde çalışan toplam 144 hemşire üzerinde gerçekleştirilmiştir. Eğitim grubundaki hemşirelere (n=62) yoğun bakım hemşireleri için geliştirilen radyasyon güvenliği eğitimi 8-10 kişilik gruplar halinde 7 oturumda yüz yüze verildi. Veriler tanımlayıcı bilgi formu ve radyasyon güvenliği bilgi formu ile araştırmacı tarafından yapılan gözlemler aracılığıyla toplanmıştır.
Bulgular: Gözlemler sonucunda eğitim grubundaki hemşirelerin iyonize radyasyona karşı koruyucu davranış geliştirmeleri hem kontrol grubuna hem de eğitim öncesi duruma göre anlamlı olarak artmıştır ($p<0,05$). Eğitim grubundaki yoğun bakım hemşirelerinin radyasyon güvenliği bilgi düzeylerinin puan ortalamalarının önemli düzeyde belirlendi. Son gözlemlerde eğitim grubundaki hemşirelerin bazı kişisel koruyucu ekipman kullanımlarında anlamlı azalma olduğu belirlendi ($p<0,05$). Eğitim grubundaki hemşirelerin radyasyon güvenliği bilgi düzeylerinde zaman içinde sınırlı bir düşüş gözlendi.
Sonuç: Araştırma kapsamında uygulanan radyasyon güvenliği eğitiminin YBÜ'lerinde çalışan hemşirelerin radyasyon güvenliğinin sağlanmasında etkili bir yöntem olduğu sonucuna varılmıştır. YBÜ'ler de çalışanların doğru radyasyon güvenlik uygulamalarına sahip olmalarının çalışan sağlığı ve hasta güvenliğine olumlu katkı sunması beklenmektedir.
Anahtar Kelimeler: Hemşirelik, radyasyon, yoğun bakım ünitesi, eğitim, korunma

Introduction

Today, it is known that the greatest amount of artificial ionize radiation (IR) exposure is caused by medical irradiation source (1). For this reason, many protection measures have been developed in order to protect the patients and health workers from risks and dangers stemming from IR exposure (2,3). Although annual permissible dose limits are determined for workers of medical irradiation, genetic disorders and carcinogenesis can emerge in people in low dose IR exposure for a long time (4). There are studies about the fact that many harmful effects such as breast cancer (5) and cataract formation in the eye (6) etc. are seen in health workers, who were exposed to low dose IR for a long time compared to normal population (2,7).

There are many studies showing that though IR has negative effects on the health of workers, health workers have insufficient information, attitudes and behaviors in protection from radiation (8,9). In a study conducted on cardiologists, it is established that cardiologists had insufficient information about protection from radiation (10) and the health workers of urology service did not sufficiently use personal protection equipment (PPE) (lead apron, goggles) during scopy investigation (11).

The nurses undertake responsibilities in many areas with IR such as intensive care units (ICUs), operating theaters etc. During care process, IR exposure due to their profession can be a significant occupational health problem for nurses because they are the health workers closest to the patients. When the studies are investigated, it is seen that the nurses have insufficient knowledge level about radiation safety compared to the other health workers (12,13). In some studies conducted specifically for nurses, it has been reported that the nurses working in the nuclear medical department do not know the basic principles of protection from radiation (14); and that the oncology nurses have not developed expected positive behaviors after radiation safety education has been performed (15).

Since the patients of ICU are not mobilized, X-ray shooting processes are carried out with mobile X-ray devices, which causes the ICU health workers to be exposed to IR. In their study carried out to measure the radiation that the doctors and nurses working in ICUs were exposed to, Xie et al. (16) stated that the doctors and nurses were exposed to radiation at a rate of 0.99 and 0.88 milisievert (msv), respectively; and this exposure showed a positive correlation with the working hours and the size of the service. When the insufficient knowledge level about radiation safety with the nurses are considered, it can be understood that this case is an important issue affecting the safety of ICU nurses and patients.

In X-ray radiographies conducted in ICU, it is in the responsibility of the nurse that the nurse accompany the patient and the taking care of the patient should not be interrupted. One study reported that some accidental extubations occurred when nurses tried to remove the patient from the machine during radiography (17). Likewise, it is possible that many tools such as ureteral catheter, central venous catheter and nasogastric catheter mounted on the patients for invasive attempts may be accidentially removed. Therefore, even during radiography, the nurses cannot go away from the environment because of patient's safety; and they can be exposed to IR more. In the literature, although there are trainings on radiation safety for nurses, there is not any standard application of this (18). With this study, after considering the working conditions of the nurses of ICUs, it is aimed to evaluate the effect of radiation safety training on the knowledge, attitude and behaviors of nurses. In accordance with this aim, the questions of the investigation are determined as follows:

1. Has radiation safety training applied to ICU nurses been effective on their radiation protection behaviors?

2. Has radiation safety education applied to ICU nurses been effective on their radiation protection knowledge and attitudes?

Materials and Methods

Trial Design

This study has been designed in quasi experimental and implemented. During the experimental design with the control group, one follow-up was performed before the intervention, and two follow-ups were performed after it. Radiation protection behaviors and knowledge levels were evaluated at one-month intervals after the intervention. Following all follow-ups, questionnaires, and observations were conducted before interventions were implemented.

Participant

The population of the study consists of nurses working in pediatrics and newborn ICUs of two hospitals which have similar properties. Within the context of the study, the training group and the control group were made up

with nurses of two different independent hospitals in order that the training can be evaluated impartially; hence, it was established that the health workers would not be affected from each other. The criteria to be included in the study are working as nurses in the pediatrics and neonatal ICUs of hospitals and being willing to participate in the study. On the other hand, the exclusion criteria of the study were determined as leaving the hospital during the process while the research was in progress (go on a leave, change the clinic etc.) and not accepting to participate in the study. The participants were appointed in 2 equal groups as training (75) and control group (75). During the process of the study, due to the leaving of some participants, the study was ended with total participants of 144 as 62 people in each the training and control groups (Figure 1).

Control group: The control group were not provided with radiation safety training prepared within the context of this study. The informative posters related with radiation safety were hung visible places of workplaces.

Training group: In the study, radiation safety training program developed specific to the ICU nurses were applied as a means of intervention to ICU nurses working in the hospital specified as training group. In the preparation of these training materials, International Radiological Protection Commission (ICRP) reports and updated literature were taken as bases (3,7,14,16,18-22). The aim of the training program is to teach ICU nurses to apply the basic standards of radiation protection by providing them with patient safety yet without hindering their services. The trainings made face to face were applied in practical terms with groups consisting 8-10 persons. In total six sessions, the intervention of the nurses in the training group was completed. The content and learning outputs of training are shown in Table 1.

Outcome Measures

Within the context of the study, the data were collected through face-to-face survey and questionnaire. Before starting the study, pretests were applied; after the homogeneity of the training and control groups was examined, intervention phase was started. The data in the study were collected by using introductory information form, radiation safety information level form and observation form.

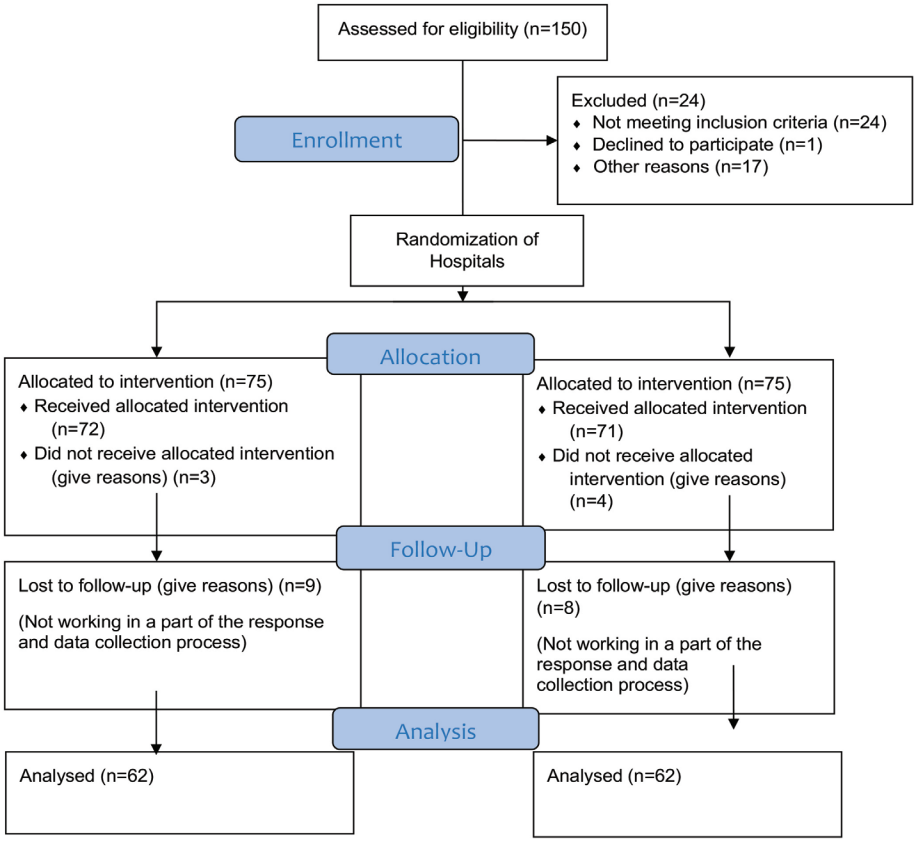

Figure 1. Consort flow diagram

Table 1. Radiation safety training program

Section	Content	Learning outcomes
Preparation and introducing	General information about issue	Making the importance of radiation safety understood and raising awareness.
Radiation safety	Definition of radiation, its sources, its biological effects, its dose unit s and the sensitivity of tissues to radiation	Knowing the difference between ionized and non-ionized radiation. Knowing the effects of radiation.
Radiated areas in hospitals	Controlled and supervised radiation areas	Knowing which areas of hospital need protection from radiation.
Basic principles to protect from radiation	Time, distance, barrier	Actions needed to be taken in radiated areas.
Protection from radiation in ICUs	Dose restriction in ICUs application of basic standards to protect from radiation in ICUs using personal protection equipment	Protection from radiation in working conditions of ICUs and providing the safety of the patients.
Questions and guidance	Institutions to obtain information on the subject.	

ICU: Intensive care unit

Introductory information form: Introductory information form consists of total 14 questions related with the working conditions of ICUs such as working years, number of shifts per month, besides sociodemographic data about the participants such as age, gender, civil status, and education level.

Radiation safety information level form: The researchers prepared it to assess nurses' radiation safety knowledge. The form was prepared based on the ICRP (22) and International Atomic Energy Agency (23) reports as well as current literature (8-16). It consists of three sections as information level about radiosensitive organs and tissues (sensitive-KL), knowledge level about the biological effects of IR (effect-KL), and knowledge level about radiological examinations having IR (examination-KL).

I. Sensitivity-KL: It is the score type obtained through truly knowing whether the organs and tissues (thyroid, blood tissue etc.) of different parts of human body are sensitive to radiation or not. The smallest score and the highest score are taken as zero and eight, respectively.

II. Effect-KL: It is the score type obtained through truly knowing the biological effects (cancer, infertility etc.) possible to occur with regard to long time low IR dose exposure. The smallest score and the highest score are taken as zero and six, respectively.

III. Examination-KL: It is the score type obtained through knowing the radiological examinations, used in different parts of the hospital, and in which IR is used and not used (MR, X-ray etc.). The smallest score and the highest score are taken as zero and twelve, respectively.

Observation form: In creating the observation form, updated literature (17-20) and guidance (22,23) were taken as bases; and the behaviors necessary to be conducted to protect from radiation in ICUs were investigated in five items. The specialists whose opinions were applied are of academician and radiology specialist doctor working at a university and at the radiation safety committee of a research hospital, respectively. Each item was scored in 5 Likert scale by the specialists and they were analyzed with the help of W analysis. At the end of the analysis, it was concluded that the scoring of each specialist were found not to be different from each other statistically (Kendall W =0.167; p=0.255); and there was a harmony between them. The observation items:

- Going away from the environment during irradiation,
- Using lead screen,
- Wearing lead apron during radiation,
- Using additional protectors during radiation (thyroid protector, goggles etc.),
- After radiological examination, ventilating the environment one stays.

Determination and Application of Observation Numbers

Defined protective behaviors were marked as "done" and "did not do" on the observation form. Daily records were attained by the researcher through observing the records of present cameras of the hospital.

The epi info Statcalc package program was used to determine the number of follow-ups. The number of monthly radiological examinations was recorded as 1,152. For this reason, it was concluded that at least 33 follow-ups were required for each group with a 5% margin of error in a two-group study design with a confidence interval of 80% before the training. In order to prevent duplicate observation of participants and to increase the confidence interval, all nurses included in the study were observed once in each follow-up. As a result, a total of 144 nurses included in the study were observed once in each follow-up.

Sample Size

G-Power 3.1.9.2 program was used in the study in order to determine the size of sample. In line with the reference, results obtained with literature scanning carried out before the study, while the effect size was 0.8 and alpha: 0.05, the sample to be taken for each group was obtained as 47 people and 94 people in total. Considering such cases as going on a leave during the study, withdrawing from the study and nurses changing their departments, all participants in training and control groups were included in the study. The data collected at the end of the study were obtained as alpha, 0.05 and total sample size, 124, while effect size, 0.99, as a result of post-hoc analysis.

Statistical Analysis

The data obtained as a result of the study were analyzed in the IBM SPSS 22 package program (Statistical Package for the Social Sciences). Frequency, percent arithmetic mean, minimum-maximum values and median were used from descriptive statistical methods. The paired simple t-test was used to evaluate the quantitative dependent variables showing normal distribution in the training and control groups. Chi-square test was used to evaluate categorical variables between groups. The McNeamer test was used to determine how the training and control groups changed during the intervention process. It was considered significant since the materiality value (p-value) was below 0.05.

Ethical Approval

Before starting the study, the necessary permission was obtained from Koç University Social Sciences Research Ethic Committee with decision number 2017.102.IRB3.055 (date: 22.06.2017). To conduct the study, the necessary permissions were obtained from the institutions to which ICUs are connected. The participants were informed in written and orally and their consent confirmations were obtained. The radiation safety training applied to the training group was later applied to control group as well.

Results

Sociodemographic and working features of the nurses: It was determined that the age average of the groups accepted in the study were training, 28.22±4.86 and control, 29.01±4.39; and that no statistically significant difference was found in age (p=0.345), gender (p=0.389), civil status (p=0.072) and education levels (p=0.931), total job experience (p=0.358) and their working types (p=0.075) and working years (p=0.358) in ICUs (Table 2).

In the pre-tests, no statistically significant difference was found in the behaviors of training and control groups in moving away from the environment (p=0.427), using protective shield (p=0.500), wearing lead apron (p=0.120), using additional protective (p=0.500) and ambient ventilation (p=0.320) that were observed (Table 3). The most frequent behavior observed in the nurses during radiological examination was moving away from the place where medical examination is done (training: 58.1%, control: 61.3%). Using protective shield (training: 11.3%, control: 12.9%) and using lead apron (training: 14.5%, control: 6.5%) and using additional protectors (training: 3.2%, control: 4.8%) and ambient ventilation (training: 6.5%, control: 4.8%) behaviors were found to be rarely applied radiation protection behaviors.

Pre-training radiation safety knowledge scores; sensitive-KL (training: 2.72±1.10; control: 2.80±1.08), effect-KL (training: 4.25±1.62; control: 4.46±1.71) scores were found to be at similar levels (Figure 2).

It was determined that the socio-demographic, working, radiation protection behavior and knowledge levels of the groups had similar characteristics (Table 2, 3, Figure 2).

Evaluation of radiation protection behaviors and knowledge scores of groups: The behavior of moving away the environment after the intervention was significantly higher in the control group than in the training group in the second and third follow-ups (p=0.000; p=0.012). On the contrary, it was observed that there was a significant difference in favor of the training group in other radiation protection behaviors such as using a radiation shield, wearing a lead apron, using additional protective equipment, and ambient ventilation (p=0.000).

It is seen that the score averages of radiation knowledge level (sensitivity-KL, examination-KL, effect-KL) have been given correct answers at similar levels in both groups, which is shown in Figure 2.

Evaluation of training group radiation protection behaviors and knowledge scores: In the evaluation of the radiation protection behaviors observed in each follow-up in the training group, no statistically significant change was observed in the protection behavior moving away from the environment (Table 4). There were 27 nurses who showed moving away behavior in the first and second follow-ups, 23 nurses in the first and third follow-ups, and 31 nurses in the first and third follow-ups (Table 4). Statistically significant increases were observed in the other four protective behaviors compared

Table 2. Sociodemographic characteristics of nurses

Introductory features		Training group	Control group	Examination values
Age	$\bar{x}$ ± SD (year)	28.22±4.86	29.01±4.39	t=-0.949 p=0.345
Working duration in ICU	$\bar{x}$ ± SD (year)	5.17±4.50	6.51±3.77	t=-1.795 p=0.075
Total working years	$\bar{x}$ ± SD (year)	3.41±3.01	3.96±3.57	t=-0.923 p=0.358
Gender	Female, n (%)	33 (53.2%)	36 (58.1%)	x^2=0.213 p=0389
	Male, n (%)	29 (46.8%)	26 (41.9%)	
Civil status	Married, n (%)	32 (51.6%)	41 (66.1%)	x^2=2.698 p=0.072
	Single, n (%)	30 (48.4%)	21 (33.9%)	
Education status	High school graduate, n (%)	9 (14.6%)	10 (16.1%)	x^2=0.444 p=0.931
	University graduate, n (%)	53 (85.6%)	52 (83.9%)	
Having shifts	Yes, n (%)	55 (88.7%)	60 (96.8%)	x^2=2.995 p=0.082
	No, n (%)	7 (11.3%)	2 (3.2%)	

χ^2: Chi-square test, t*: independent simple t-test, p: significant value, ICU: intensive care unit, $\bar{x}$ ± SD: mean ± standard deviation

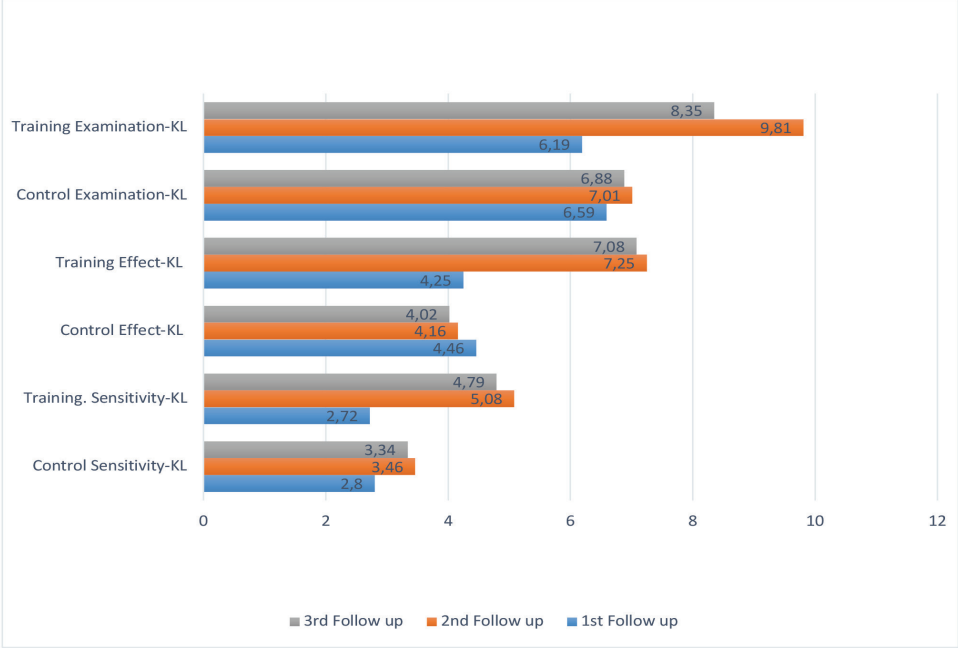

Figure 2. Evaluation of knowledge score averages in training and control groups

to the pre-intervention status (p=0.000). In the ICU, there were 51 people, who did not use protective shields during the radiological examination before the intervention, but there were 47 people, who applied it in the second and third follow-up after the intervention. Similarly, of 51 nurses, who did not use lead aprons, 43 nurses started using lead

Table 3. Investigation of radiation protection behaviors and radiation knowledge scores of training and control groups

Radiationprotection behaviors	Groups	1st Follow-up		2nd Follow-up		3rd Follow-up	
		Yes (n/%)	No (n/%)	Yes (n/%)	No (n/%)	Yes (n/%)	No (n/%)
Moving away the environment	Training	36/58.1%	26/41.9%	43/69.4%	19/30.6%	41/66.1%	21/33.9%
	Control	38/61.3%	24/38.7%	60/96.8%	2/3.2%	53/85.5%	9/14.5%
Examination values		x²*=0.134 p=0.427		x²*=14.676 p=0.000		x²*=6.332 p=0.012	
Using shield	Training	7/11.3%	55/88.7%	57/91.9%	5/8.1%	53/85.5%	9/14.5%
	Control	8/12.9%	54/87.1%	33/53.2%	29/46.8%	29/46.8%	33/53.2%
Examination values		x²*=0.076 p=0.500		x²*=21.437 p=0.000		x²*=20.739 p=0.000	
Wearing lead apron	Training	9/14.5%	53/83.5%	59/95.2%	3/4.8%	51/82.3%	11/17.7%
	Control	4/6.5%	58/93.5%	11/17.7%	51/82.3%	10/16.1%	52/83.9%
Examination values		x²*=2.148 p=0.120		x²*=72.465 p=0.000		x²*=54.240 p=0.000	
Using additional protectives	Training	2/3.2%	60/96.8%	54/87.1%	8/12.6%	46/74.2%	16/25.8%
	Control	3/4.8%	59/95.2%	11/17.7%	51/82.3%	7/11.2%	55/88.7%
Examination values		x²*=0.208 p=0.500		x²*=59.785 p=0.000		x²*=50.121 p=0.000	
Ventilating the environment	Training	4/6.5%	58/93.5%	57/91.9%	5/8.1%	47/75.8%	15/24.2%
	Control	3/4.8%	59/95.2%	13/21.0%	49/79.0%	11/17.7%	51/82.3%
Examination values		x²*=0.151 p=0.320		x²*=63.509 p=0.000		x²*=63.509 p=0.000	

x²: Chi-square test, p: significant value

Table 4. Examination of the training group's radiation protection behaviors and knowledge scores

Observed behaviors		1st & 2nd Follow-up		1st & 3rd Follow-up		2nd & 3rd Follow-up	
		Yes	No	Yes	No	Yes	No
Moving away the environment	Yes	27	9	23	13	31	12
	No	16	10	18	8	10	9
Examination values		x²*=0.412 p=0.230		x²*=0.516 p=0.472		x²*=0.674 p=0.832	
Using protective shield	Yes	6	1	6	1	52	5
	No	51	4	47	8	1	4
Examination values		x²*=46.173 p=0.000		x²*=42.188 p=0.000		x²*=0.245 p=0.219	
Using lead apron	Yes	8	1	8	1	51	8
	No	51	2	43	10	0	3
Examination values		x²*=44.290 p=0.0000		x²*=46.173 p=0.000		x²*=38.205 p=0.000	
Using additional protectives	Yes	1	1	1	1	46	8
	No	53	7	45	15	0	8
Examination values		x²*=4.429 p=0.000		x²*=48.167 p=0.000		x²*=40.196 p=0.000	
Ventilating the environment	Yes	3	0	3	0	47	10
	No	54	5	44	15	0	5
Examination values		x²*=4.429 p=0.000		x²*=52.019 p=0.000		x²*=42.023 p=0.000	

x²*: McNeamer test, p: significant value

aprons at the last follow-up after the intervention. There were 53 nurses, who did not use an additional PPE before the intervention, they used it at the first follow-up after the intervention, and 45 nurses used it at the last follow-up. Fifty four nurses, who did not ventilate the environment after the radiological examination, started to ventilate the environment in the first follow-up (Table 4). In the second and third follow ups made with a one month interval after the training, no statistically significant change was observed in the behavior of moving away from the environment and using protective shields (p=0.832; p=0.219). However, at the last follow-up (3rd follow-up), it was determined that there were significant decreases in wearing lead apron, additional PPE use and ambient ventilation protection behaviors. It was observed that after the intervention, 8 people using lead aprons, 8 people using additional PPE, and 10 people who ventilated the environment after radiological examination in the first follow-up did not apply these protective behaviors in the last follow-up (Table 4).

As shown in the graph, the radiation knowledge level score averages show remarkable rises, while these rises in control group are limited. As a matter of fact, remarkable score rises are observed in the training group at the first sight. Although some slight decreases are observed in sensitivity-KL, effect-KL scores in the last observation, this is more obvious in examination-KL score average (Figure 2).

Discussion

In order to prevent the effects of long-term low-dose IR exposure, radiation safety training developed specifically for ICU nurses was applied within the scope of the study. For this purpose, in the pre-tests (1st follow-up) in the experimental design conducted in two different hospitals, it was observed that the study groups had insufficient knowledge and behavior in radiation protection (Table 3, 4). When the protective behaviors of the training group during the radiological examination in the pre-training ICUs were examined, it was determined that the most protective behavior of the nurses was going away from the environment and they were insufficient in the use of PPE (Table 3). After the training, while no significant variation was observed in the doing away protection behavior in the training group, a significant increase was found in other protective behaviors (Table 4). Going away from the beam source is one of the basic principles of radiation protection and the square of the distance to the beam source is inversely proportional to the amount of radiation received (23). In this case, sufficient distance from the beam source will be effective in protection. However, it is not always possible to implement this situation in ICU working conditions. Divatia and Bhowmick (17), in their study in ICUs, reported that when nurses go out of the ICU during imaging, patients connected to the mechanical ventilation device may leave the device, and this will cause complications such as mortality that may develop due to hypoxia and an increase in the length of stay in the hospital. In addition, another problem is how far going away from the beam source will provide protection. When the sources are examined, values between two and six meters are given at the point of how far going away from the beam source should be (24,25). An important reason for this situation is that the position of the person changes relative to the beam source and the variability of the applied radiation dose. In ICUs, going away from the beam source may cause various accidents and complications in the patient, and it is not always a safe method of protection by itself, due to the ambiguity about how far away the person should be. In the second and third observations after the training, it was determined that while the going away and protection behavior was significantly higher in the control group (Table 4), there was a significant increase in other protective behaviors in the training group compared to the control group (Table 3). This situation shows that after the training, the use of PPE gained importance in the protective behaviors of the training group rather than going away from the environment.

In the last follow-up (3rd follow-up) in the training group after the radiation safety-training program was implemented, a significant decrease was observed in the protective behavior of additional protective, lead apron and ambient ventilation (Table 4). Although the radiation safety training given to the training group significantly increased the use of PPE, it is clear that there was a partial decrease in the use of PPE over time. In the literature, many reasons such as not adopting protective behaviors, personal beliefs and sensitivities are shown as the reasons for the decrease in the protective behaviors of health workers about occupational health and safety over time (26-28). In addition, the availability of PPE is an important factor affecting its use 15. When examined in terms of radiation protection, Flôr and Gelbcke (29), in their study on nurses working in the cardiac catheterization unit, found that the nurses did not use the PPE equipment used in radiation protection because they found it heavy and uncomfortable. In another study conducted on nurses in neonatal ICUs, it was stated that the use of PPE was closely related to employee-related

risks (30). Except for this, it is thought that this causes a decrease in the risk perception of time-dependent nurses and a decrease in the use of PPE over time, due to the fact that the use of PPE is disturbing and heavy. The knowledge levels of intensive care nurses on radiation protection were examined in three sections where basic radiation safety issues were questioned. In the evaluation made in the study groups before the training, it was observed that their knowledge about IR was quite limited (Table 3,4). Looking at the studies in the literature, there are studies showing that healthcare professionals from different professions such as doctors, dentists, and radiology technicians do not have sufficient knowledge about radiation safety (12,31,32). In a study on intensive care nurses, it was stated that 62.7% of the nurses had little knowledge about radiation safety, and the remaining 37.3% had moderate knowledge (33). In all these studies, different levels of information deficiencies have been identified due to different measurement tools. However, there are also studies reporting that nurses are more inadequate than some healthcare professionals such as doctors and radiology technicians (12,13,34). Since the level of knowledge about radiation protection is positively correlated with radiation protection behaviors (11), obtaining the right information is also an important requirement for developing correct behavior about radiation safety.

After the radiation safety training, it was determined that the level of knowledge about radiation safety among the nurses increased in the measurements made both in the training group and compared to the control group (Figure 2). In similar studies conducted, it is shown that radiation safety training provides increased knowledge at different levels (15,19). For this reason, it is an expected result consistent with literature that there is an increase in IR knowledge level in training group. However, in the last measurement, it is seen that there is a limited decrease in the knowledge level, which is more obvious in examination-KL knowledge average (Figure 1). In the third observation, there is a parallel situation in the decrease of protection behaviours and knowledge level of ICU nurses (Table 3,4). In their study, Morishima et al. (20) stated that the level of radiation protection knowledge of cardiology nurses decreased over time. In line with these data, which we have reached a similar conclusion with the literature, it has been concluded that it is an important necessity to conduct trainings periodically in order to perpetuate the increasing level of knowledge.

If the last follow-up was carried out three or six months after radiation safety training, this would have given more information about the persistence of radiation protection behaviors. However, the last follow-up could be made only one month after the second follow-up due to the frequent occurrence of situations such as leave for holiday and the nurses' change of service. In the study, since there was no measurement tool with reliability and validity in Turkish to measure the radiation knowledge level of ICU nurses, the evaluation of the radiation knowledge level was made using descriptive statistical methods and visuals.

Conclusion

The findings obtained within the scope of the study show that the radiation safety training developed for ICU nurses is an effective tool in ensuring radiation safety. However, in order to prevent the correct protection behaviors and decrease in knowledge level depending on time, the trainings should be organized periodically.

*This study was produced from the data of the Doctoral Thesis published in Koç University Health Sciences Institute Nursing Department (Thesis No: 568819).

Ethics

Ethics Committee Approval: Before starting the study, the necessary permission was obtained from Koç University Social Sciences Research Ethic Committee with decision number 2017.102.IRB3.055 (date: 22.06.2017).

Informed Consent: The participants were informed in written and orally and their consent confirmations were obtained.

Authorship Contributions

Surgical and Medical Practices: H.B., A.B., Concept: H.B., A.B., Design: H.B., A.B., Data Collection and Process: H.B., Analysis or Interpretation: H.B., A.B., Literature Search: H.B., A.B., Writing: H.B., A.B.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. World Health Organization. Communicating radiation risks in paediatric imaging: Information to support health care discussions about benefit and risk. World Health Organization; 2016. p. 11-2. Available from:URL: https://www.who.int/publications/i/item/978924151034
2. Tang FR, Loganovsky K. Low dose or low dose rate ionizing radiation-induced health effect in the human. J Environ Radioact. 2018;192:32-47.
3. Vano E, Sanchez RM, Fernandez JM. Strategies to optimise occupational radiation protection in interventional cardiology using simultaneous registration of patient and staff doses. J Radiol Prot. 2018;38:1077-88.
4. Chang DS, Lasley FD, Das IJ, Mendonca MS, Dynlacht JR. Stochastic, Deterministic, and Heritable Effects (and Some Radiation Protection Basics). Basic Radiotherapy Physics and Biology. 2021:337-48.
5. Preston DL., Kitahara CM, Freedman DM, Sigurdson AJ, Simon SL, Little MP, et al. Breast cancer risk and protracted low-to-moderate dose occupational radiation exposure in the US Radiologic Technologists Cohort, 1983-2008. Br J Cancer. 2016;115:1105-12.
6. Azizova TV, Bragin EV, Hamada N, Bannikova MV. Risk of Cataract Incidence in a Cohort of Mayak PA Workers following Chronic Occupational Radiation Exposure. PLoS One. 2016;11:e0164357.
7. Baselet B, Rombouts C, Benotmane AM, Baatout S, Aerts A. Cardiovascular diseases related to ionizing radiation: The risk of low-dose exposure (Review). Int J Mol Med. 2016;38:1623-41.
8. Shabani F, Hasanzadeh H, Emadi A, Mirmohammadkhani M, Bitarafan-AR, Abedelahi A, et al. Radiation Protection Knowledge, Attitude, and Practice (KAP) in Interventional Radiology. Oman Med J. 2018;33:141-7.
9. Ditkofsky N, Shekhani HN, Cloutier M, Chen ZN, Zhang C, Hanna TN. Ionizing Radiation Knowledge Among Emergency Department Providers. J Am Coll Radiol. 2016;13:1044-9.
10. Carpeggiani C, Kraft G, Caramella D, Semelka R, Picano E. Radioprotection (un)awareness in cardiologists, and how to improve it. Int J Cardiovasc Imaging. 2012;28:1369-74.
11. Jindal T. The Knowledge of Radiation and the Attitude Towards Radio-Protection among Urology Residents in India. J Clin Diagn Res. 2015;9:JC08-11.
12. Balsak H, Güneş G, Ulutaşdemir N. Knowledge, Attitude and Behavior of Radiology Professionals about the Harmful Effects of Radiation Which is Used for Diagnosis. 2016;2:31-51.
13. Jacob K, Vivian G, Steel JR. X-ray dose training: are we exposed to enough? Clin Radiol. 2004;59:928-34.
14. Alotaibi M, Saeed R. Radiology nurses' awareness of radiation. Elsevier. 2006;25:7-12.
15. Dauer LT, Kelvin JF, Horan CL, st. Germain J. Evaluating the effectiveness of a radiation safety training intervention for oncology nurses: A pretest - intervention - posttest study. BMC Med Educ. 2006;6:32.
16. Xie Z, Liao X, Kang Y, Zhang J, Jia L. Radiation Exposure to Staff in Intensive Care Unit with Portable CT Scanner. Biomed Res Int. 2016;2016:5656480.
17. Divatia JV, Bhowmick K. Complications of endotracheal intubation and other airway management procedures. Indian J Anaesth. 2005;49:308-18.
18. Ohno K, Kaori T. Effective education in radiation safety for nurses. Radiat Prot Dosimetry. 2011;147:343-5.
19. Kim O, Kim MS, Jang HJ, Lee H, Kang Y, Pang Y, et al. Radiation safety education and compliance with safety procedures-The Korea Nurses' Health Study. J Clin Nurs. 2018;27:2650-60.
20. Morishima Y, Chida K, Katahira Y, Seto H, Chiba H, Tabayashi K. Need for radiation safety education for interventional cardiology staff, especially nurses. Acta Cardiol. 2016;71:151-5.
21. Needham G, Grimshaw J. Guidelines for healthcare professionals who prescribe imaging investigations involving ionising radiation. European Commission, 2008. p.383-98. Available from: URL: https://www.sergas.es/docs/profesional/boapraticaclinica/rp118.pdf
22. Valentin J. The 2007 recommendations of the International Commission on Radiological Protection. Ann ICRP. 2007. p.103. Available from: URL: https://icrp.org/docs/ICRP_Publication_103-Annals_of_the_ICRP_37(2-4)-Free_extract.pdf
23. Bennett GF. International basic safety standards for protection against ionizing radiation of and for the safety of radiation sources. Journal of Hazardous Materials. 1996;45:282.
24. McGovern PM, Vesley D, Kochevar L, Gershon RRM, Rhame FS, Anderson E. Factors affecting universal precautions compliance. J Bus Psychol. 2000;15:149-61.
25. Menzel HG, Harrison J. Effective dose: a radiation protection quantity. Ann ICRP. 2012;41:117-23.
26. Friis RH. Occupational Health and Safety for the 21st Century. Burlington: Jones & Bartlett Publishers; 2014.
27. Kang J, O'Donnell JM, Colaianne B, Bircher N, Ren D, Smith KJ. Use of personal protective equipment among health care personnel: results of clinical observations and simulations. Am J Infect Control. 2017;45:17-23.
28. Levin PF. Test of the Fishbein and Ajzen models as predictors of health care workers' glove use. ResNurs Health. 1999;22:295-307.
29. Flôr R de C, Gelbcke FL. Radiation protection and the attitude of nursing staff in a cardiac catherization laboratory. Texto & Contexto-Enfermagem. 2013;22:416-22.
30. Tanrıverdi H, Akova O, Latifoğlu NT. Yenidoğan Yoğun Bakım Ünitelerinde İş Kazaları Riskleri Ve Nedenlerine Yönelik Bir Araştırma. Business & Management Studies: An International Journal. 2015;3:234-60.
31. Ayatollahi J, Ayatollahi F, Ardekani AM. Occupational hazards to dental staff. Dent Res J (Isfahan). 2012;9:2.
32. Ünal ES, Geliş K, Baykan P. Investigation of awareness levels about the radiation safety of personnel working in the imaging units of the hospitals in Agri, Turkey. J Radiat Res Appl Sci. 2018;11:111-5.
33. Azimi H, Majd Teimouri Z, Mousavi S, Kazem Nezhad Leyli E, Jafaraghaee F. Individual protection adopted by ICU nurses against radiation and its related factors. J Holist Nurs. 2018;28:18-25.
34. Huda W. Radiation doses and risks in chest computed tomography examinations. Proc Am Thorac Soc. 2007;4:316-20.