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Educational Tool Proposals for Perception and Minimization of Occupational Hazards to Protect Health Professionals, the Community and Users of Radiation Therapy and Nuclear Medicine

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Abstract

Nuclear medicine and radiation therapy offer diagnostic and therapy services. These fields have grown in recent years by expanding coverage for the increasingly earlier treatment of serious diseases. In healthcare institutions, because of the risks, managers must provide continuing education at different levels in bioethics and biosafety according to their radioprotection program, and they must manage the legal exigencies concerning the health follow-up of the team members and patients. Health professionals work in these environments treating patients with different procedures and radionuclide schemes. The undesirable biological effects, such as stochastic and/or deterministic effects of ionizing radiation, may affect people's quality of life. The morbidity can vary from common problems, such as inflammation, to major unseen problems, such as mutations, with different risks of disease severity. Ultimately, death may occur after large accidental exposures. Managers need to consider psychological problems, side effects and iatrogenic diseases in patients and occupational diseases and accidents that can vary from small to large scale. Nuclear medicine and radiation therapy professionals need special education and training courses. The educational tools that are proposed here were based on Brazilian legislation for radiotherapy and knowledge of quality control, biosafety and bioethics. Good management and minimization of risk are necessary, and a high level of comprehension is required for the health professional staff member responsible for the health of individuals and an environment that guarantees success in both radiation therapy and nuclear medicine services. Some tools can be used to train professionals to minimize occupational risks and risks that threaten patient health. Checklists were prepared on a few topics concerning issues and recommendations regarding the containment of radionuclides and avoiding contact with reagents, waste and patient secretions and exposure during and after patient care.

Keywords: Occupational safety; Psychological support; Radiation therapy; Nuclear medicine; Education of health professional; Biosafety; bioethics

Introduction

Radiation therapy is the medical application of ionizing radiation for therapeutic purposes. Nuclear medicine is a medical specialty that uses unsealed sources for diagnostic and therapeutic purposes [1-4].

The effects of ionizing radiation exposure should be considered by the medical staff of health care services with a preventive focus. Providing training courses and updates for all healthcare, cleaning and maintenance personnel is necessary [5].

Everyone should be aware of the type and dose of radiation or contamination that is possible for an individual participating in an occupational activity or receiving diagnostic protocols and/or treatment.

Increased risk of radiation exposure may occur as a result of ignorance or lack of safety procedures. To prevent hazards from different well-known effects, such as stochastic, deterministic, somatic and genetic or hereditary effects due to ionizing radiation, managers of healthcare institutions must follow rules set by agencies that control health protection for workers, citizens and the environment.

In cities around the world, the control of radioactive compounds and education and surveillance for working with radioactive compounds falls under the National Commission of Nuclear Energy (CNEN), in association with Ministries of the Environment, Health and Labor (MMA, MS, MTE, respectively). The recommendations of the National Councils on Radiation Protection and Measurements should be followed in each country.

Hofe in 1970 commented on the importance of training and emphasizing the importance of explaining specific behaviors that are required for carrying out health activities characterized by the knowledge, skills, and attitudes of health professionals [6]. The current legislation of the MS and MTE recommend continued education for health professionals in human health care institutions to protect patients under their care [7]. The MTE also strongly recommended a high level of knowledge and comprehension by professionals in their field of work.

In terms of economic performance and professional reputation, as well as environmental, safety and societal outcomes, the management of risk must be carried out by technical managers of the institution. According to the rules for health institutions, such as in Brazil and other countries, the classification of risks must follow guidelines. Figure 1 shows the occupational/environment risk group classifications according to regulatory standards established by the Ordinance of the Ministry of Labor In Brazil, named NR32, which recommend and guide the safety and health of healthcare professionals in the workplace providing healthcare services [5,8].

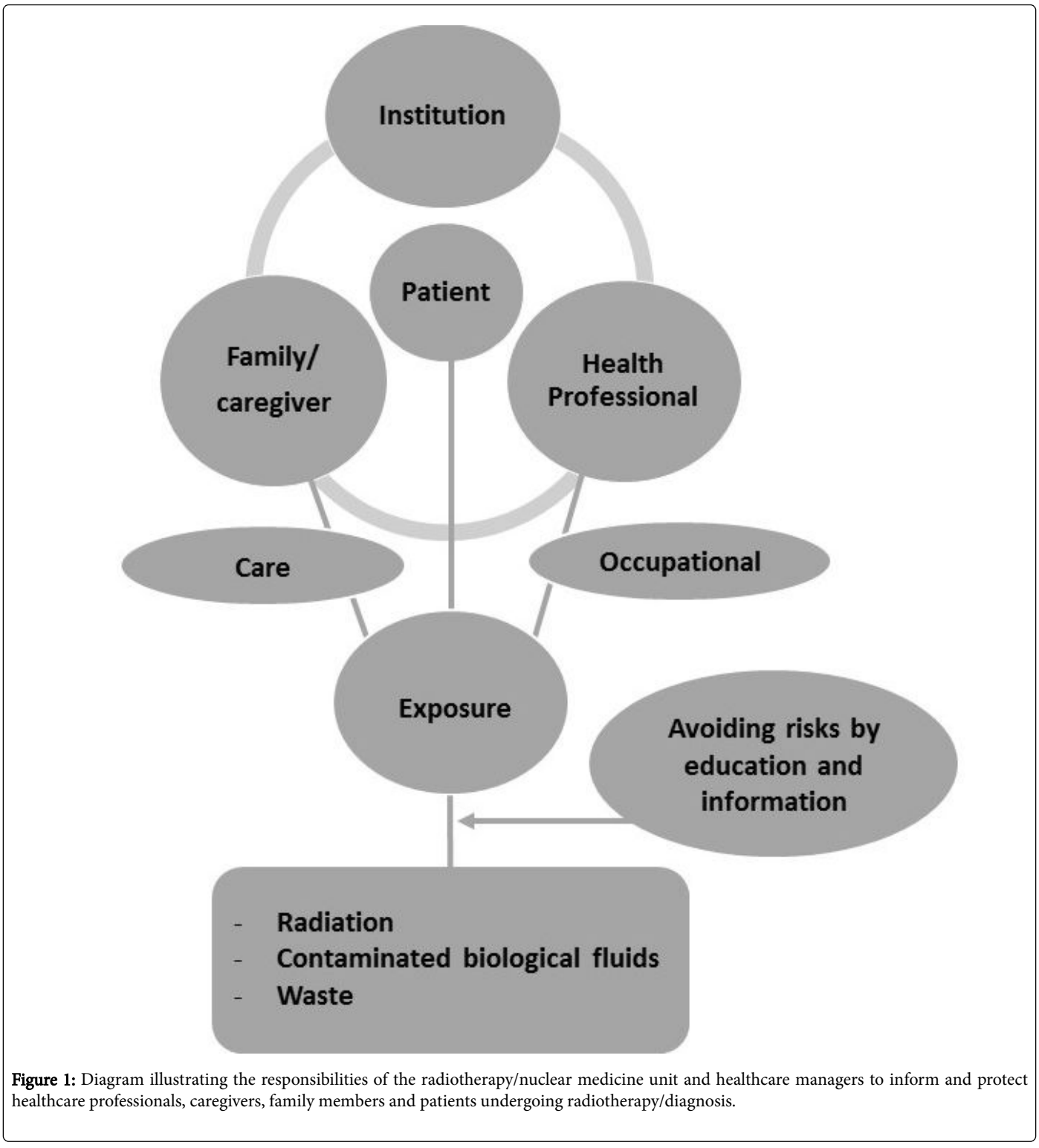

Figure 1: Diagram illustrating the responsibilities of the radiotherapy/nuclear medicine unit and healthcare managers to inform and protect healthcare professionals, caregivers, family members and patients undergoing radiotherapy/diagnosis.

The institution or unit that provides radiotherapy and nuclear medicine services has the responsibility to inform and protect health care workers, caregivers and relatives of patients and the patients undergoing radiation therapy. Although there is variation with the

level of education and public knowledge, the commitment and co-responsibilities required to help avoid the risks of contact with devices and radioactive sources and protect the environment are shown in Table 1. The aim of this proposal, based on Brazilian education and legislation, is to establish some tools that can be used in the training of healthcare professionals to promote health and minimize occupational risks and risks to individuals treated in healthcare institutions and to develop instruments to be used for education in the fields of biosafety and environmental and occupational health.

Physical risk (Green) – Group 1	Noise; Vibration; Ionizing radiation; Non-ionizing radiation; Cold; Heat; Abnormal pressure; Humidity.
Chemical risk (Red) – Group 2	Dust; Fumes; Mist; Fog; Gases; Vapors; Substances, compounds or chemical products in general.
Biological risk (Brown) – Group 3	Viruses; Bacteria; Parasites; Fungi; Toxins and poisons, allergens; Prions.
Ergonomic risk (Yellow) – Group 4	Intense physical effort; Lifting and transporting weight; Inadequate posture; Strict control of productivity; Enforcement of excessive working pace; Working day and night; Extended working hours; Monotony and repetitive activity; Other conditions that cause physical and/or psychological stress.
Accidental risk (Blue) – Group 5	Inappropriate physical arrangement; Machinery and equipment operated without protection; Inadequate lighting; Electricity; Probability of fire or explosion; Inadequate storage; Poisonous animals; Other situations in which risk may contribute to the occurrence of accidents.

Table 1: Classification of the main occupational risk groups according to their nature and the standardization of corresponding colors. Source: Modified from the NR32-MTE-Brazil and Ordinance No. 25, December 29th in 1994, MTE-Brazil. *Republished due to incorrectness of the original, in the Diário Oficial of 30/12/94, Section 1, pp 21280-21282. Republished on 15/12/95 - Section 1 - pp 1987-1989, Ministry of Labor and Security Secretariat Employment and Health.

The aim of this proposal is to establish some tools that can be used in the training of professionals to promote health and minimize occupational risk and the risks to the individual treated in the healthcare institutions and to develop some instruments that can be used for education in the field of biosafety and environmental and occupational health.

Material and Methods

In the preparation of this proposal, we created some checklists with points of interest in bioethics, biosafety and legal issues considering available recommendations from different Brazilian governmental institutions, such as the Brazilian Commission on Nuclear Energy (CNEN), Brazilian Ministry of Health (Ministério da Saúde, abbreviated MS), Ministry of Labor and Employment (Ministério do Trabalho e Emprego, abbreviated MTE), Ministry of the Environment (Ministério do Meio Ambiente, abbreviated MMA), and international institutions such as International Commission on Radiological Protection (ICRP) American Council on Radiation Protection and Measurements (NCRP) and International Atomic Energy Agency (IAEA) [1,2,9-13].

We analyzed the classic literature and current legal documents from national and international agencies that regulate and control healthcare institutions that offer radiation therapy and nuclear medicine services. We translated and analyzed the Brazilian final version of the documents that currently regulate and guide all healthcare professionals in the workplace in healthcare institutions [5,7,12]. Additionally, we used some fundamental principles and knowledge of biosafety, bioethics and educational philosophy.

Results and Discussion

The proposal includes one questionnaire and five checklists focused on educational issues concerning biosafety, bioethics and legal requirements for radiation therapy and nuclear medicine.

The proposal suggests that one questionnaire should be initially filled out by workers who are qualified and have credentials for the intended activity in nuclear medicine and radiotherapy. Training for the application of the checklists will be provided, and instructors will be present during the administration of the questionnaire. The study will be conducted under the supervision of an occupational engineer or physician, or possibly the Occupational Risk Prevention Commission at the institution. The instructors will have appropriate expertise and knowledge of aspects of biosafety, ethics and occupational health in the area of healthcare. After explaining the different types of hazards and risks, the information will be recorded on a personalized assessment questionnaire, shown as a model in Table 2.

Name of trainee: **Registry/ID:**		**Department:**	**Date:**	**Supervisor :**
Level of instruction:				
Physical risk Group1	**Chemical risk Group 2**	**Biological risk Group 3**	**Ergonomic risk Group 4**	**Accidental risk Group 5**
Example: Monitoring of sealed source implant (radionuclide)	**Example:** Contact with chemical agent	**Example:** Contact with patients with a possible respiratory infection. Contact with contaminated blood. Cleaning litter and restroom after patient use.	**Example:** Care of anxious patient, stressed patient	**Example:** Inadequate use of Personal Protective Equipment (PPE) and lack of shield

Table 2: Questionnaire to be fill out by the trainee to register the type of the risk identified. The professional in training must identify the

activity that is associated with the risk identified under the supervision of the accident prevention committee or technician in charge of the sector/company.

To complete this questionnaire (Table 2), the professional must take into account all the activities that were developed to identify the occupational hazards and thus obtain a risk assessment of the workplace. The perception of risk is considered the first step in avoiding problems with accidents and achieving health promotion for health workers and the institutional team, in addition to taking reasonable caution with the patient under their care.

In this step, the main risk groups that will be initially assessed include physical risks (e.g., ionizing radiation) and ergonomic risks in the event of stress (in the case of anxiety or depressed patients who need some psychological support or psychiatric treatment for additional indications). The health professional should be encouraged to solicit psychological assistance if they feel it is needed to achieve successful treatment without complications.

The professional must take into consideration whether the patient is immunosuppressed and whether steps should be taken to prevent contamination in social and home environments. For epidemic or endemic questions, consideration should be given for patients leaving the clinic or hospital.

Professionals should carefully specify the methods and appropriate protective devices for each case. Information on security to prevent contamination must be focused on the patient and their families and caregivers [5]. Other important information concerning general aspects must be taken into account, such as ethical awareness among health professionals in the care of patients with a lower level of education and economic situation. Future proposals must be established by the team for patient care in their institutions.

To prepare the five checklists proposed here, we considered some recommendations from different countries including the International Atomic Energy Agency (EAE), Brazilian Nuclear Energy Commission (CNEN), which controls and regulates the use of radionuclides in various countries, Brazilian Ministry of Health (MS), Ministry of Work and Employment (MTE) and Ministry of the Environment (MMA).

Regarding services in nuclear medicine, the employer is required to keep the workplace available for inspection by the Radiological Protection Program (PPR), approved by the Nuclear Power Control Commission, and for diagnostic radiology services approved by the Health Surveillance Commission, according to international standards described in various documents from different countries.

The Radiological Protection Plan should contain information such as period of validity, the responsible professional and a possible substitute as an effective member of the service work team, recommendations to be considered in the Program of Occupational Health Control and approved by the Internal Commission for Accident Prevention or by the technician in charge.

In the first checklist model (Checklist 1), some items are given as examples to be covered by responsible professionals in the updated course, such as the conditions in which the employee's activities in this area are performed daily. The risk assessment for ionizing radiation should be carefully evaluated to minimize accidents and occupational diseases. The staff can empower the employees to establish good measures previously identified by the group.

The employees need to know that recommendations must be followed, and they should have the capacity to recognize the risks and also know the various actions offered by managers and conditions that must be provided by the employer. Some of these aspects are detailed in Checklist 2 and can be evaluated by interested professionals who should consider specific situations for each case.

The professional training program may include verification of the knowledge of standards that must be addressed by the local and national current regulating norms. As in other international sites, the American Council for Radiation Protection and Measurements [11,13] has recommended that hospitals should have detailed plans previously prepared for patient care during a nuclear or radiological accident.

Planning should include patient transportation, special conditions for facilities that receive and maintain treatment-emergent patients with injuries caused by radioactivity. It is important to think about the psychological assistance required by the victims and individuals with irradiation and contamination or people exposed to radioactive products.

Training on ionizing radiation includes some interesting courses for emergency responders that should enhance the ability to take appropriate measures to protect themselves and the public. Finally, boosting confidence about how to effectively manage an emergency involving radiation or radioactive materials is necessary.

The radiotherapy services should adopt at least a minimal level of security devices, and the treatment rooms should have doors with interlock systems to prevent unauthorized access while operating the equipment. Indicator lights for equipment in operation should be located in the treatment room and at the point of outside access in a visible position.

The controlled area is subject to special security and safety rules to control normal exposures, prevent the spread of radioactive contamination and prevent or limit the extent of potential exposures. The supervising area should have conditions for occupational exposure to ionizing radiation, even if specific safety and security measures are not normally required.

For brachytherapy, the preparation and storage room workers are forbidden to engage in any activity not related to the preparation of sealed sources, and the containers used to transport supplies must be labeled with the radiation symbol, and radionuclide activity must be removed.

The employee must be aware of the conditions of the Nuclear Medicine Service and should be informed of the training data relating to the structure and site strategy. The staff must meet the recommendations, in general, that are adopted and supervised by the state, national and international agencies.

The employees must know the recommendations and have the capacity to know the risks and various actions that are the responsibility of the employer.

Do you remain in the area for the shortest time as possible for the procedure?
Are you aware of the radiological hazards associated with your work?
Did you undergo initial training on radiological protection?
Do you wear appropriate PPE to minimize risk?
Do you use the measurement of the amount of radiation according to your biological condition as evaluated by occupational medicine in your workplace?
Are all pregnant women dealing with ionizing radiation kept away and relocated to another area?
Are the individual dosimeters calibrated and monitored exclusively by laboratories accredited by the national nuclear agency?
Is the external individual monitoring measured monthly?
In the event of a suspected accidental exposure, is there a program so that the dosimeters are submitted for reading within 24 hours?
In the case of the occurrence or suspicion of accidental exposure to radioactive sources, is there a plan to adopt additional procedures for individual monitoring, clinical evaluation and complementary tests, including cytogenetic dosimetry?

Checklist 1: Location of areas where sources of ionizing radiation exist.

Was a program implemented with group safety measures related to radiological risks?
Is there a qualified professional responsible for radiation protection?
Was there initial training on radiological protection for employees?
Is there an update program on radiological protection for employees?
Are there individual records of training given to employees?
Are there instructions concerning the radiological risks supplied to the employees?
Is there an official written and known record for the employee on the instructions related to radiological risks?
Are there radiation protection procedures adopted for setting radioactive installations?
Is there a record of the written results on the doses of routine exposures and accidents and emergencies upon receipt?
Is there a daily exposure record given to the medical coordinator of the occupational health program or physician in charge of the tests?
Is there, for each institutional employee with occupational activity in radioactive area, an updated individual record?
Is there exclusive and differential control of the times and periods of occupation in the area and inside the radiation room?
Is the recommended dosimeter utilized by personnel during occupational activities?
Is there a recommended dosimeter available for use for each professional?
Do the personnel use the available and recommended dosimeter?
Are there recorded reports of monthly and annual doses that were received by each person?
Did you receive an update course in this area in the last year?
Do the workers know the importance of the emergency exposure and accident reports?
Have there been previous occupational exposures to radiation sources?
Was the worker informed that the individual health record provided by law must be kept updated and be kept for thirty (30) years after the end of their employment?
Is there a radiological Protective Program? Is it reviewed?
Do the workers know whether the radiation protection service is located in the same area as the radioactive installation?
Are compatible operating conditions guaranteed for the necessary activities, observing the norms of the National Radioactivity Commission and the National Health Commission?
Does the radiological protection service perform individual monitoring of workers regarding use of PPE?

Is there a technical supervisor for promoting the integration of radiological protection activities in this service?
Is the international symbol for radiation outside and inside the area of controlled access?
Is there identification regarding the type of radioactive element, activity and type of emission on the sources of waste, its packaging, containers and shields?
Are there values for the dose rates and measurement dates at significant reference points close to the radiation sources in the workplace in accordance with the radiation protection program?
Is there identification of outgoing and incoming exits for normal working conditions and for emergency situations?
Is the location of safety equipment easy to be find?
Are there procedures to be followed in case of accidents or emergency situations?

Checklist 2: Recommended standards for occupational health care and accident prevention.

In a professional capacity, the training plan may include verification of knowledge of the standards that must be addressed by the service and professionals that are described in the third checklist model (Checklist 3). Radioactive material contamination rarely represents an immediate danger to the health of the victim or to responder, which reduces the need for immediate decontamination and allows greater flexibility in selecting the decontamination options. However, in large institutional big accidents, similar steps can be taken as those recommended for preparations for terrorism acts, according to the NCRP [13], for example, the steps and activities needed avoid the spread of risk. In this case, they suggest that federal, state and local emergency responders should develop plans, training and exercises to test and coordinate their capability to respond according to national strategies. Additionally, we have reviewed documents from the Brazilian Energy Nuclear Commission (CNEN) that have very good protocols and guidelines for handling irradiated and radionuclide contaminated individuals. Probably the protocols were well established after the radiation accident with 137Cs in September 1987 due to an abandoned radiotherapy clinic in the state of Goiania. The clinic owner left behind a 137Cs pump, which was found by scrappers who opened the sealed source and exposed it to many people in the city [7,14-16].

Is the location intended for internal storage of decaying radioactive waste located in a controlled access area and is a sign posted?
Does the place intended for internal storage of decaying material have adequate shielding?
Is there adequate room in the compartments that allow the segregation of wastes for each group of radionuclides considering the physical half-life and physical status?
Is the room for patient hospitalization and administration of radiopharmaceuticals properly shielded?
Do the patient rooms have walls and floors with rounded corners and covered with waterproof materials that enable decontamination?
Is there a bathroom in the patient´s room?
Does the patient room used for the administration of radiopharmaceuticals have lead barriers for shielding by the bedside?
Are there signs of the presence of ionizing radiation outside the patient's room?
Are there hazard warnings for radiation in risk sectors?
Is there controlled access to the room designated for the administration of radiopharmaceuticals to the patient?
Are there simulators for the training of employees for manipulating sealed sources utilized in brachytherapy?
Is the preparation of the sources utilized for brachytherapy manual low doses conducted in a specific room with controlled access, only allowing the presence of people directly involved in this activity?
Is the handling of low dose rate sources carried out exclusively with the use of certain tools and with protective shields?
Are the garments of patients and bed linens monitored for the presence of sealed sources after each application?
Are protocols provided for incidents of loss of radioactive sources?
Is there a personal monitor for measuring occupational dosages?
Is there a Geiger-Muller monitor?
Is there an armored door in the nuclear medicine/ radiation therapy service?
Is there a lead barrier?

Is there a thyroid protector available?
Are there lead aprons available?
Are there lead protective goggles available?
Are there waterproof liners available for therapeutic procedures?
Is there waterproofing of floors and walls?
Are there plastic cases on switches, doorknobs, phones, mattresses, pillows, toilets and faucets?
Are there lead coffers for storage of radioactive waste?
Is there a syringe protector available?
Is there an armored cabinet?
Are there lead protective visors in treatment areas?
Are there available transport trolleys?
Are there emergency alarms in the personnel radiation dosimeters?
Are the numbers of standard protective clothing (i.e., bunker gear) and respiratory protection devices sufficient to protect emergency responders against personal contamination while conducting life-saving and other critical missions?
There is a remote emergency medical service (EMS) for personnel in case of accident?
Dou you consider other items for protection and risk minimization? Specify:_____

Checklist 3: Safety strategies for the professional staff.

To prevent risks of non-stochastic effects, the limit doses of safety must be obeyed. The radiation protection program aims to protect all individuals potentially exposed because of work, diagnostic procedure or treatment. The stochastic effects should be within the security limits of standardization protocols. In this way, the practice of the ALARA principle (as reasonably achievable) in the developed world is currently well established [17].

Considering this radiation safety principle with the objective of minimizing the exposure of patients and workers and producing the minimum amount of radioactive waste, all of these actions follow reasonable methods. Nevertheless, because of fear of damage caused by radioactivity, patients undergoing diagnostics and therapeutic procedures can be in state of stress and anxiety that is worse than that expected by the condition of the original disease.

The employees must be aware of the conditions of radiotherapy and nuclear medicine services and should be informed during training about strategies to indicate psychological or psychiatric intervention if necessary. Some questions are included in Checklist 4 to guide the ethical issues and treatment of patients.

The suggestions for other checklists are found below, focusing on the discussion of the training course. Professionals should handle explanations and provide a safe space in visiting rooms, and showing movies, photographs, and proposing other activities may benefit the patient and their families. Some suggestions for the training of ethical and safety behaviors toward the patient are found in Checklist 4.

Are professionals aware of the importance of their emotional and technical support to patients in their care?
Do team members have a good mood and good psychological structure to support the patients and offer explanations to relieve the patient's and his companion's doubts?
Is there training and psychological support for professionals who deal directly with patients at different severity levels?
Does the professional have enough information about the radiopharmaceutical product used in the patient's care?
Do professionals have the ability to clearly and objectively inform the patients about care without creating local clusters to avoid risk of infection in epidemics?
Do professionals know how to communicate the details of the amount of radiation to be received by the patient?
Is there training and psychological support for professionals who deal directly with patients at different severity levels?

Checklist 4: Empowering skills and ethical profile of professional technicians.

Health professionals must be aware of self-care in occupational activity as well as patient care. Even in cases considered rare, they have to explain the basis for patient care to family or caregivers. The patient must be safe both inside and outside the institution. Some recommendations need to be explained concerning patient contact and handling secretions, fluids and waste in patient radiotherapy. There should be understanding of what can be contaminated by direct and indirect contact. Some important issues were included in Checklist 5. Moreover, these issues must be previously discussed among staff and are under responsibility of the technician in charge of the program for prevention and minimization of risks in the workplace. Every health professional should consider the importance of the Radiation Protection Program (PRP). In nuclear medicine, PRP includes a set of measures aimed to protect humans, their descendants and the environment from possible undesired effects caused by ionizing radiation. The program should adopt the recommendations and basic principles established by the National Commission of Nuclear Energy of the state and the country. The occurrence or suspicion of accidents involving unsealed sources, subject to external exposure or internal contamination, requires additional procedures for individual monitoring, clinical evaluation and complementary tests, including cytogenetic dosimetry, and *in vivo* and *in vitro* analysis. The clinical procedures should specify the control and monitoring of sealed and unsealed sources, and technicians and technical experts should know all the legal procedures and responsibilities at the end of activities and when closing the clinic [3,7,14,18,19].

Is it easy to register and identify the type of patient contact, including secretions, waste and fluids of patients treated with radiotherapy?
Is physical risk easily identified?
Can you identify the biohazard and forms of contagion and the entry routes and routes of infection/contamination?
Do you know what precautions to take to avoid risk of contact in dealing with the patient?
Do you know if the patient subjected to radiotherapy had a serological diagnosis in his/her clinical record?
When an accident happens with biological samples, fluids, secretions and debris, do you know how to proceed and what to use for the biological decontamination?
Do you know where to go and who to inform, especially the infection expert, in the case of accidents?
Does the building have an adequate area for isolation?
Do you know how to avoid or minimize risks through the use of PPE?
In the case of an accident, do you know previously if specific antibiotics and anti-retrovirals are available in cases of prior knowledge of the patient's infection?
Did you receive special training on the supervision practices for this problem?
Do you know how to properly dispose of the waste from the residential clinical care of patients undergoing radiation therapy?

Checklist 5: Conditions and care for contact situations of infected or contaminated patients treated in nuclear medicine and radiotherapy.

Our aim was to develop a convergent proposal regarding the importance of training professionals on the issues presented based on areas of bioethics and biosafety and the legality of the care and protection of patients in health services. The themes of the strategically separated checklists can serve as initial models that can be improved and reformulated by specific groups as needed for nuclear medicine and radiation therapy.

The awareness about the importance of health care professionals will culminate in new lists that can be created to address different realities and the need for different demands.

This special information for the medical team requires self-care and complete care for patients who use these services. Good management and minimization of risk and promotion of the quality of life and health of the staff guarantee the success of radiation therapy and nuclear medicine.

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