

Risk perception among workers exposed to ionizing radiation: a qualitative view

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Abstract – Ionizing radiation is energy in wave or particle form that can be absorbed by occupationally exposed professionals. With exposure, diseases may occur as defined by the International Agency for Research on Cancer Working Group on the Evaluation of Carcinogenic Risks to Humans 2000. Therefore, identifying hazards, assessing risks, and evaluating experiences of the involved parties, available resources, and work processes is necessary. We analysed risk perception compared with the pillars of radiological protection (justification/optimization/limitation) and the principles of distance/time/shielding. We used qualitative methodology under the phenomenological paradigm to assess participants' perceptions regarding the ionizing radiation risk using conversational interviews. The data collection period was 2019–2020. The interpretative work was conducted by thematizing interviews, which were categorised and schematized for analysis. The practices of five participants with at least 20 years of experience in radiation use were explored. Five categories were identified. We found that the 'As Low As Reasonably Achievable' principle was recognised based on distance/time/shielding and according to the International Atomic Energy Agency (IAEA) and Bonn Call for Action. The justification associated with the risk/benefit was not associated with the fear of being wrong, with the understanding that, according to the IAEA, 30% of procedures are not justified.

Keywords: ionizing / radiation / ethic / radiation risk / protection

1 Introduction

Risk perception and the understanding thereof is reflected through thoughts communicated by the senses, complemented by judgement and experience; this relationship translates into the perception of danger (Baquerin *et al.*, 2013). The generated opinion depends on the information received, which attenuates or magnifies the observed risk (Prades *et al.*, 1999). A subjective assessment then occurs to measure the probability of an accident, incident, or illness due to risk exposure (Rodríguez *et al.*, 2015).

Ionizing radiation exposure represents a frequent uncertainty when identifying hazards and assessing risks and safety in occupational health (Min Trabajo, 2015; Ferdiana, 2022). Weighting methodologies with quantifiable scales have been used to identify hazards and assess risks (NTC, 2004; GTC, 2012); however, perception has an individual connotation and varies widely, and personal attributes valued by whoever is exposed should be considered (Rodríguez *et al.*, 2015). These

differences arise from a lack of objective information or comprehension rather than training (Arranz, 2010), as the information is based on limiting doses to acceptable levels (ICRP, 1991; ICRP, 2007), depending on defined contexts and concern associated with radiation use and likelihood of delayed effects (Richardson *et al.*, 2015; Oak Ridge Institute for Science and Education, 2017). The effects trigger disease development in target organs, haematological alterations, or solid cancer formation (Sasaki *et al.*, 2014; Hernández *et al.*, 2020), resulting in increased healthcare burdens that translate to disability, loss of working capacity, or disability pension payments (Riesgos Laborales, 2011; Min Trabajo, 2014).

Knowledge of subjective information on exposure to ionizing radiation motivated us to conduct this study, which involved X-ray technologists who manipulate the emitting sources for diagnosis and treatment.

In addition, presence of diseases induced by working with ionizing radiation may occur, so it is necessary to evaluate indirect factors such as compensation payments, family violence or fear due to its use (Hori, 2020), which can hurt the mental health of workers and the psychological and social consequences in the lives of large populations (Raisio, 2023).

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2 Materials and methods

We used qualitative methodology under a phenomenological paradigm by using conversational interviews to evaluate the participants' perceptions of the exposure risk. Data collection was performed from 2019–2020 using semi-structured interviews, including the participants' workplace experiences. Participant data was anonymised to customise the content and provide confidentiality. Open-ended questions were asked, containing core topics associated with occupational health and safety, such as knowledge, skills, ergonomics, quality of emitting sources, equipment maintenance and handling, personal relationships, and waste management. The interview began with a question that could be adapted to the of the interviewees' responses to promote flexibility among participants (Troncoso and Amaya, 2017). Participants expressed their opinions, which were recorded and transcribed verbatim. The scheduled interviews were conducted away from the workplace; participants provided written informed consent after we explained the study objective.

The interview scripts contained guiding questions within each topic to deepen interactions with participants, as follows:

Based on your experience in the position you hold, what do you know about occupational hazards?

What knowledge do you have about ionizing radiation?

Which protective measures do you know?

How long have you been working in the healthcare area and what positions have you held?

Does the healthcare-providing institution regularly perform training/updates?

What is your opinion about the teams there? What is your opinion about the equipment you use?

What can you tell us about overtime and night shifts at the healthcare facility?

In your experience, what do you know about accidents and incidents?

Which actions should you perform after filling a clinical record?

Homogeneous sampling was considered. Therefore, participants had to meet the inclusion criteria: Colombian nationality, years in position, and training received. We identified participants with similar profiles to describe common situations within a specific work group. In total, practices were explored among five participants with > 20 years of experience after the study objectives and conditions were explained.

The work prior to data collection involved six phases: data familiarisation, initial category or code generation, topic search, topic review, topic definition and naming, and report preparation (Braun and Clarke, 2006). Considering the coding processes conducted independently by the researchers, five categories were obtained and assessed using the information obtained and literature reviewed as follows: occupational risk, qualification and workplace environment, occupational incidents, preventive measures against occupational risk, and equipment and technology use.

3 Results

The results are shown schematically according to the categories analysed and summarised in the figures that follow.

3.1 Occupational risk

Next, we analysed the occupational risk category based on the participants' narrative. The analysis and interpretation of the work experience data was conducted considering individual lifestyles, feelings, and expressions of risk, and the understanding that ionizing radiation exposure is a real phenomenon although it cannot be felt, seen, or smelled; penetration can modify internal structures at the cellular level, which was understood by the participants.

To understand the category of occupational risk in this group of participants, three major themes were identified from the analysis of the information obtained through the interviews. To facilitate understanding, a diagram was created (Fig. 1), and the questions asked were as follows. Based on your experience in the position you hold, are you aware of the occupational risks? (e.g., physical or biological, risk classes, TOE, average premium, high risk, vacation periods). What knowledge do you have about ionizing radiation? (e.g., stochastic and deterministic effects, heredity, and cellular effects can occur). During your time in the service, have you experienced discomfort or are you aware of any health alterations related to your work performance? (e.g., thyroid alterations, clinical histories, medium corpuscular volume, origin of cataracts, dosimetric values, environmental/personal, dry skin). What protection measures do you know? (e.g., exposure distance, direct/indirect exposure, shielding [screens], times, remote control, collimation, personal protective equipment [PPE] required, amperage).

For the participants, exposure to radiation is considered a daily occupational risk and is conceived as something profound, although is part of daily activity and is constant in their work day; their provision of care means that at any time an emitting source or piece of equipment used to generate radiation as appropriate requires exposing themselves to dispersed traces that can be absorbed according to the procedure, physical space in the health institution, and clinical condition of the patients.

The understanding of occupational risk showed a subjective component associated with individual explanation. These results relate to the perception of occupational risk, and the accounts of experiences of the participants focused on understanding, exposure, and probability as an effect of their own interpretations.

Alex's interview highlighted the learned concepts, as follows:

'As a teacher once taught me: any minimum produces a reaction, i.e., any dose of radiation you receive produces an effect. Therefore... one should protect oneself as much as possible.' Exposure is associated with equipment use, fear, and health damage.

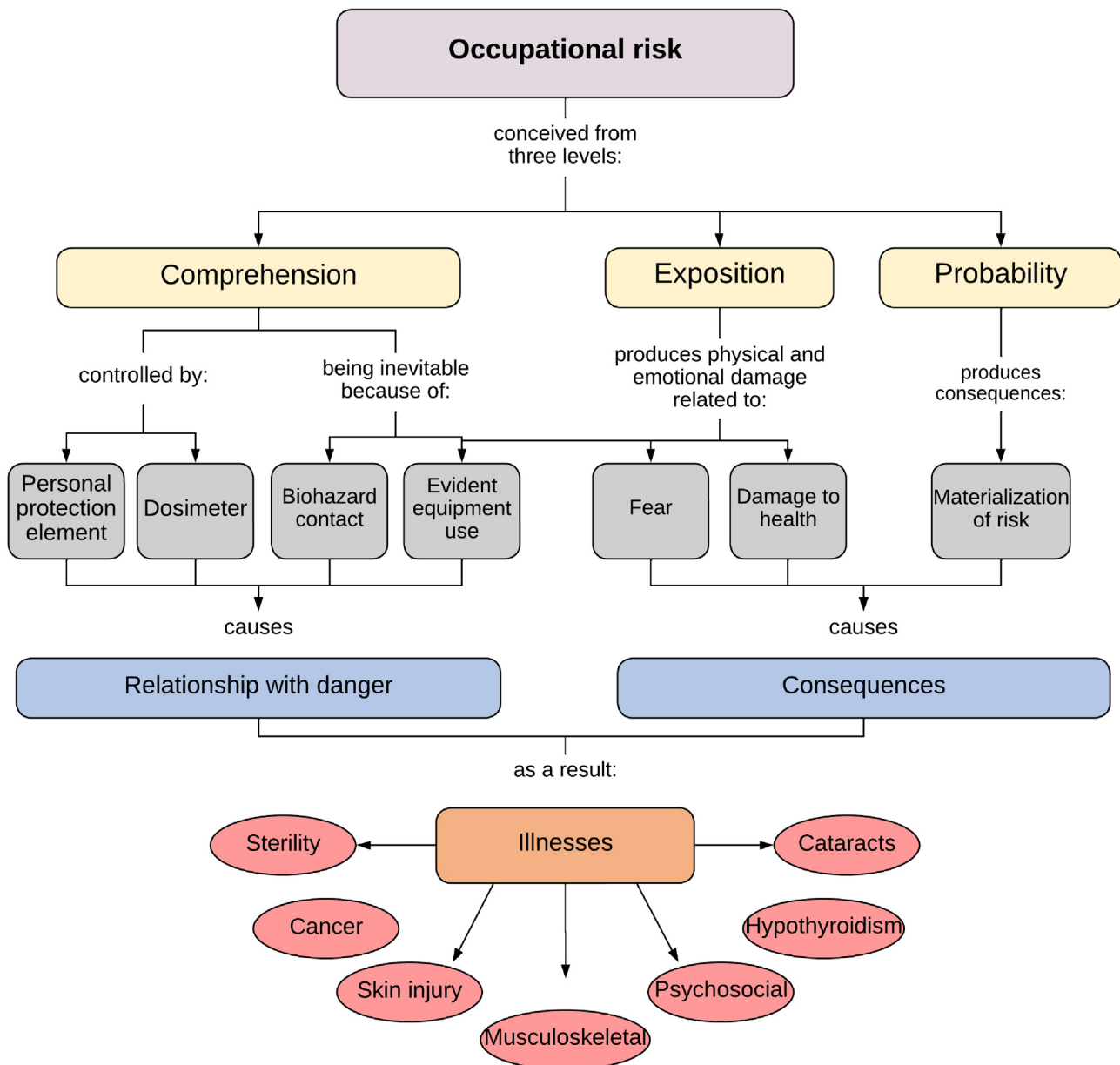


Fig. 1. Occupational Risk. The second row (yellow colour) corresponds to the circumstances related to how the risk is perceived by the participants. The third row (grey colour) defines the methods used to reduce the risk and what it produces in the participant. Row four (blue colour) represents the causes of exposure according to the participants and the red colour represents the results or outcomes according to the participants.

Raul pointed out: 'Waves and particles ... Nobody likes to be irradiated, one is at risk!!!!'.

Within the answers associated with probability, Lucy stated: 'I think that radiation affects the people who work with X-rays, because they are very hypocritical, sceptical...'. Gladys complemented this thought when she said: 'I try to do things well and they still criticise....'.

The risk can be materialized and has consequences as mentioned by Ana: 'Radiation is invasive, it can cause us genetic alterations, cancer, sterility in women, even in men'. Regarding their understanding, participants considered risk control through distance, Raul stated 'The distance helps

us to measure radiation, thus decreasing the relationship with danger and avoiding the materialization of the risk'.

Ana, like other participants avoided the relationship with danger and took preventive measures by using vests, a dosimeter, keeping the door closed, and performing collimation.

The responses obtained from Lucy and Gladys lead to the conclusion that when working to improve people's quality of life, compliance with clinical guidelines and working towards an accurate diagnosis implies ignoring the other's position and puts into play individual criteria to understand radiation, including feelings and sensations to define the understanding of the risk according one's experiences at work over time.

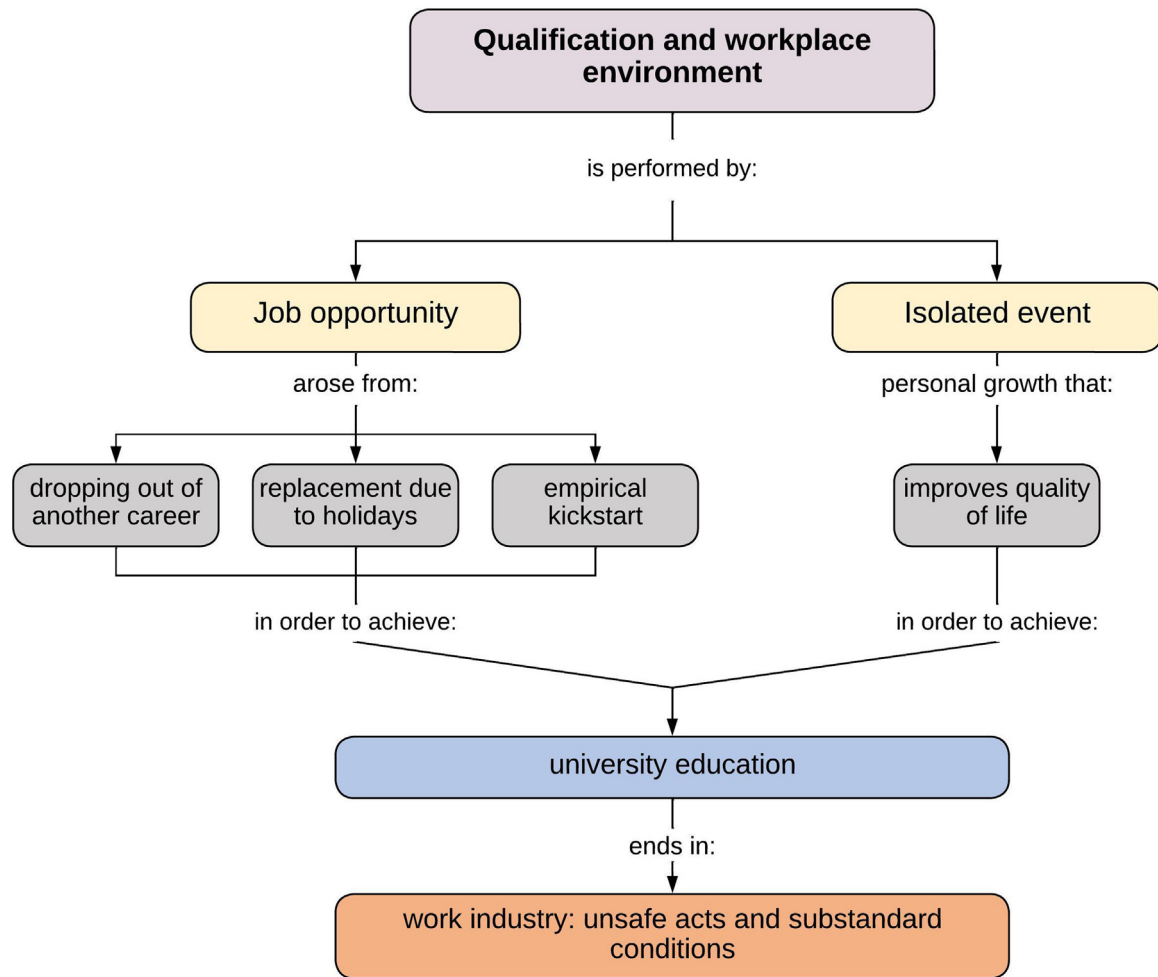


Fig. 2. Qualification and workplace environment. The second row (yellow colour) represents what the participants considered could be given in two ways. The third row (grey colour) describe the choices made by the participants. The fourth row (blue colour) represents the need for education and orange represents the potential outcomes considered by the participants.

3.2 Qualification and workplace environment

The responses obtained from the participants can be linked to the narratives created by the questions asked. The questions associated with this chapter include:

How long have you been working in the health area and what positions have you held? (including daily/annual work hours, average number of interventions, frequency, most common procedure). What has been your experience in the position you hold? (*i.e.*, time in this position, what areas, type of protection used, X-ray, nuclear). Could you tell me how you perform any of these procedures and in which area you have the greatest performance, or experience?

What training did you take for the position you hold? (such as schooling or empirical beginning).

Does the health institution offer continuous training/updates? (*i.e.*, held separately, conferences, seminars, continuing education, constant training).

The reasons participants chose these professions are summarised and include aspects sometimes driven by ignorance, opportunities, the privilege of receiving a

short-term pension for life, enjoying two vacations a year, or by improving one's professional profile.

Figure 2. This chapter describes the degree of university training and the reasons that led to choosing the profession. The topics of analysis of professional qualification and work environment were analysed from the feelings expressed by the participants, which are organised according to their stories and allow us to understand how one chooses their work field according to decisions made throughout their life.

A job opportunity arises at a moment leading to independent decisions where individual and social changes are sought and desired.

The qualification and work environment for some participants in this study was described through job opportunities or isolated events. Gladys said: '*I studied law, and as fate would have it I ended up studying radiology*'.

Others, such as Lucy, Alex, and Ana, began empirically or by taking vacation jobs and then went on to study at a university.

Gladys: '*I was growing and learning with them*'.

Alex: '*I started and then I had three years of training*'.

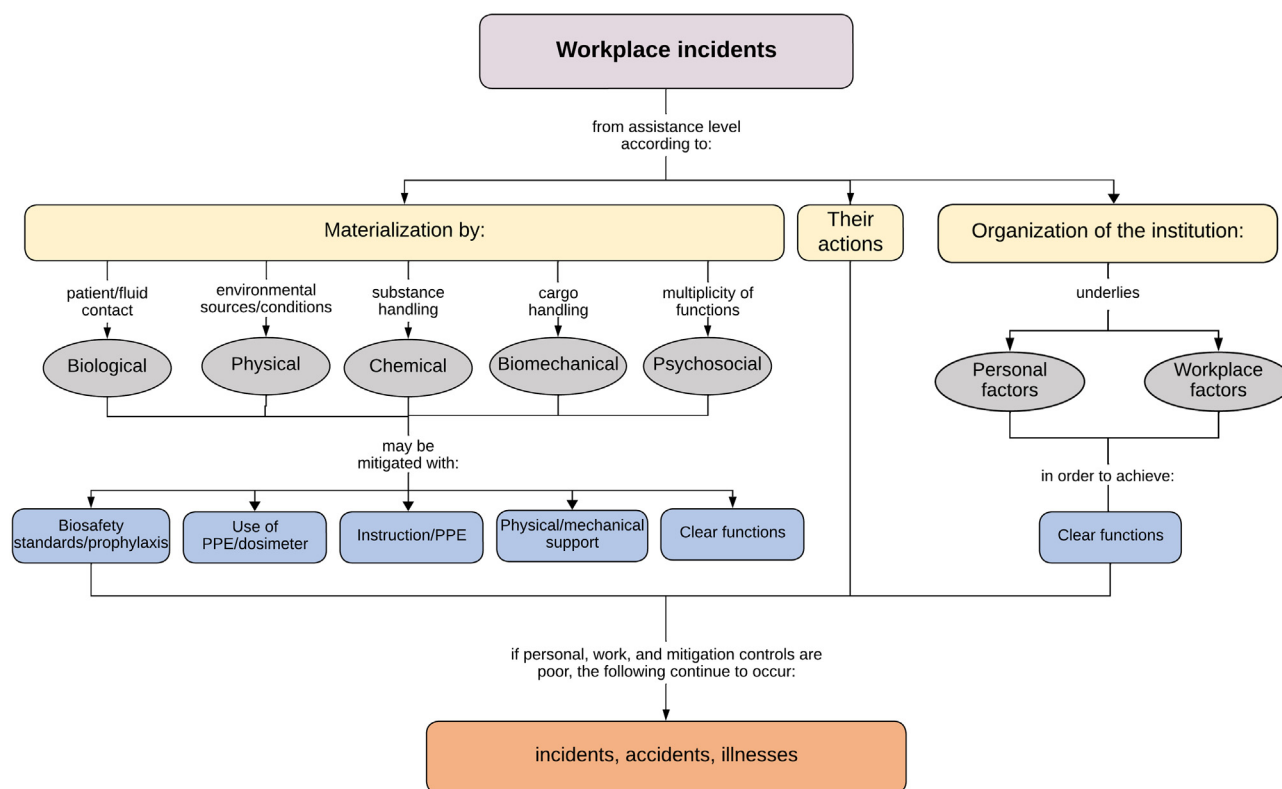


Fig. 3. Workplace incidents. The second row (yellow colour) presents the participants perceptions of how incidents can materialize. The third row (grey colour) represents the classification of the dangers and basic causes according to the participants. The fourth row (blue colour) represents methods to control unwanted events and orange represents the potential outcomes.

Lucy: 'I started working compensatory holidays and shifts'.

When a job opportunity is identified, regardless of the reason driving the change, a risk is immediately introduced. Thus, radiological risks are not risks assumed by either the exposed worker or the employer, indicating a substantial difference with other risks, such as psychosocial, chemical, biomechanical, and biological risks. In this case, the physical risk from radiation in the health sector may go unnoticed; therefore, the relationship between these risks must include the knowledge and recognition they deserve.

The performance of procedures involves working conditions derived from patient care.

Ana commented: 'I have worked in mammography, conventional X-rays, special studies, colon tests through enema and urography'.

Alex: 'They came where I was working, I saw a pneumothorax and said that this patient has a pneumothorax!'.

The challenges imposed in life and regulatory influence make empirical work more technical, with educational requirements proposed to carry out this type of work. The relationship with technological advances and educational demands is clear; receiving instructions strengthens professional behaviour and, together with experience, demonstrates competencies in the workplace. However, the same participants recognised the need for constant updating to maintain competency with respect to the use of new technologies.

3.3 Workplace incidents

The participants conceived workplace incidents from the possible materialization, that is, conversion to an accident, and also from the organisation, which is linked to administrative and managerial processes and from their own actions combining their experience and knowledge. To facilitate understanding, a diagram was created (Fig. 3). The questions associated with this analysis and that delimited this category are:

How many procedures, exams, do you perform or develop on average in your work activity? (e.g., daily schedule, hours/comfort ratio, times/movements).

What personal or work benefit has the institution or the health entity where you work provided you? What features does the equipment have? (e.g., weight, material, frequency of use).

Among the aspects of experience highlighted by the participants, labour incidents were derived from the assistance and were expressed in three cases in which feelings and perceptions associated to the biological danger were observed.

Lucy: 'Once we took care of a girl with meningitis during night shift, and they had every single one of us take antibiotics...'

Alex: 'I had to sweep, clean up vomit, mop up urine, everything'.

Gladys: 'Here we are exposed to biological risk because we handle emergencies....'.

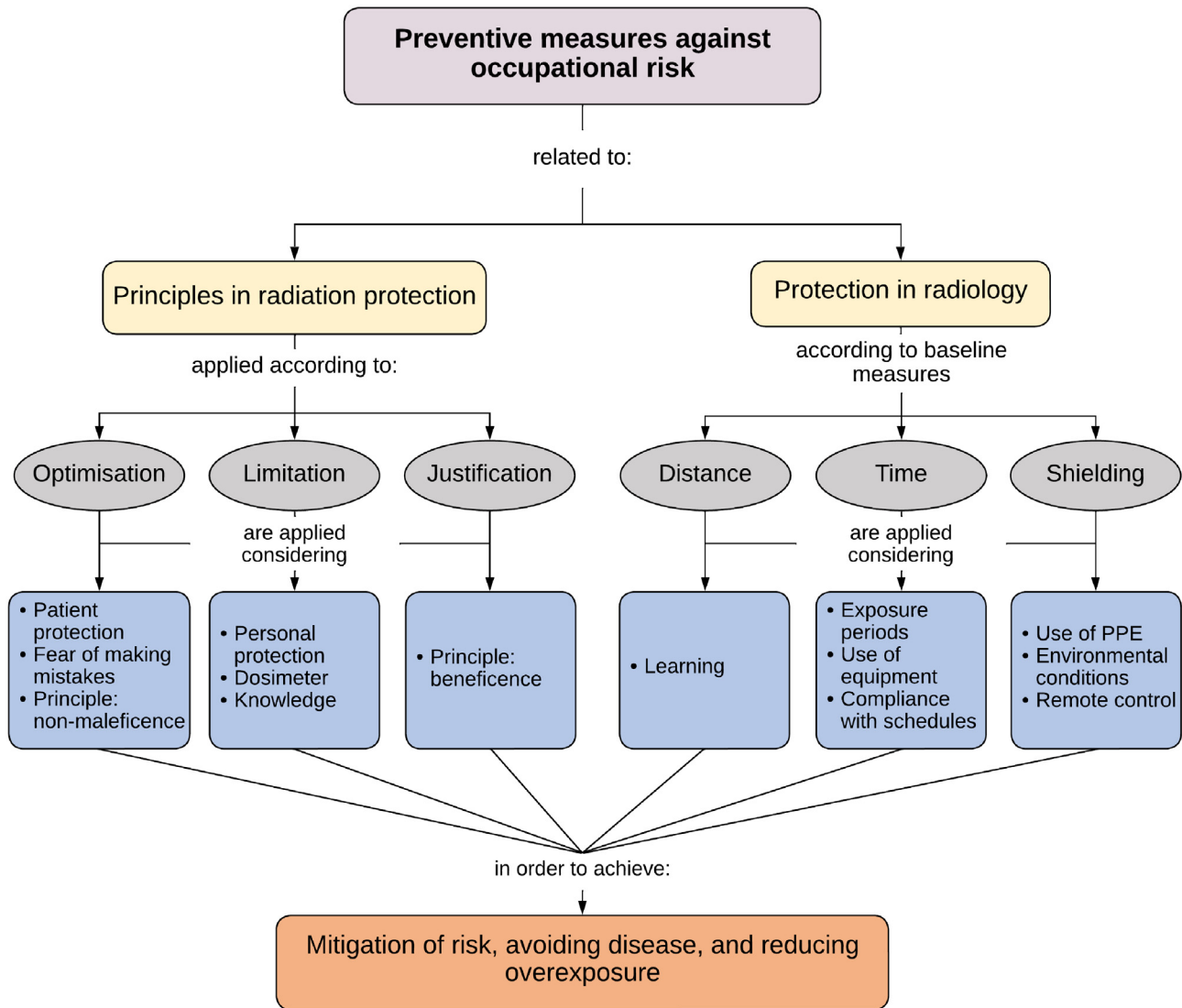


Fig. 4. Preventive measures against occupational risk. The second row (yellow) represents how the participants reported preventive measures. The third row (grey boxes) provides details of the radiation protection principles according to the participants. The fourth row (blue colour) describes the elementary things for your application.

Based on their stories, physical incidents happened because of workplace conditions.

Ana commented: 'The darkroom is really very small, the room is cold and dark'.

Raúl stated: 'The dosimeters went over the allowed limit, but this was never known...'

Alex: 'One is directly exposed to rays, those are daily incidents, besides, the scattered radiation, the secondary radiation, patient radiation...'

Gladys: 'With those PPEs, we have had several issues: they let the radiation pass...'

As for the chemical factors, Alex commented: 'The developer and fixer emit fumes; one had to read the instructions to know that kind of risks and it was always stressful'.

As for using loads and materializing a biomechanical risk, Gladys said: 'Sometimes you must try to sit the patient with the

stretcher bearer and the auxiliary, because it is vertical; so, everyone is exposed'.

Alex: 'It was necessary to use force to move the patient to the stretcher'.

Alex, like other participants, found themselves alone when providing assistance and stated: 'People were not going to say that it was the hospital's fault, but that we were to blame... People come aggressive despite the fact that one is providing a service... they blamed me for the consumption of plates'. Hence, the materialization of psychosocial risks was revealed.

Workplace incidents were a common occurrence; however, not all were reported either due to ignorance, because they did not generate consequences or disabilities, or due to forgetfulness. Under-reporting was noted in their notification and not all were investigated, since most incidents did not cause apparent injuries and causing them to go unnoticed.

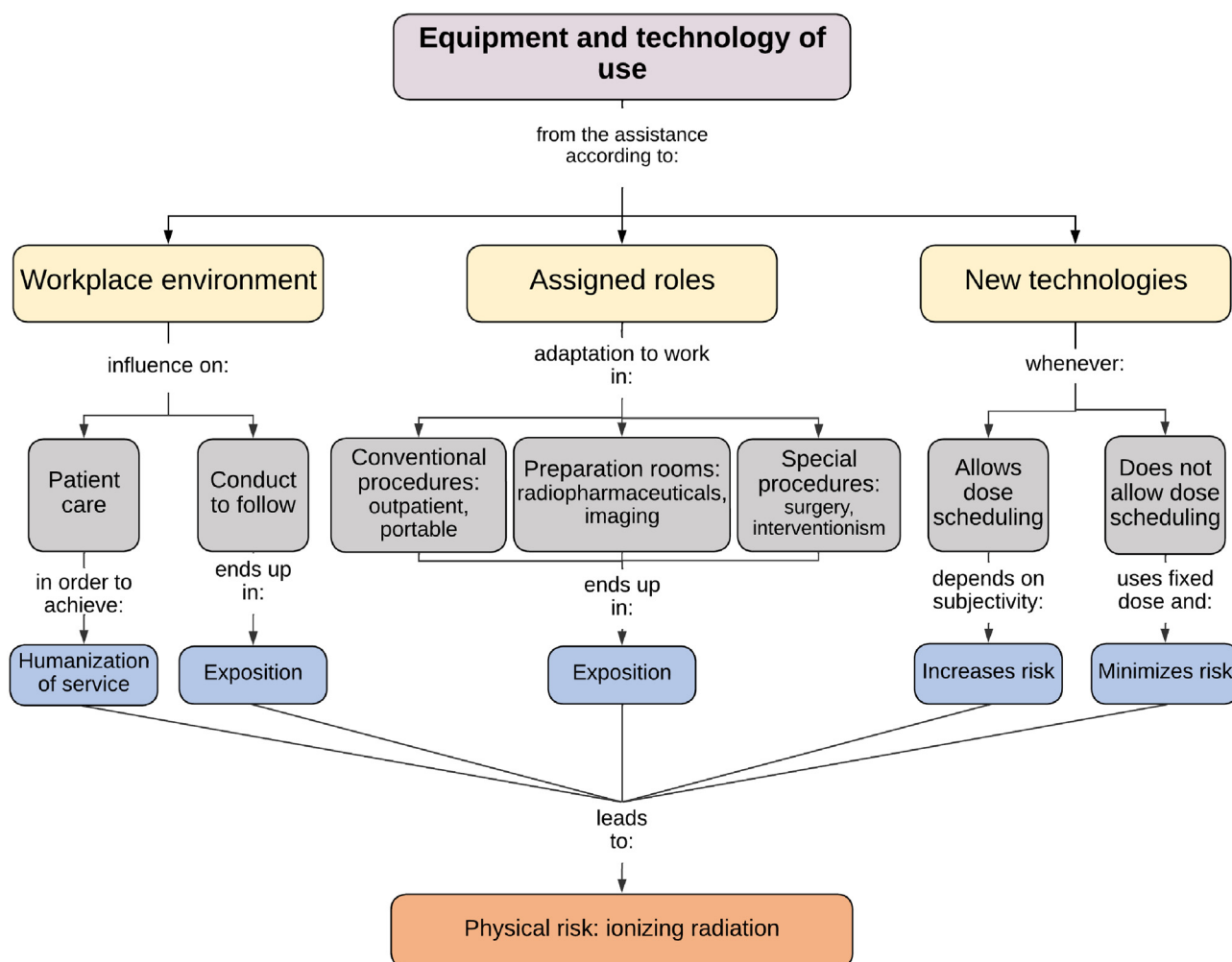


Fig. 5. Equipment and technology use. The second row (yellow boxes) provides details of participants daily work. The third row (grey colour) refers to actions taken by participant in the patient's presence. The fourth row (blue boxes) corresponds to the results and the fifth row (orange colour) to exposure to physical risk.

3.4 Preventive measures against occupational risk

The questions associated with this chapter and that delimited this category are:

What is your opinion about the equipment you use? (*i.e.*, equipment performance quality, functionality, reliability, safety).

About the facilities? (*e.g.*, leaded walls, concrete, shielding, surveillance, Geiger meters).

What do you know about the maintenance of equipment and areas?

What actions does the entity take in the event of equipment breakdowns, or how do they avoid them? Are there periodic visits from control entities, do they have radiation protection certification (virtual/in-person)?

Do you know the damage correction and prevention processes for this equipment? (*e.g.*, corrective/preventive, periodicity).

How often and how is the equipment cleaned? (*e.g.*, carried out by the technician, technologist, doctor, general services).

Figure 4 represents the structure provided by the data.

The comparison between what was described by the participants and what was normatively suggested required flexibility and sensitivity to 'recognise' what happens during the inquiry, and critical thinking was applied in the analysis to construct the category. Risk prevention measures are related to the principles of radioprotection and basic measures in radiology.

To improve preventive measures against occupational risk, activities associated with radiological protection were mentioned by the participants, as commented by Ana: 'Exposure: distance, time, and shielding'.

Raúl: 'I learned it during four semesters at university'.

Ana: 'The inverted square!'.

Raúl: 'The skirt, the screen, the distance...'

Distance is one of the best radio protection methods and the most commonly used in routine work; it is an effective way of protection and is also the most economical. When a participant moves away from a radioactive source it is expected that less radiation is received, and if the distance is doubled, half the radiation would be received.

For the participants, implementing and understanding these measures is based on learning that has been acquired academically, which influences their work behaviour and has a solid basis in radiological protection. The participants are aware that the use of PPE must always be a primary prevention measure; however, they should never be used as the only strategy for prevention and risk control, but rather as an intervention in the hierarchy of controls in protection.

On using the principles of radioprotection, *Alex* stated: *'The dosimeter, plus the gloves...'*.

Ana: *'The dosimeters with the range, collimation, shielding, and a closed door'*.

Lucy: *'The remote control in the rooms'*.

Raúl: *'Collimators, walls, and radio protection standards'*.

Gladys: *'Whenever there is a buzzer'*.

These stories establish that the workers' actions are based on the measure of shielding. However, participants mentioned that the walls in the past were not the same, and now they are more resistant and regulatory compliance and requirements have changed.

Participants described the measures used to reduce the chances of becoming ill in the long term. *Ana* said: *'We are prone to cancer...'*.

The principle of radio protection that contemplates the optimal use of radiation is the 'As Low As Reasonably Achievable' (ALARA) principle, although workers fear for themselves and consider the situations that may expose their body, thereby inducing changes. It is one's obligation to minimise exposure and prevent harm.

3.5 Equipment and technology use

In this analysis, equipment and technology use was conceived from the hired work, from professionalism and from assistance. The following questions were associated with this chapter and serve to guide its interpretation:

Can you say the eleven training items required by Resolution 482 of 2018 in Colombia?

What do you know about the training programme in radiation protection and safety?

Whenever equipment is going to be used, do you use the manuals?

Do you use instructions for handling, cleaning, precaution, isolation, demarcation?

Inverse square envelope, what is how you define it?

Figure 5 represents the structure provided by the data. To understand the use of equipment and technologies among the participants, characteristics derived from the workplace environment, assigned functions, and use of technology were considered. When defining the behaviours that follow, we found comments such as those from *Gladys*: *'One manually places the voltage, for children one option, for someone thin another, for a fat person another, you know...'*.

This description demonstrates that manual programming can cause errors associated with subjectivity, or administrative errors, which depend on the understanding of individual anatomy and use of lower or higher voltage doses.

As for prioritising care, *Gladys* commented: *'I don't have any buts, they bring me the name of the patient and that is my priority'*.

Lucy: *'In three minutes you are handing over the results and then you get the patient to smile, to thank me, this is everything, it is amazing'*.

Ana: *'We can handle a higher kilovoltage which is penetration in a short time, so that we don't repeat a patient'*.

The participants stated that they fulfilled their assigned functions, highlighted their work, and prioritised care when it is up to them. The patient is the priority, and the participants described acting quickly when required. For the participants in this study, the use of equipment and technologies in the work environment involves the use of techniques and procedures required to achieve patient care.

Follow-up and adherence to functions is monitored, as *Ana* mentioned: *'We have parameters for wrist and foot with so much time, it depends on thickness'*.

Gladys: *'I perform special studies, the other partner does portable, and another one does surgery'*.

Lucy: *'We all rotate: portable, special, surgeries'*.

Raúl: *'I work in conventional, angiography, and tomography services'*.

Alex: *'One could improve contrast; I never hesitated if I had to do 3,4,5,6 to better see the pathology'*.

Gladys: *'Now you take several shots and you choose the one you want'*.

When any manipulation occurs by man, the possibility of error is considered. These descriptions demonstrate that manual programming can cause errors associated with subjectivity, or administrative errors, which depend on the understanding of individual anatomy and use of lower or higher voltage doses.

The participants declared that new technologies are better and relate time to exposure, suggesting the inclusion of protective measures used in health activities, with the basic principles of radioprotection put into practice.

All these perceptions, arguments, languages, and behaviours are based on the perspective of the participant, and can therefore be influenced by particular interests and desires, although must be considered from different perspectives, whether by manipulation or the use of smaller magnitudes while maintaining what is technically proposed in the diagnostic process. However, workers are influenced by their feelings and perceptions, while understanding the cognitive process comprising recognising, deciphering, and giving meaning to make judgements based on impressions derived from the physical and social environment, where learning, memory, and symbolisation intervene.

The use of new technologies was mentioned in the following comments.

Ana: *'...equipment with sensors, we don't use chassis, we have to keep in mind which part the right part is directed to in order to avoid confusion'*.

Raúl: *'The equipment today is more sophisticated'*.

Gladys: *'We have very modern equipment, they print everything, you don't have to think too much'*.

Lucy: *'They are good, the delay is minimal and the exposure is less'*.

The consequences of radiation risk were expressed by several participants.

Raúl: *'Cardiology is where one is irradiated the most; this is the problem with angiography'*.

Lucy: 'I used to have very good eyesight, but now I can't see very well up close'.

Raul: 'During 12 h, we performed about 40 procedures of all...'

Alex: 'You end up knowing the tricks of the equipment and it is up to oneself to fix it'.

Ana: 'The mammograms had to be performed using chemicals and an extractor, but an old machine...'

Procedures related to optimisation can be violated, and activities related to dose manipulation, in which the principle of radioprotection (ALARA) may not be observed.

4 Discussion

Understanding of occupational risk depends on the participants views and perception, which are influenced by factors such as institutional context, available resources, and workplace processes (Scheer *et al.*, 2014). The participants understood the workplace environment, physical consequences, and triggering of behavioural changes.

Numerous studies have shown a deficit in knowledge about radiation protection among healthcare professionals (Bayatiani *et al.*, 2023; Housni *et al.*, 2023) which leads to a misuse of protective tools. In our study, it was found that the participants knew the basic principles of radiation protection. However, during the investigation and in individual participant perceptions, low use of PPE, especially glasses, vests, and screens (Poveda and Plazas, 2020) was observed, as well as the material weight they are made of, resulted in increased risk perception, known as 'biomechanical risk', which is the result of long working days when using leaded protection elements (Puerta and Morales, 2020) and is associated with cumulative trauma injuries.

Although the risks of cancer induction and non-cancer disease from radiation exposure have been documented (Bazyka *et al.*, 2018), the use of radiation was associated and recognised with short- and long-term health impairments among participants. Education, training, and communication processes can increase knowledge and perceptions of radiation care (Schieber *et al.*, 2020).

Regarding qualifications and workplace environments, non-compliance with working conditions caused discomfort among workers. Some participants began their work empirically; however, they later attained a 3-year university education, which when compared with training in other countries, provides knowledge of the radiological protection (both theoretical and practical) necessary to autonomously deal with the technical aspects of performing medical imaging procedures using ionizing radiation (Faggioni *et al.*, 2017). This empirical learning may produce a low-risk perception related to maturity or adolescence, considering that a person's views are formed according to their environmental context, learning style, and epistemic curiosity. Hence, each participant is responsible for their own preparation and training in a given context (Navarrete, 2013). The accumulated experience of the participants should be addressed in order to reduce the radiation dose variability and raise awareness of the effect of doses on the patient, worker, and patient's health as reported by (Zanca *et al.*, 2020), leading to standardised protocols in the future as described in the Bonn Call for Action.

The most common occupational incidents among the participants were associated with the physical conditions of the organisation (Gil, 2012), indicating proportionality between the occurrence of incidents and their culmination as accidents (Mejía *et al.*, 2019). Although exposure to low doses of radiation and cognitive dysfunction seem inconsistent according to the literature, the stress associated with the real or perceived exposure derived from the multiplicity of tasks found in this research has a negative impact, producing psychological stress and overlapping with pro-inflammatory effects (Collett *et al.*, 2020). This suggests that occupational safety is co-constructed by workers when their feelings are considered and a notification and reporting process is maintained (Rossignol, 2015).

Studies on prevention against occupational risk include terms associated with standards in radiology without knowing their applied basis such as distance, time, and shielding. Owing to the limited and poorly applied knowledge of radiological protection, knowledge gaps exist in dose use, training, and effective education (IAEA and WHO, 2012; Faggioni *et al.*, 2017), leading to diagnostic or treatment errors, although the participants bear the greatest responsibility in dose administration (Soffia *et al.*, 2017; Schieber *et al.*, 2020;).

Participants understood that radiological studies can harm patients, the environment, and themselves and also considered that the risk-benefit ratio is not isolated from the fear of making a mistake, since 30% of the procedures are not justified (EC, 2000). Among participants, little acknowledgement of radiation protection principles such as justification and optimisation were found (Malone and Zölzer, 2016); some stated that the number of procedures depended on their perception, excluding academic concepts (Zölzer, 2020), indicating that this is not just a matter of science, but clearly has consequences and ethical issues.

Some studies mentioned the use of older technologies and equipment that clearly correlate to the perception of increased exposure risk related to equipment ageing (Zanca *et al.*, 2020). However, some risk factors such as patient obesity are strong predictors for defining radiation doses, which are understood as deviations in healthcare processes, leading to higher exposure for both workers and patients (EC, 2012).

Dose optimisation, a multi-step process including everything from a quality assurance plan to the dose effect on patients and image quality (Tsapaki, 2020), involves keeping patient exposure at the minimum necessary level to achieve the required diagnostic or interventional objective (IAEA, 2009). The participants were aware of the theory and were experienced; however, in practice, this principle was weakly applied among these participants. The repetitiveness of processes and use of numerous repeated tests was described by the participants in their daily procedures, without considering that radiation use was associated with cancer risk, while ignoring the patient's self-care and cancer risk (IARC, 2000) and their own self-care, as well as care for others and the environment (Garcés and Giraldo, 2013; Prasarn, 2014). Therefore, safety standards must be optimised because there is no such thing as 'very little' radiation (OEIA, 2016). The procedures described were barely practiced according to the ALARA concept.

5 Limitations

This study was limited by the number of participants included in the analysis. This process takes time, requires resources, and involves expert participation and a greater number of professionals involved in the practice to be able to extrapolate the findings to similar groups with the same characteristics. We expect that similar work will contribute to the perception of radiological risk in the future.

6 Conclusions

This study revealed how administrative controls could help when workers' feelings were considered.

Minimal adherence to radio protection norms was observed; participants worked in various places, and some did not use protective elements on the job. These findings are useful and may help develop strategies to reduce the exposure risk.

The ALARA principle was barely acknowledged according to distance/time/shielding, with notable poor safety standards and lack of training among the participants.

Implementing training in healthcare institutions or academia considering a preventive approach for radiation use is necessary.

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Conflicts of Interest

The authors declare that they have no conflict of interest.

Data availability statement

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

Author contribution statement

All authors have read and agreed to the published version of the manuscript.

Ethics approval

Ethical approval was not required.

Informed consent

Written informed consent was obtained from all participants.

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