Enhancing
Radiation safety culture
in health care

Guidance for health care providers

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Contents

Acknowledgements

Abbreviations

AAPM	American Association of Physicists in Medicine
ANRDR	The Australian National Radiation Dose Register
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
BSS	International Basic Safety Standards
CT	computed tomography
FORO	Ibero-American Forum of Radiological and Nuclear Regulatory Agencies
HLM	high-level management
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IOMP	International Organization for Medical Physics
IRPA	International Radiation Protection Association
MRI	magnetic resonance imaging
OSART	Operational Safety Review Team
PET	positron emission tomography
PPE	personal protective equipment
QUATRO	Quality Improvement Quality Assurance Team for Radiation Oncology
RELID	Retrospective Evaluation of Lens Injuries and Dose (study)
RSCHC	radiation safety culture in health care
SAFRON	Safety in Radiation Oncology
SPECT	single-photon emission computed tomography
SRP	Society of Radiological Protection
SWOT	strengths, weaknesses, opportunities and threats
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
WANO	World Association of Nuclear Operators
WHO	World Health Organization

Executive summary

This publication focuses on radiation safety culture in health care, which encompasses all uses of radiation for the improvement of health via the prevention, diagnosis, treatment, recovery or palliation of disease, illness and injury. It provides a framework to establish, maintain and enhance safety culture in health care. It is primarily addressed to health professionals and other stakeholders having an interest in radiation protection – including regulators, manufacturers of medical devices, experts and health care managers. It may be appreciated by patients, staff in health care applications of radiation and the public alike.

The publication highlights ten traits describing patterns of organizational and individual thinking/behaving, which define a positive safety culture. Further, a set of tools to assess the existing level and quality of radiation safety culture is proposed and case studies/good practice examples from different settings and regions of the world are presented and can be used as a basis for the development of derivative assessment and implementation tools appropriate to local contexts and for developing training materials.

The key messages of the publication are the following:

- ⊕ Actions taken to enhance the protection and safety of patients and personnel involved in medical use of radiation represent radiation safety. These actions lead to radiation safety culture when organizational and individual characteristics and attitudes that determine how everyone practices radiation safety are considered and embedded within an organization (e.g., ideas, values, behaviours and customs).

- ⊕ Anyone with a safety concern or perceived safety concern should be empowered to raise awareness and resolve the issue before commencing activities.

- ⊕ Leadership, management and personal accountability are critical factors in enhancing radiation safety culture, and those involved in radiation safety should prioritize them as such.

- ⊕ Understanding the errors affecting patient safety has developed from a simple causal model to one that considers a complex mix of behaviours and interactions influencing the environment and outcome.

- ⊕ Implementing the principles of justification and optimization is essential to ensure that radiation used in health care is managed safely.

- ⊕ Engagement strategies must be tailored to the diverse groups of stakeholders contributing to radiation safety culture.

- ⊕ Everyone in the diverse groups of stakeholders is responsible for assuring a strong radiation safety culture in health care aiming that patients are imaged and treated correctly.

- ⊕ Communication, education and training are considered essential for establishing and maintaining radiation safety culture.

- ⊕ There needs to be consistent and coordinated understanding of radiation safety culture among the many stakeholders within health care, which acknowledges the varying perceptions.

- ⊕ Everyone can participate in strengthening safety culture. There are international, national and local initiatives to help health care providers improve radiation safety.

- ⊕ A combination of optimal tools is required to establish and maintain radiation safety culture. This includes standards and regulations, policies and procedures, education and training, audit activities, communication strategies, reporting and learning systems, checklists, verification procedures, time-out procedures as well as technical developments.

⊛ A positive safety culture can be defined by ten traits: leadership responsibility, individual responsibility, continuous learning, effective safety communication, respectful work environment, problem identification and resolution, environment for raising concerns, decision-making, questioning attitude and work processes.

⊛ Good practices to improve safety culture shared by radiation health care providers can be adopted/adapted around the world.

⊛ Existing frameworks proposing assessment tools and performance indicators can be adopted and adapted to the local context to assess level and quality of radiation safety culture.

It is recognized that the prime drivers that influence safety culture in different parts of the world are cultural, social and economic factors. It is important that these can be both contextualized for deeper understanding and shared for greater learning and benefit. Any generic framework may be perceived as difficult to implement in practice, as specific situations may warrant specific considerations. Indeed, safety culture is fundamentally a local condition that differs between and within organizations. Therefore, while the proposed framework can be adopted at regional and/or national levels, its implementation requires adaptation to the local context.

Underpinning all else, is the final key message below.

Safety is not just the sum of rules, policies, procedures and processes. The real building blocks of safety are trust, communication and culture.

Introduction

As the leading global health agency, the World Health Organization (WHO) considers patient safety as fundamental to the provision of health care in all settings WHO (2021a). Radiation safety culture is a topic of increasing interest and importance globally (Rühm et al., 2023). The ultimate goal of safety culture is to increase safety. Radiation safety encompasses every action taken to improve the protection and safety of patients and personnel involved in medical exposure. This is transformed into radiation safety culture by consideration of *how* everyone involved practices radiation safety and the extent to which messages about safety culture are embedded within the facilities and centres where medical exposure occurs. Culture incorporates both characteristics and attitudes of organizations and individuals, and includes the ideas, values and customs that are shared and accepted by people in a society and that determine appropriate attitudes and behaviour (IRPA, 2014). In order to understand and influence radiation safety culture it is necessary first to explain what is meant by the phrase.

1.1 What is radiation safety culture?

The phrase "radiation safety culture" rather than "radiation protection culture" is used as safety goes beyond protection; it includes other aspects of safe radiation use such as the safety of radiation sources. Safety culture is addressed in World Health Organization (WHO) quality and safety documents (WHO, 2018; WHO, OECD & World Bank, 2018) and IRPA guiding principles (IRPA, 2014), among other publications (Berris et al., 2017). It is also addressed in a foundational International Atomic Energy Agency (IAEA) report (IAEA, 1991), and referred in the International Basic Safety Standards (BSS) (IAEA, 2014) as well as in IAEA technical reports (IAEA, 2020a). The Bonn Call for Action, a result of the International Conference of Radiation Protection in Medicine held in Bonn, Germany in December 2012 and co-sponsored by IAEA and WHO, encouraged every organization and stakeholder to contribute to the implementation of 10 actions to improve radiation protection in medicine, one of which relates directly to strengthening radiation safety culture in health care (IAEA & WHO, 2014). This is discussed in more detail in Chapter 4.

The radiation safety culture of any organization is defined by the attitudes, behaviours and actions of its stakeholders towards radiation safety. It is necessary for health professionals involved in radiation protection to develop their own policies relating to radiation safety culture and make provisions for it to be embedded at the highest management level in their organization, in order for the developed culture to be sustainable over the long term. Organizational structure institutionalizes how people interact with each other, how communication flows and how relationships are defined. It also reflects the value-based choices made by the professionals. Embedding safety culture within an organization is by far the most effective way of delivering the performance to which humans aspire.

Radiation safety culture in health care is related to, but subtly different from, radiation protection principles and practice; the culture reflects the ethos and motivation that is needed to successfully apply and sustain the principles and practice.

> ☢ **Key message**
>
> Actions taken to enhance the protection and safety of patients and personnel involved in medical use of radiation represent radiation safety. These actions lead to radiation safety culture when organizational and individual characteristics and attitudes that determine how everyone practices radiation safety are considered and embedded within an organization (e.g., ideas, values, behaviours and customs).

1.2 Benefits of a radiation safety culture

A solid radiation safety culture addresses radiation safety of all those involved in health care applications of radiation, including patients, staff and the public in general and leads to good patient outcomes, and so is intimately connected to the quality of patient care.

Patient safety can be defined as the prevention of harm to patients and is considered indistinguishable from the delivery of high-quality health care (Institute of Medicine, 2004). Patient safety practices have been defined as those that reduce the risk of adverse events related to medical care across a range of diagnoses or conditions (Shojania et al., 2001). This definition works well with imaging and therapeutic radiation applications considering the potential effects of a misdiagnosis or incorrect treatment site on the body but may fall short conceptually when considering the prevention of harm.

Quality of care is the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge (WHO, OECD & World Bank, 2018). Safety and quality cannot be separated in any medical practice, as safety is one of the elements of the concept of quality of care. These elements are summarized in Fig. 1 (WHO, 2022a). In this context, radiation safety must be always linked to quality when setting up policies and programmes. The radiation protection principles of justification and optimization must also be considered in the context of both safety and quality. Both patient safety and quality should be embedded in radiation safety in health care by defining a system of care delivery that achieves each of the following:

- prevention of errors;
- learning from any errors that do occur;
- building on a culture of safety that involves health care professionals, organizations and patients.

Fig. 1. Elements of health care quality (WHO, 2022a)

1.3 Current trends and need for action in health care

The trends in health care across the globe involve rapidly advancing scientific and technological developments, and their implementation. This includes the availability of new techniques for imaging and treating patients, and wider availability of radiation generating equipment. Such developments bring great benefits to patients but are also associated with an increased radiation dose burden, which affects patients, the staff caring for them and by extension the wider community. A notable example is the worldwide rapid increase in the use of computed tomography (CT) with an increasing number of individual patients with high cumulative doses resulting from recurrent CT exams (Rehani & Hauptmann, 2020). The benefits of this technology are considerable but, due to the relatively high doses involved compared to other imaging modalities, the requirement for justification and optimization of exposure, and the potential detriment if these principles are not adequately addressed, also grow in importance. This is illustrated through, for example, evidence of patients receiving over 100 mSv through recurrent CT imaging and through interventional fluoroscopy in non-accidental situations (Rehani et al., 2020; Brambilla et al., 2020). A conservative estimate shows nearly one million patients reach this level every year globally and nearly 20% of these are below 50 years of age (Rehani et al., 2020; Li et al., 2020). The volume of usage of radiation in medicine and the associated risks surpass those of any other use of radiation.

Other developments that require new, and complex, radiation safety considerations are those involving combinations of radiation technology, including those combining ionizing and non-ionizing radiation techniques. Such technologies blur the boundary between different modalities, as in hybrid imaging, for example positron emission tomography-CT (PET-CT), single-photon emission computed tomography-CT (SPECT-CT) and PET magnetic resonance imaging (PET-MRI) image-guided radiotherapy (e.g., guided by CT, ultrasound or MRI) and intra-operative therapies. There are also many new radionuclides being investigated for use in molecular imaging and therapy, referred to as theranostics. These personalized therapies require new radiation safety considerations regarding optimization of radiopharmaceutical doses and dose schedules when utilizing the same (or very similar) radiopharmaceutical/s for both imaging and therapeutic purposes. Multimodality technology raises its own challenges. For the hybrid technologies outlined above, there is an additional requirement for good coordination and communication between the different disciplines.

Developments in technology can lead to equipment that gives inherently lower doses than older equipment, but this may be outweighed by the rapid increase in the use of the imaging equipment that might be unnecessary and/or inappropriate, as justification and optimization remain key issues. Such developments require a corresponding rate of development in associated training and expertise, and availability of staff from appropriate disciplines. For this reason, trends in radiation safety training programmes and availability of competent medical physicists, radiologists and radiographers/technicians will also have an impact on radiation safety culture.

Keeping in mind that the benefits of safe and effective use of advanced radiation technology are proven, the drivers for strengthening safety culture are not linked to reducing their application in health care but to preventing inappropriate handling. This includes for example unjustified and/or not optimized imaging procedures, unnecessarily repeated imaging, lack of optimization in image-guided interventional procedures, lack of follow-up of patients with potential tissue reactions associated with relatively high cumulative doses, occurrence of incidents and adverse events and staff not using adequate protection during procedures, among others. While radiation protection and safety can contribute to reduce the chances of inappropriate handling of radiation technology, strengthening radiation safety culture can make such reductions sustainable.

It is also particularly important to support the implementation of new radiation technologies as inappropriate use of such technologies may increase risk and result in harm for patients and/or workers. The highest number of radiation fatalities and the highest number of acute injuries resulting from accidents relates to medical uses of ionizing radiation. An example of such patient harm occurred in a public hospital in France, where over 5000 cancer patients treated between 1987 and 2000 were overexposed due to a systematic calculation error (Tamarat & Benderitter, 2019)

1.4 A historical perspective

As early as 2000, the US Institute of Medicine urged in its report *To err is human: building a safer health system* (Institute of Medicine, 2000) health care organizations to implement initiatives to improve safety in health care. This publication represented a milestone in the evolution of safety culture in medical settings in the context of radiation. A number of other international publications followed:

In 2008, WHO published a *Radiotherapy risk profile* (WHO, 2008) mapping the risks from incidents and adverse events in radiotherapy based on a review of available literature. It was shown that 3125 patients were reported to be affected by radiotherapy incidents between 1976 and 2007. About 1% (N=38) of the affected patients died due to radiation toxicity (overdose). More than 4500 near misses (N=4616) were reported in the literature in the years 1992 to 2007.

Also in 2008, the United Nations Scientific Committee on the Effects of the Atomic Radiation (UNSCEAR) completed a comprehensive review of accidents involving ionizing radiation exposure from 1945 to 2007 (UNSCEAR, 2011). UNSCEAR reported that the highest number of fatalities (46 deaths) and the highest number of acute injuries (623 cases) resulted from accidents related to medical uses of ionizing radiation. UNSCEAR noted that the actual number is likely higher, since many accidental and unintended exposures in health care are not known or reported.

An international study called Retrospective Evaluation of Lens Injuries and Dose (RELID) was initiated by IAEA in 2008 and its findings indicated that the incidence of lens changes typical of ionizing radiation exposure were found in a large fraction of interventional cardiologists, interventional technologists and nurses working in catheterization laboratories (Duran et al., 2011; Rehani et al., 2011; Vano et al., 2013).

In 2012, the International Commission on Radiological Protection (ICRP) published a review of radiation induced tissue reactions, paying particular attention to circulatory disease and cataracts, because of recent evidence of higher incidences of injury than expected after lower radiation doses; suggesting that threshold doses would be lower than previously considered (ICRP, 2012).

In 2014, IRPA published the *IRPA guiding principles for establishing a radiation protection culture*. The publication explained that developing a "field culture" in addition to the science, engineering or medical culture is a way to anticipate problems and to obtain the commitment of all employees (IRPA, 2014). The publication also showed that embedding radiation protection at a cultural level within an organization is by far the most effective way of delivering the performance to which humans aspire, in order to:
- give visibility to the fundamentals of radiation protection (science and values);
- promote radiation risk awareness;
- promote shared responsibility among practitioners, operators, managers and regulators;
- maintain the radiation protection heritage and facilitate its transmission;
- improve the quality and effectiveness of radiation protection.

Interest and activity in radiation safety culture in medicine has continued in many parts of the world, as is reported in the literature (Abuzaid et al., 2019; Akinlade & Kelani, 2019; Binjola, 2020; Buckley et al., 2020; Chapple et al., 2017; Cortese, 2020; Eisa & Saleh, 2020; Hammer & Russell, 2020; Soliman et al., 2020; Livingstone & Varghese, 2017; Ralston & Yuen, 2018; Regan & Clark, 2017; Rose & Rae, 2017; Yari et al., 2019). The need for radiation safety culture in health care has been further highlighted through inappropriate use of imaging (Bouëtté et al., 2019; Bianco et al., 2018; Oikarenen et al., 2009; Malone et al., 2012), observed variation in radiation dose for the same examination in similar clinical settings (Hart, Hillier & Shrimpton, 2010; Shrimpton et al., 2016; Holroyd & Edyvean, 2018) and limited use of diagnostic reference levels (Vassileva et al., 2013; Vassileva et al., 2015; Salama et al., 2017; Roch et al., 2020; Rehani, 2015a). The considerations of image quality in radiation dose surveys and for establishing reference levels have been recently emphasized (Kharita et al., 2020; Padole et al., 2019; Rehani, 2015b).

1.5 Methodology for content development

After the publication of the *IRPA guiding principles on radiation protection culture*, IRPA, IAEA, IOMP and WHO organized a special session on radiation protection culture during the 4th Asian and Oceanic Congress of Radiation Protection, Kuala Lumpur, Malaysia (in May 2014). Based on the feedback collected from participants it was agreed to launch a new common initiative focused on radiation safety culture in health care. This was mainly driven by the intention to enable synergies and join efforts, in order to achieve greater impact and efficiency by combining and complementing the roles and mandates of these organizations and expanding the scope of stakeholders to be engaged.

This publication was conceived from a project that sought to address enhancing radiation safety culture in health care worldwide. The first step of this project was the organization of six regional workshops from 2015–2019, on radiation safety culture in health care, which included representatives from the following health professional sectors (in alphabetical order): dentists, engineers, health physicists, interventional cardiologists, medical physicists, nuclear medicine physicians, paediatricians, radiation oncologists, radiologists, radiological technologists, radiographers, along with regulatory bodies, health authorities, manufacturers, and patients' associations. The aim of the workshops was to collect stakeholders' feedback, identify key elements of radiation safety culture in health care, and also to set priorities for establishing and maintaining a strong radiation safety culture on all continents, with examples from diagnostic radiology, image-guided interventions, radiation therapy and nuclear medicine.

Fig. 2 summarizes the professional groups that provided stakeholder views during the six regional workshops, though it is by no means an exhaustive list of those involved.

Fig. 2. Professional groups involved in regional workshops

• Dentists
• Nuclear medicine physicians
• Radiation oncologists
• General practitioners
• Family doctors
• Paediatricians
• Emergency physicians
• Other referring physicians

RADIATION EXPOSURE PRESCRIBERS/REFERRERS

• Medical physicists
• Health physicists
• Radiation protection experts

DOSE ASSESSORS/ OPTIMIZERS

PATIENTS and FAMILIES

OTHER PROFESSIONAL GROUPS

• Nurses
• Physician assistants
• Bioengineers

RADIATION EXPOSURE DELIVERERS/PROVIDERS

• Radiologists
• Radiographers and other radiological technologists
• Nuclear medicine physicians
• Dental practitioners
• Cardiologists
• Gastroenterologists, orthopaedists, vascular surgeons

Each of these regional workshops aimed to identify priorities and analyse the organization's strengths, weaknesses, opportunities and threats (SWOT) as described in Table 1 via their professional groups, including local representatives of non-profit-making medical associations, oversight organizations and health care professionals as well as patient and manufacturer representatives. The feedback collected during these six workshops informed the second step of this project, resulted in the development of this document.

Table 1. Six regional workshops on radiation safety culture in health care[1]

Workshop	Topics
Regional workshop on Radiation Protection Culture in Medicine in Latin America (Buenos Aires, Argentina, April 2015)	• Key components of radiation protection culture. • Perspective on radiation protection culture in medicine in Latin American countries. • Priorities for establishing a strong radiation protection culture in medicine.
Regional workshop on Radiological Protection Culture in Medicine in Europe (Geneva, Switzerland, December 2015)	• Raising awareness and developing radiation safety attitudes. • Radiation protection in management and quality-assurance systems, with strong leadership and commitment to radiation protection. • Reporting events, learning and improving. • Strengthening the commitment of manufacturers with protection and safety. • Enhanced involvement of professional societies (stakeholders' involvement).
Regional workshop on Radiation Safety Culture in Healthcare (Stellenbosch, South Africa, November 2016)	• Key elements for establishing and developing a general approach to RSCHC. • Particular considerations for building a strong radiation safety culture in paediatric imaging. • Strengths, weaknesses, opportunities and threats (SWOT) analysis for improving RSCHC in Africa. • How to engage patients/parents in RSCHC improvement. • Tools and indicators for assessing RSCHC.
Regional workshop on Radiation Safety Culture in Healthcare (Doha, Qatar, February 2017)	• Key elements for establishing and developing a RSCHC general approach. • Setting priorities for building a solid RSCHC. • Role of patients and patient associations in developing radiation protection culture. • SWOT analysis for improving RSCHC in the Middle East. • Tools and indicators for assessing RSCHC.
Regional workshop on Radiation Safety Culture in Healthcare (Kuala Lumpur, Malaysia, November 2017)	• Key elements for RSCHC. • SWOT analysis for improving RSCHC in Asian and Pacific countries. • Role of patients and patient associations in developing a RSCHC. • Setting priorities for building a solid RSCHC. • Tools and indicators for assessing RSCHC.
Regional workshop on Radiation Safety Culture in Healthcare (San Diego, the USA, February 2019)	• Key elements for RSCHC — stakeholders' views and examples from radiology, image-guided interventions, radiotherapy and nuclear medicine. • SWOT analysis for North America: vision, challenges and opportunities. • Role of patients and patient associations in developing a RSCHC. • Setting priorities for building a solid RSCHC. • Tools and indicators for assessing RSCHC.

RSCHC: radiation safety culture in health care
SWOT: Strengths, Weaknesses, Opportunities and Threats

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[1] The first regional workshop for Latin American countries, hosted by the Argentine Society of Radiation Protection, was held in Buenos Aires, Argentina, in April 2015. The second regional workshop for European countries, hosted by WHO, was held in Geneva, Switzerland, in December 2015. The third regional workshop for African countries, hosted by the Radiological Society of South Africa, was held in Stellenbosch, South Africa, in November 2016 and the fourth regional workshop for Middle Eastern countries, hosted by Hamad Medical Corporation, was held in Doha, Qatar, in February 2017. The fifth regional workshop for Asian countries, hosted by the Malaysian Ministry of Health, was held in Kuala Lumpur, Malaysia, in November 2017. The sixth regional workshop for North American countries, hosted by the Health Physics Society, was held in San Diego, the USA, in February 2019.

1.6 Management of conflict of interests

External experts acting in their individual capacity were required to complete a standard WHO declaration of interests' form. All declarations were reviewed on the criteria for assessing relevant financial and non-financial conflicts of interests. None of the interests declared was found to be significant.

1.7 Outline of the document

Chapter 1 defines radiation safety culture in health care and describes the methodology applied to identify the need for its implementation. Chapter 2 presents safety culture in a number of other industries, with a view to identify lessons that may be learned and applied to radiation safety culture. Chapter 3 then considers the special characteristics of health care settings that influence safety culture, along with the various stakeholders involved and differences relating to regional factors. In Chapter 4 the topic of organizational management is addressed in terms of its impact on radiation safety culture, and this includes a review of the various international publications in this area. The range of tools available for developing and maintaining radiation safety culture are described and discussed in Chapter 5, with Chapter 6 going on to look at ways of assessing radiation safety culture, in order to determine current status and the effect of any intervention and development. Finally, a number of real-life scenarios are presented in Chapter 7, as examples of practical ways of improving radiation safety culture. The Annex provides information on key resources for radiation safety culture.

2 Lessons from safety culture in various sectors

As noted in the IRPA *guiding principles for establishing a radiation protection culture* (IRPA, 2014) in terms of understanding radiation safety culture as a combination of habits and knowledge of radiation protection, there are no differences between sectors (medical, research, nuclear industry). An overview of radiation safety culture should consider:

- all its aspects for patients, workers, population and the environment;
- all exposure situations;
- both scientific and social dimensions.

Experience from other high-risk settings such as aviation and nuclear power industries indicate that human mistakes rarely result from neglect, but instead from failures in the systems, processes and procedures applied to these settings. For example, an analysis of causes of radiotherapy accidents shows that neglect and poor housekeeping together are an attributable factor in only 5% of cases (Boadu & Rehani, 2009). Most errors, then, are potentially avoidable or at least can be mitigated (Miziara & Galego, 2022). A brief look at safety culture within these industries, together with a more broadly look at global health care, allow some lessons to be drawn that may assist in enhancing radiation safety culture in health care.

2.1 Aviation industry

The aviation industry's safety track record has been built up over many decades and is the result of a built-in conservative approach to operations and a safety culture, which other industries can use as a model. There will always be incidents, but in terms of physical injury of passengers during a specific trip, commercial air transport is the safest form of travel today. This safety record is attributed to the continuous improvement process particularly in the area of safety culture. These efforts are a joint venture, where airports, airlines, air navigation service providers, pilots' unions, flight staff unions and manufacturers, work together. The way that aviation approaches routine functions is being increasingly used by other sectors to improve their safety performance. The development of a robust and open safety culture within the aviation sector shows how real progress can be made towards enhancing safety culture in other sectors.

For example, a system called Crew Resource Management promotes a culture of open communication and teamwork by all parts of the airline operation. Where problems arise, or even have the potential to arise, any member of the crew (in the aircraft or on the ground) is made to feel comfortable with speaking up and raising the issue. If a critical safety issue is a concern the flight does not leave the ground until all members of the aircraft crew, ground crew and air navigation service are satisfied that the problem or perceived problem is resolved.

> ☢ **Key message**
>
> Anyone with a safety concern or perceived safety concern should be empowered to raise awareness and resolve the issue before commencing activities.

2.2 Nuclear power industry

The phrase "safety culture" was first introduced to the nuclear industry as part of the IAEA assessment of the causes of the 1986 Chernobyl accident (IAEA, 1991). The United States Nuclear Regulatory Commission also recognized that the 1979 accident at Three Mile Island was partially a management problem, though they did not use the phrase "safety culture" but instead used the term "human factors". These accident investigations provided synergy for research and development in nuclear safety culture. The Fukushima accident in Japan in 2011 highlighted that, though much has been learned about strengthening safety culture in nuclear power, there are more lessons to adopt. The 2011 Fukushima Daiichi accident in Japan led to a number of concrete actions, aiming to strengthen the global nuclear safety framework in response to the accident. The IAEA 2011 Action Plan defined a programme of work to strengthen nuclear safety and through initiatives such as the European Stress Test, the adoption of the 2015 Vienna Declaration on Nuclear Safety in accordance with the objectives of the Convention on Nuclear Safety, as well as the multitude of national and regional initiatives, many safety improvements have been developed and implemented.

The IAEA conducts missions to nuclear power facilities to observe and evaluate the safety systems. Among these missions is the Operational Safety Review Team (OSART) mission, where a team of international experts conducts in-depth technical reviews of operational safety performance at nuclear power plants. Alongside the technical focus, OSART missions also review the factors affecting the management of safety and the performance of personnel, within the context of an embedded safety culture and other organizational issues. Some of the topics that are reviewed in the three-week missions are: assessing to what extent leadership and management personnel foster safety culture; training and qualification of personnel; accident management; and human-technology-organization interaction.

OSART missions provide the host country and the relevant institutions (plant and utility management, the regulatory authority, other governmental authorities) with an objective assessment of the operational safety at the reviewed nuclear power plant compared with the IAEA Safety Standards (IAEA, 2014). For the commercial nuclear power industry, nuclear safety remains the overriding priority. Although the same traits apply to radiological safety, industrial safety, security and environmental safety, nuclear safety is the first value adopted at a nuclear station and is never abandoned.

The World Association of Nuclear Operators (WANO) is a non-profit-making, international organization. WANO's members (mainly owners and operators of nuclear power plants) operate approximately 460 nuclear units in over 30 countries and areas worldwide. The WANO peer review programme provides a critical assessment of station safety performance and culture by an experienced team of global industry peers against nuclear industry standards of excellence as defined by WANO performance objectives and criteria. WANO has described the essential traits and attributes of a healthy nuclear safety culture, with the goal of creating a framework for open discussion and continuing evolution of safety culture throughout the commercial nuclear energy industry (WANO, 2013). This document builds on the knowledge and experience developed since the earlier publication of *Principles for a strong nuclear safety culture* (INPO, 2004). For example, WANO explains how leadership among plant managers, which is one the nine traits of safety culture, contributes to strong performance and resilience in the industry.

> ### ☢ Key message
>
> **Leadership, management and personal accountability are critical factors in enhancing radiation safety culture, and those involved in radiation safety should prioritize them as such.**

2.3 Health care industry

There are important distinctions between the health care industry and those of aviation and nuclear power industries in terms of safety culture: in the former, risks are faced on a daily basis and are high, while in the latter, safety focuses on preventing accidents and minimizing risks. Patient safety is a framework of organized activities that creates cultures, processes, procedures, behaviours, technologies and environments in health care that consistently and sustainably lower risks, reduce the occurrence of avoidable harm, make error less likely and reduce its impact when it does occur. Protection focuses on people and behaviour (culture) to prevent harm to the user and others when hazardous equipment is being operated.

WHO has conducted three consecutive campaigns called "Global Patient Safety Challenges" (Donaldson et al., 2017). Under the themes "clean care is safer care", "safe surgery saves lives" and "medication without harm", these campaigns have secured strong commitments from health ministers, professional bodies, regulators, health system leaders, civil society and health care practitioners. They also engaged patients and patient advocacy associations. They allowed an evidence-based analysis of the key problems and proposed solutions, encouraged high-profile actions to change behaviour, generated passion and enthusiasm and fostered strong leadership and extensive internal and external communication. These campaigns recognized that errors arise from a range of sources, often combined, including human errors, equipment errors and software-related issues.

When errors and/or near misses happen, some are reported but many remain unreported. A paradigm shift in thinking about safety in health care came with the realization that when things went wrong it was seldom due to an error by a single individual or just an equipment failure; rather a complex mix of actions and interactions influenced the nature of the operating environment, which contributed to the failure (Fig. 3). In this "systems thinking" view of safety in health care, a more holistic approach to patient safety is adopted.

Fig. 3. The paradigm shift in thinking about safety in health care
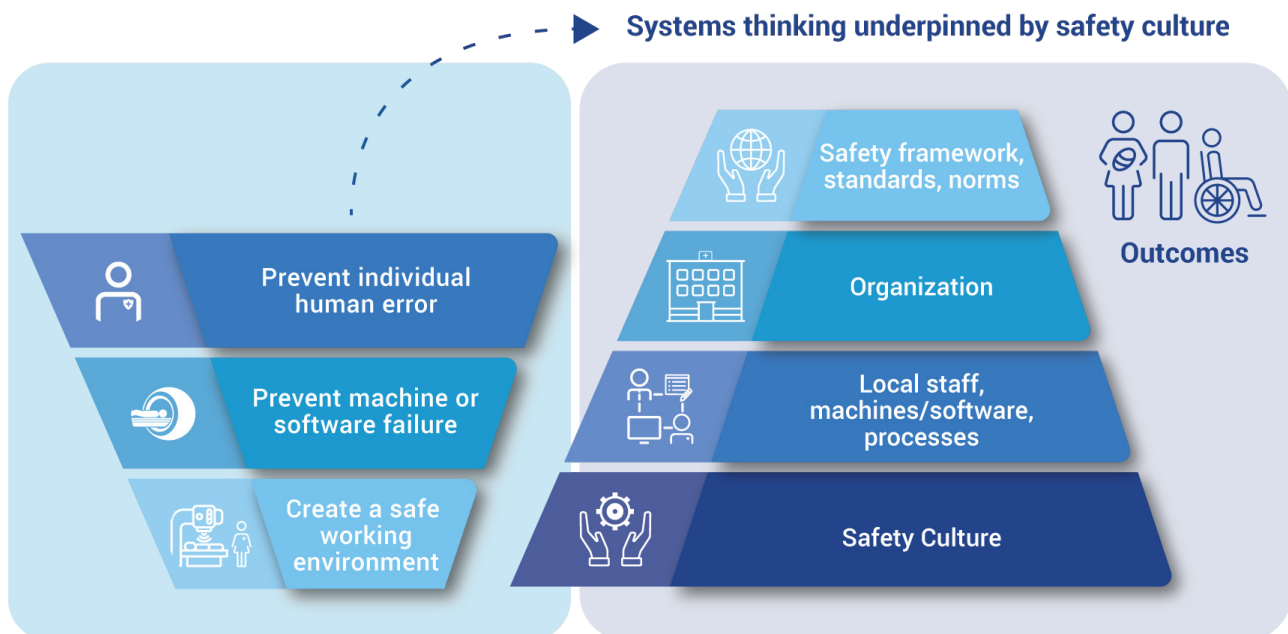
Some medical specialities have developed tools to improve safety and patient outcomes. Two that have a long history of safety culture improvements are the delivery of blood and blood products and the medical practice of anaesthesiology.

> ☢ **Key message**
>
> **Understanding the errors affecting patient safety has developed from a simple causal model to one that considers a complex mix of behaviours and interactions influencing the environment and outcome.**

2.3.1 Administration of blood and blood products

Transfusion reactions can be a significant cause of increased hospital stays and adverse patient outcomes (Abdallah et al., 2021). Transfusion reactions occur in up to 1 in 100 transfusions, making them an important clinical consideration of which to be aware for patients receiving transfusion (Delaney et al., 2016). WHO has prepared guidelines for clinical transfusion practice that include process steps and identify the roles and responsibilities of each professional. This is an example of the use of established work processes, one of the WHO safety traits (WHO, 2020).

2.3.2 Anaesthesia

The administration of anaesthesia has a long history of safety improvements and innovations in reducing the number of both medically harmful consequences and deaths by improvements in safety culture. This initiative is supported by professional organizations through the development of the Anaesthesia Patient Safety Foundation (Dutton et al., 2019). The Foundation has provided guidance in the area of patient safety and has identified 11 building blocks of a safety culture in anaesthesia Some of the building blocks are similar to the safety initiatives identified by other high-risk industries, such as communication, a non-punitive approach and development of safety-focused work processes (Box 1).

Box 1. Building blocks of a safety culture in anaesthesia

1. Use a transparent, non-punitive approach to reporting and learning from adverse events, close calls and unsafe conditions.

2. Use clear, just and transparent processes to recognize and differentiate human errors and system errors from unsafe blameworthy actions.

3. Adopt and model appropriate behaviours and champion efforts to eradicate intimidating behaviour.

4. Develop policies that support a safety culture, enforce these policies and communicate them to all members of the care team.

5. Recognize team members who report adverse events and close calls, identify unsafe conditions and suggest ways to improve safety; and create a "feedback loop" that shares these "free lessons" with all team members.

6. Determine an organizational baseline measure on safety culture performance using a validated tool.

7. Analyse safety culture results from across the organization to identify ways to improve quality and safety.

8. Use safety assessment data and surveys to develop and implement unit-based quality and safety initiatives and strengthen the safety culture.

9. Embed safety culture team training into quality improvement initiatives and processes.

10. Assess system strengths and weaknesses and prioritize them for improvement.

11. Report safety culture assessment every 18 to 24 months to review progress and sustain improvement.

Source: Anesthesia Business Consultants (2017).

Radiation safety culture in the health care sector

Health care is unique among radiation-using sectors in that it is the only sector in which a tangible benefit is obtained from planned direct irradiation of human beings. This chapter addresses radiation safety culture in the health care sector highlighting the role and views of different stakeholders including radiation protection professionals.

3.1 Specific considerations in the health care sector

The aims of the health care sector – the prevention of death and/or the improvement of life quality – are fundamentally different from those of other sectors such as the nuclear, industrial or research sectors, and it must be recognized that this inevitably leads to different priorities and a different mindset in the workplace. In the health care sector, the patient and their diagnosis or treatment will be the focus of attention, and this is likely to take priority over radiation protection considerations.

Radiation safety culture is thus applicable to all modalities and sectors of radiation use in health care, but its interpretation and application needs to consider the risks in specific situations, in a graded approach to practice. This is necessary to ensure that resources are deployed responsibly. It is acknowledged that consideration of radiation safety culture in the health care sector encompasses the two clearly different categories of a) patient exposure, and b) occupational exposure. Although the technical challenges may differ, it is expected that improvements in radiation safety culture will have beneficial effects in reducing both staff and patient doses, though not necessarily to the same degree as there is greater scope for reduction of patient doses as patients are intentionally exposed to obtain a benefit. Choosing between two techniques providing the same medical response, the less irradiating technique is, in terms of radiation protection, of greater benefit to the patient.

As good patient care is the primary aim of health care professionals, it is not surprising that radiation protection, along with most other aspects of safety, focus on the patient. Guidance on the control of patient exposure is developed to varying extents in different countries and, in many cases, is proactively implemented (Martin, 2011; Image Gently Alliance, 2023; Image Wisely, 2023). Many professions can be involved, from the requesting of an examination, through its execution and reporting, to ensuring the availability of results to all appropriate health care professionals. Radiation safety culture, therefore, needs to encompass all those who could affect the exposure of the patient, and this presents a challenge.

There is also considerable scope to improve the culture associated with the protection of health care staff from radiation exposure. It has been observed (Cole et al., 2014) that, in some respects, the health care sector potentially has a weaker level of radiation safety culture than, for instance, that in the nuclear sector, with differing views from radiation workers on the value of health or medical physics. This may include a perception that the medical physicist or radiation protection officer is a hindrance to the task in hand. For the majority of health care workers, occupational doses and associated risk are extremely low, but increasing complexity and scale of interventional radiology is accompanied by a rising potential for significant doses to the staff involved, particularly for eyes and extremities, and a poor safety culture may lead to unintended exposure, especially for those working with radioactive materials

☢ Key message

Implementing the principles of justification and optimization is essential to ensure that radiation used in health care is managed safely.

Radiation hazard in the health care sector also has some different characteristics from those commonly found elsewhere. The most common source of radiation exposure in the health care sector originates from X-ray machines (primary beams incident on the patient and scattered radiation from the patient) which produce very high dose rates for short periods of time but can be switched off. Another common exposure source is the radionuclides used in nuclear medicine, which may result in significant doses to the fingers of those handling short-lived radiopharmaceuticals. Most exposure in the other sectors results from working with radioactive materials and/or waste and, although dose rates are lower, they are present all of the time. In addition, in the health care sector the primary methods of restriction of exposure of staff are administrative, or the use of personal protective equipment, rather than use of design and engineering control measures, although the latter are used in radiotherapy facilities. This hierarchy of control is shown in Fig. 4.

Fig. 4. Restriction of exposure in health care (hierarchy of control)

HIERARCHY OF CONTROL

EXAMPLES APPLICABLE TO
RADIATION SAFETY IN HEALTH CARE

most effective

ELIMINATION

REMOVE THE HAZARD
*Prevent unnecessary exposure
(justification and optimization)*

SUBSTITUTION

REPLACE THE HAZARD
*Choose a less irradiating technique
equally appropriate*

ENGINEERING

ISOLATE PEOPLE FROM THE HAZARD
*Radiation shielding, safety barriers,
bunker design*

PROCESS

CHANGE BEHAVIOR
*Administrative controls, policies,
regulations, procedures*

PPE

**USE PERSONAL PROTECTIVE
EQUIPMENT**
*Lead aprons, goggles, thyroid collars,
disposable gloves*

least effective

PPE: personal protective equipment

3.2 Key stakeholders for radiation safety culture in health care

Radiation protection professionals within an organization must take the central role in supporting management to drive and embed radiation protection culture throughout the organization. In addressing their wider responsibilities, the radiation protection practitioners must be aware that interaction with wider stakeholders can assist in the development and application of workplace culture (IRPA, 2014). It is important to create the conditions to apply the guiding principles for stakeholder engagement (see Annex).

As has been described, there are numerous stakeholders involved within any radiation safety culture framework in health care (Fig. 5). Without all of these being informed, involved, and heeded there is little chance of achieving lasting improvements. It is therefore necessary to identify all the stakeholders involved and then to facilitate communication between them. This has been one of the major drivers and successes of the series of regional workshops on radiation safety culture in health care organized during the development of this document.

Fig. 5. Radiation safety culture in health care: key stakeholders
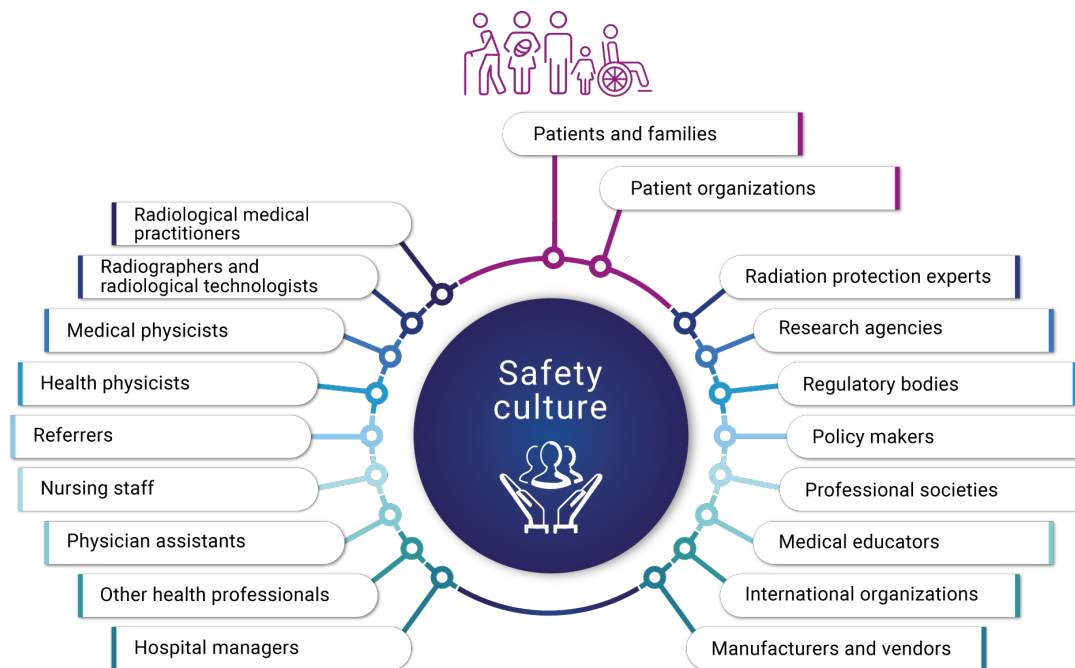
Stakeholders relevant for radiation safety culture in health care can be broadly divided into three categories:

1. This includes all professional groups who either work with radiation in health care or are involved in the pathway of patients who utilize it for diagnosis or treatment. This group includes those who deliver radiation to patients, those who assess the dose of radiation delivered, those who prescribe radiation for patients and those who teach or advise on radiation dose optimization.

2. This group of stakeholders comprises outside bodies, involved directly or indirectly with radiation safety, and includes regulators, international bodies and national professional bodies, all of whom are considered in more detail in Chapter 4. Manufacturers and vendors of equipment for nuclear medicine, radiotherapy, diagnostic and interventional radiology have an important role. Radiation safety culture is essential to ensure that both radiation medical devices and radiological facilities are designed in conformance with conditions of radiation protection and safety with a common goal to minimize radiation in an approach that conforms to as low as reasonably achievable. These stakeholders can be encouraged by recognizing their contribution to support safety culture through the development of technological solutions to improve radiation protection that consider sustainability and performance of equipment in different resource settings (IAEA & WHO, 2014).

3. This group of stakeholders is probably the most beneficial from an enhanced safety culture in health care: patients and caregivers as well as volunteers enrolled in research programmes and patient advocacy groups. Patients travel through the entire care pathway and have a holistic view of the health care system. As end users of this system, patients need to have full insight into the outcome of their care and could provide a valuable perspective on how health care can be made safer. They can bring insights from their experiences of care that cannot be replicated or replaced by the experience of the health care providers, managers or researchers; they can serve as vigilant observers and can indicate if something goes wrong or needs attention (WHO, OECD & World Bank, 2018). Patients can be afraid to express their expectations or may not know what their expectations are; they need help and support to understand this. Patient involvement must be appropriate and should be integrated into all areas and services as much as possible. It is essential to identify patient advocates and champions and include education to help patients to participate more effectively. Both patients and their advocates should be empowered to feel confident to engage with safety, to ask questions and spot errors and to be actively involved in an informed decision-making process. Patients undergoing radiological diagnostic or therapeutic procedures can help enhance safety culture if provided with the right information, tools and resources to make informed decisions about their care.

The role and views of different stakeholders will be expanded throughout the publication, but it should be noted here that they will all have different priorities and concerns, which may inevitably lead to some tension within a culture framework. Different specialisms and bodies will have, or raise, different challenges. Communication between stakeholders is of great importance and there are many examples of how this can be implemented. Promoting and creating a positive work environment based on mutual respect is one of the cultural traits in the nuclear industry. Shared understanding and adequate communication among workers and professionals are helped by creating the conditions for enthusiastic and effective participation in meetings. Where appropriate, such meetings are open not only to the workers and professionals involved in a radiation protection service, but also to public and other sectors, via for instance, "Local Information Commissions" that are held in the vicinity of nuclear power plants. This positive environment is always useful in the medical sector; practical examples are awareness campaigns regarding medical exposure and dose reduction in radiology in the USA (e.g., Image Gently/Image Wisely) which help to create a mutual culture of understanding between professionals and patients.

> ☢ **Key message**
>
> **Engagement strategies must be tailored to the diverse groups of stakeholders contributing to radiation safety culture.**

3.3 Key issues for establishing and maintaining a radiation safety culture

The feedback received at the regional workshops provided a snapshot of how different groups of stakeholders view the key issues in radiation safety culture. Fig. 6 shows a word cloud summarizing all the key issues presented across one of the workshops, so it amalgamates the views of all stakeholders. Even allowing for some bias in terms of available groups of stakeholders at each event, and possible evolution over time, it is clear that there are some key issues that underpin most if not all concerns. The chief among these is the issue of communication, along with education, training and patient engagement.

Fig. 6. Relative importance of key issues in radiation safety culture for relevant stakeholders[2]

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[2]   This is an adaptation of a word cloud that was generated at the 5th Regional Workshop on Radiation Safety Culture in Health Care, held in November 2017 in Kuala Lumpur, Malaysia. The size of each word is proportional to the number of times the word was used in stakeholder feedback.

Fig. 7 shows the commonalities and singularities of perspectives among the three stakeholder groups described in section 3.2 based on the feedback collected during the workshops organized in different regions.

Fig. 7. Commonalities and singularities identified by stakeholders related to radiation safety culture[3]
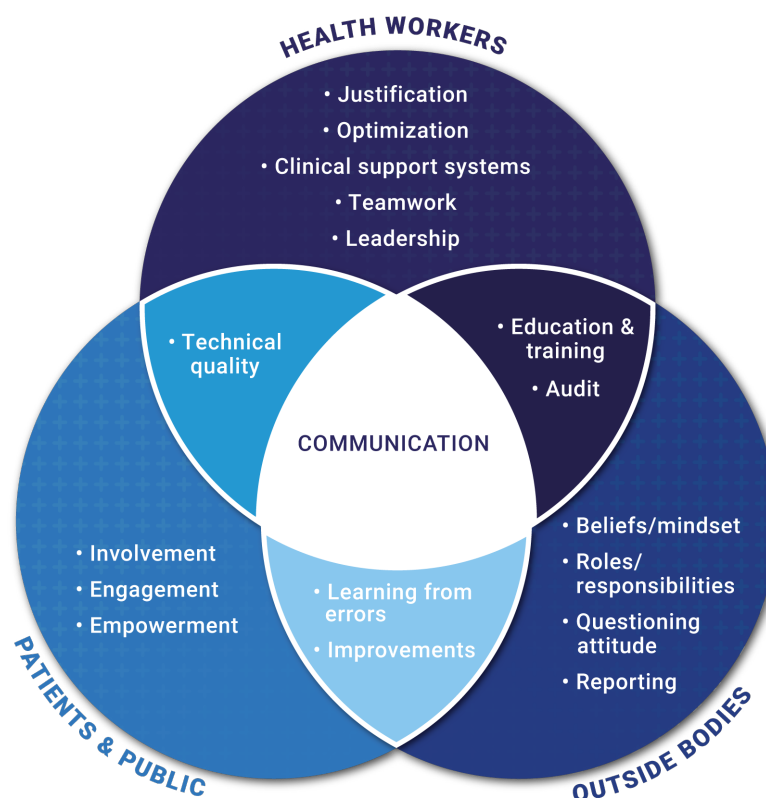
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[3]   Stakeholders' perspectives on establishing and maintaining radiation safety culture in health care based on feedback collected during the regional workshops.

3.4 Regional challenges of radiation safety culture in health care

Holding workshops in different parts of the world allowed the identification of challenges and opportunities specific to each region. These arise from differences in both resources and local culture and can influence the development of a good radiation safety culture in various ways. These challenges include:

- lack of integration between radiation protection, quality of care and safety policies;
- lack of awareness of radiation doses and associated risks;
- lack of supporting radiation protection legislation in some countries;
- hierarchical organizational structures;
- education and training variability;
- leadership/management commitment.

Each regional workshop conducted a SWOT analysis specific to that region. Fig. 8 shows the results of these analyses, grouped by those traits specific to regions and those common to all. It can be seen that there are common strengths and opportunities relating to national and international leadership and engagement, with some regional opportunities identified such as standards of equipment and more local initiatives. Lack of resources was seen as a common weakness, though to varying degrees and in different ways (financial or staff). Threats were identified differently across the regions, and typically included issues related to politics, local culture including hierarchy issues, and lack of follow through in initiatives.

Fig. 8. Results of SWOT analysis showing common and regional issues

3.5 Safety culture in the medical use of non-ionizing radiation

The prime focus of this document is enhancing radiation safety culture with respect to ionizing radiation. However, radiation safety culture applies to both ionizing and non-ionizing radiation use, as non-ionizing radiation is becoming of increasing interest when considering medical imaging. Patterns of thinking and behaving which define a positive safety culture in organizations and individuals are applicable to all the medical applications of radiation, thus including ionizing and non-ionizing radiation. While specific radiation safety issues may differ, there was consensus in the regional workshops that enhancing radiation safety culture in medical facilities contributes to quality and safety in the medical use of both ionizing and non-ionizing radiation, thus resulting in better patient outcomes and staff protection. Therefore, some examples of radiological medical procedures utilizing non-ionizing radiation, where safety culture is particularly relevant, are discussed below.

Non-ionizing radiation applications are increasingly being used in health care. Among them is MRI. The strong magnetic field used during MRI may cause serious injuries to patients and staff in the MRI area. Implementation of MRI safety culture decreased the risk of harm to patients and staff (Crisp & Dawdy, 2018; Yong et al., 2019). Established MRI safety actions and tools include:

- official guidance documents on safety policies and procedures;

- formal and specified MRI safety education for MRI staff;

- online access to MRI safety information and apps for MRI safety;

- restricted access with MRI safety zone labels;

- dress codes to exclude magnetic material;

- use of nonmagnetic MRI equipment;

- MRI safety questionnaire;

- ferromagnetic screening;

- management of implants;

- scanner implant safety management software;

- event reporting and quality improvement analysis.

Ultrasound is used in medicine for diagnostic and therapeutic purposes. When applied for patient treatment (e.g., physiotherapy, drug delivery or cancer therapy), it produces changes in human tissues. The differences between ultrasound pulsing regimes used in medical imaging (B-mode, pulsed and colour flow Doppler) lie in the lengths of the pulses used, their repetition frequency and the pressure in the pulses. Different ultrasound modalities used for imaging purposes are generally considered safe. However, tissue sensitivity to the thermal and mechanical effects of ultrasound makes the difference in the terms of safety; of most concern is ultrasound imaging of fetuses. Therefore, in obstetric settings, the output intensity threshold as well as the thermal index and the mechanical index should be appropriately set. All ultrasound scans, and in particular obstetric exams, should only be performed when there is a clear clinical indication, and only by trained medical professionals who understand the modality and are aware of its safe use. Ultrasound safety statements have been published by professional societies, such as the World Federation for Ultrasound in Medicine and Biology (WFUMB, 2020). Ultrasound safety actions and tools to be considered include the following.

- New ultrasound machines for imaging purposes should be produced with low thermal and mechanical indices to effectively prohibit possible thermal and mechanical adverse effects;

- Ultrasonographers should perform exams only when clinically indicated and keep the ultrasound exposures under the threshold level of ultrasound bio-effects;

⊕ It is necessary to increase awareness of ultrasound hazards and safety procedures through specified education, learning and training programmes;

⊕ Up-to-date recommendations should be provided by ultrasound professional societies.

The increasing use of hybrid imaging through the fusion of two or more complementary imaging modalities calls for a holistic approach in radiation safety culture. In addition to the combination of two imaging modalities using ionizing radiation (e.g. PET-CT or SPECT-CT) today the fusion of images produced by ionizing and non-ionizing radiation became more common (e.g. PET-MRI, MRI and CT angiography, ultrasound and MRI). Different profiles of clinical and technical knowledge need to be combined to ensure appropriate use and to capture the full potential of hybrid imaging. It requires collaboration of nuclear medicine physicians, radiologists, medical physicists and radiation chemists, and different kind of technicians as well. The interpretation requires familiarity with anatomic imaging, radiation chemistry, molecular biology and metabolism. All those types of health practitioners must be involved in patient care and are therefore key players in maintaining and enhancing a positive radiation safety culture (Griffiths, 2015).
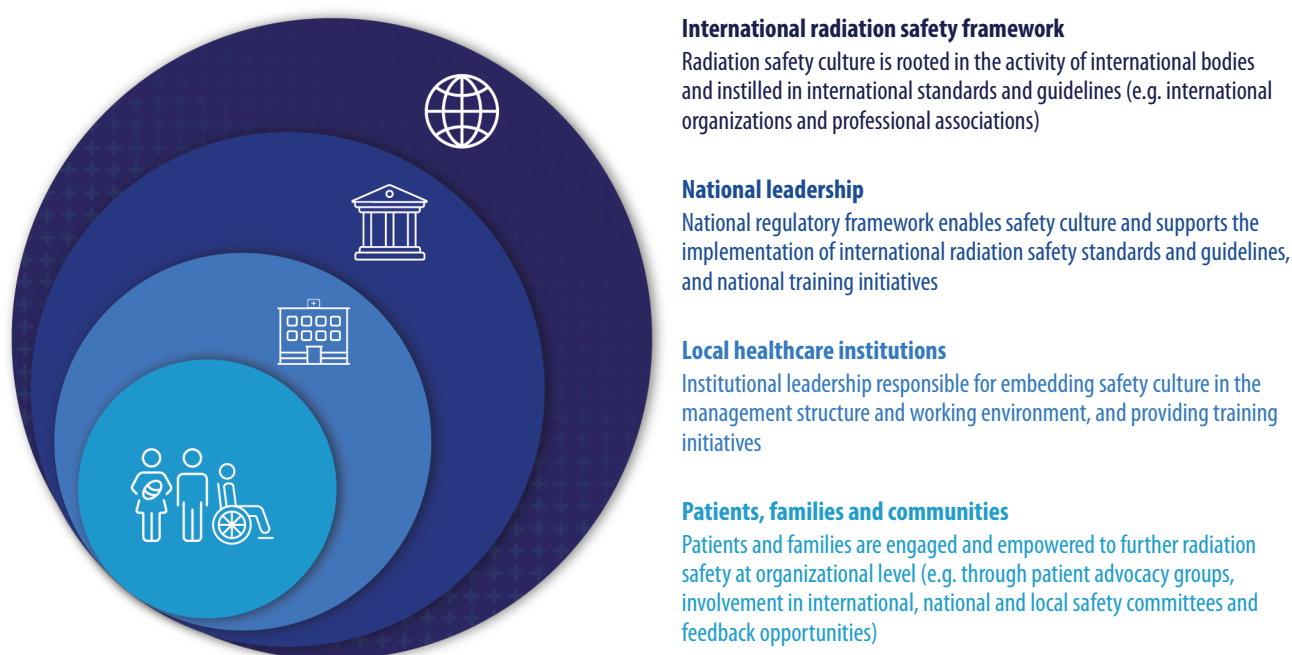
> ⊛ **Key message**
>
> **Everyone in the diverse groups of stakeholders is responsible for assuring a strong radiation safety culture in health care aiming that patients are imaged and treated correctly.**

4 Organizational management of radiation safety culture in health care

Building or enhancing radiation safety culture is important on various management levels, from local institutions up through national policies to international frameworks (Fig. 9). The organizational management of radiation safety culture is presented in this chapter.

Fig. 9. Organizational management of radiation safety culture at various levels

International radiation safety framework
Radiation safety culture is rooted in the activity of international bodies and instilled in international standards and guidelines (e.g. international organizations and professional associations)

National leadership
National regulatory framework enables safety culture and supports the implementation of international radiation safety standards and guidelines, and national training initiatives

Local healthcare institutions
Institutional leadership responsible for embedding safety culture in the management structure and working environment, and providing training initiatives

Patients, families and communities
Patients and families are engaged and empowered to further radiation safety at organizational level (e.g. through patient advocacy groups, involvement in international, national and local safety committees and feedback opportunities)

4.1 International radiation safety framework

An international radiation safety framework provides the overarching structure under which all else will reside, and so is of particular significance. Such an international framework could be rooted in the activity of the relevant international organizations involved and be instilled in the resultant standards and guidelines that are produced and the various publications of professional associations in this area

4.1.1 International organizations

The IAEA, along with seven other co-sponsoring organizations,[4] published in 2014 the BSS (IAEA, 2014). These standards address the management of radiation risks to people and the environment that may arise from the use of radiation and radioactive material and include a specific requirement for radiation protection and safety to be effectively integrated into the overall management system of a given organization. The BSS also establish additional detailed requirements on the protection and safety elements of the management system, for promoting a safety culture and for considering

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[4] The BSS are cosponsored by the European Commission, the Food and Agriculture Organization of the United Nations, IAEA, the International Labour Organization, the Organisation for Economic Co-operation and Development/the Nuclear Energy Agency, the Pan American Health Organization, the United Nations Environment Programme and WHO (alphabetical order).

human factors within that culture. These include the requirement of the principal parties to promote and maintain safety culture (Box 2), thus indicating the importance of safety culture in the safe and beneficial use of radiation around the world through the implementation of binding international instruments and national safety infrastructures to assure the safe use of radiation. Further guidance to support the implementation of the BSS in medicine is provided in the IAEA safety guide Radiation protection and safety in medical uses of ionizing radiation (IAEA, 2015a).

Box 2. How to promote radiation safety culture

The international radiation basics safety standards (BSS) include a requirement to promote and maintain safety culture by:

a) Promoting individual and collective commitment to protection and safety at all levels of the organization;

b) Ensuring a common understanding of the key aspects of safety culture within the organization;

c) Providing the means by which the organization supports individuals and teams in carrying out their tasks safely and successfully, with account taken of the interactions between individuals, technology and the organization;

d) Encouraging the participation of workers and their representatives and other relevant persons in the development and implementation of policies, rules and procedures dealing with protection and safety;

e) Ensuring accountability of the organization and of individuals at all levels for protection and safety;

f) Encouraging open communication with regard to protection and safety within the organization and with relevant parties, as appropriate;

g) Encouraging a questioning and learning attitude, and discouraging complacency, with regard to protection and safety; and

h) Providing means by which the organization continually seeks to develop and strengthen its safety culture.

Source: IAEA (2014).

The International Conference of Radiation Protection in Medicine in Bonn, Germany, in December 2012 co-sponsored by the IAEA and WHO and hosted by the Government of Germany through the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety focused on identifying and addressing issues arising in radiation protection in medicine and resulted with a call for actions. The Bonn Call for Action was developed to strengthen radiation protection of patients and health workers overall; to attain the highest benefit with the least possible risk to all patients by the safe and appropriate use of ionizing radiation in medicine; to aid the full integration of radiation protection into health care systems; to help improve the benefit/risk dialogue with patients and the public; and to enhance the safety and quality of radiological procedures in medicine. The Bonn Call for Action highlighted 10 main actions identified as being essential for the strengthening of radiation protection in medicine, including one (Action 8) to "Strengthen radiation safety culture in healthcare" with sub-actions (Box 3). Information about activities on implementation of the Bonn Call for Action is available (IAEA, 2020b).

The Seventy-second World Health Assembly adopted in 2019 resolution WHA72.6 on global action on patient safety, recognizing that improving and ensuring patient safety is a growing challenge to health service delivery. This resolution urged Member States to recognize patient safety as a health priority in health sector policies and programmes and requested WHO to formulate a global patient safety action plan in consultation with Member States and all relevant stakeholders. In response to this request, WHO initiated the development of a global patient safety action plan providing an action-oriented framework for the implementation of strategic patient safety interventions at all levels of health systems globally in the decade 2021–2030. The action plan provides a list of suggested actions for governments, civil society, international organizations, health care facilities, WHO and other intergovernmental organizations to enhance safety for patients and also for health workers. Enhancing safety culture in included in several of the strategic actions proposed in this action plan (WHO, 2020).

Box 3. Action 8 of the Bonn Call for Action, and its sub-actions

Action 8 of the Bonn Call for Action identifies as a priority to **strengthen radiation safety culture in healthcare** and calls to:

a) Establish patient safety as a strategic priority in medical uses of ionizing radiation, and recognize leadership as a critical element of strengthening radiation safety culture;

b) Foster closer co-operation between radiation regulatory authorities, health authorities and professional societies;

c) Foster closer co-operation on radiation protection between different disciplines of medical radiation applications as well as between different areas of radiation protection overall, including professional societies and patient associations;

d) Learn about best practices for instilling a safety culture from other areas, such as the nuclear power industry and the aviation industry;

e) Support integration of radiation protection aspects in health technology assessment;

f) Work towards recognition of medical physics as an independent profession in health care, with radiation protection responsibilities; and

g) Enhance information exchange among peers on radiation protection and safety-related issues, utilizing advances in information technology.

Source: IAEA & WHO (2014).

4.1.2 Professional organizations

The IRPA *guiding principles for establishing a radiation protection culture* (IRPA, 2014) incorporate approaches from different countries and regions of the world, and from different sectors: medicine, industry and regulators; a common document applicable to all sectors using radiation, about culture from the perspective of professionals, geared towards professionals. Its objectives are to foster a belief in the success of cultural approaches, and to provide guidance to help equip radiation protection professionals to promote a successful radiation protection culture in their organization and workplace. The principles are founded on the belief that embedding radiation protection at a cultural level within an organization is by far the most effective way of delivering the safest and best performance possible.

Radiation protection professional organizations provide the voice of the profession to governments, to other professional organizations nationally and internationally, and provide guidelines to members of the profession. They provide authenticity to guidance, which becomes important when there are so many different voices of individuals available through assorted media. While the area of radiation safety culture is not subject to contradictory opinions, it benefits from such authenticity to propagate effective actions to convert daily safety actions into a culture of safety (Fig. 10).

Besides moving institutions towards a comprehensive safety culture, professional organizations join hands with national organizations to develop guidance that is taken up by regulatory bodies to provide national legislation, as discussed more in the next chapter. Another role professional organizations play is organizing sessions in professional meetings and conferences that reinforce the (need for) safety culture, and these have been deemed an important function of such organizations (Sanders et al., 2020). Websites of professional organizations provide an important way to promote and propagate the message. Creation of task groups addressing safety culture and preparing reports on this topic is another useful mechanism that many professional organizations utilize.

Fig. 10. From routine action to safety culture

Health professionals

Health professionals involved in medical imaging often take it for granted that major part of their day-to-day work is aimed at patients and staff radiation safety. A common underlying assumption is that safety culture is inbuilt in their work.

They often believe that safety culture is ensured if:
- patient doses are routinely assessed;
- diagnostic reference levels are established, and patient doses are compared with them; and
- optimizing doses with reference to image quality is a routine activity.

These are safety actions but **this is not safety culture in itself**.

Professional organizations

Professional organizations provide the voice of the profession to other stakeholders and provide guidance to professionals.

When one or a few persons carry out safety assessments and perform actions for optimization of protection and safety, this is still radiation safety.

When everyone in the organization participates, takes responsibility for radiation safety, and there is evidence for safety culture traits being adopted, then, **safety culture is in place**.
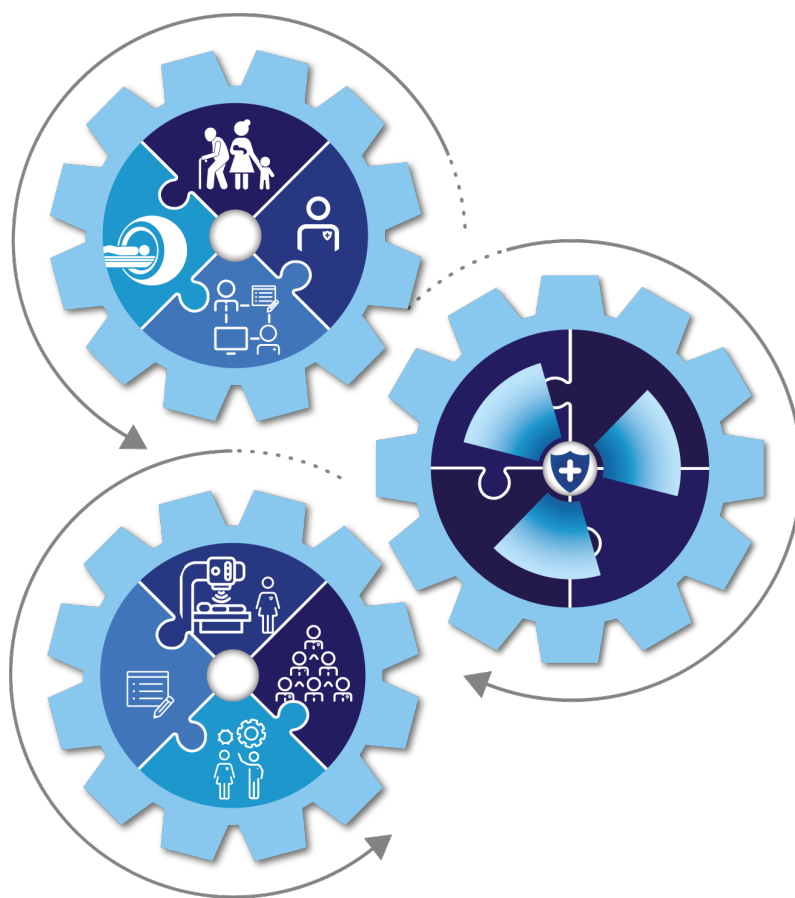
4.2 National regulatory level

The important role of leadership has been highlighted in several of the regional workshops and is an important factor in determining safety culture. Such leadership starts at a national level (The Joint Commission, 2017). Organizational management of radiation safety at national level shows considerable variation globally, although the underlying principles governing roles and responsibilities are generally applicable. At national level, a regulatory framework is required to implement international standards and guidance. Such regulatory structure, while not necessarily equating to a good radiation safety culture, underpins and facilitates its development. Additional drivers at national level include the following.

- ☢ **Health care structure:** This varies considerably between countries and yet is quite important, as it will influence how culture is "passed down" in terms of what the expectations are from the perspective of local practitioners, hospitals and private health care centres.

- ☢ **Government funding:** This is again variable and may be based on a number of different models. A common model is to relate funding to patient care – often in terms of patient outcomes (number of examinations, treatments, etc.) – which may limit explicit funding for background activities such as radiation safety and protection. As an illustration, funding may be provided specifically for equipment, but without any allocation for staff with the appropriate knowledge, facilities or ancillary equipment needed to ensure its safe use. Government targets may also relate to specific issues such as screening programmes, and cost–effectiveness

may not incorporate radiation protection considerations. Income generation may take precedence over safety issues – for example, carrying out unnecessary CT examinations.

- ☢ **National training initiatives:** These can provide an impetus to improve radiation safety culture, as recently evidenced in Greece (Sotirios et al., 2020).

4.3 Local health care institutions

Safety culture refers to a local environment that encourages collaboration, quality and safety. A generative safety programme status requires a profound understanding by management and employees of the relevant safety culture principles, methods and tools needed (Classic et al., 2014). At local level, organizational management of radiation safety is pivotal for development of a good culture, though the drivers for this may be subtly different depending on country context and will likely include the following.

- ☢ **Management structure:** This will determine local governance and should ideally embed radiation protection and culture within the management structure. The presence and operation of a radiation protection committee within an institution is of great importance here.

- ☢ **Local resource issues:** These are often linked to national issues, but may also be affected by local factors, particularly if there are insufficient staff with necessary training.

- ☢ **Quality initiatives:** These will often be set locally and could include incorporation of radiation protection in terms of what patients expect when they come for a specific procedure. This should ideally be part of the overall process of ensuring a high-quality radiation safety culture.

- ☢ **Training:** At a local level, training should be part of the education system and an integral part of daily practice, rather than relying on occasional external training opportunities. Informal integrated training onsite has often been shown to be more effective than formal offsite courses.

4.4 Patients, families and communities

The patients, together with their community and caregivers, have already been identified as key stakeholders. Engaging and empowering patients and families support the journey to safer health care (WHO, 2021a). They can, and should, influence management at an organizational level through patient advocacy groups, inclusion of patient representatives on appropriate committees and a variety of feedback opportunities. There is an opportunity to engage such representation not only in broad patient safety issues but also in relation to specific aspects of radiation safety culture. This will be a two-way communication process, which provides information and education on radiation safety issues to those who will be on the receiving end of both the benefit and the risk and allows organizations and professional stakeholders to learn from patient experience and priorities.

> ☢ **Key message**
>
> Everyone can participate in strengthening safety culture; there are international, national and local initiatives to help health care providers improve safety at the facility level.

5 Tools for establishing and maintaining radiation safety culture in health care

There are many potential tools for use in both establishing and maintaining radiation safety culture. Some of these are discussed below, but the list is by no means exhaustive, and others are available and new ones may emerge.

5.1 Standards and regulations

While not strictly a tool, the development of standards in radiation safety, and associated regulations may provide a foundation and framework for developing an effective radiation safety culture, though it has been shown that professionals in low-income countries perceived regulations to be significantly more important for improving safety than their counterparts in developed countries (Berris et al., 2017). Standards, such as the BSS, set by international bodies include requirements for safety assessments and management systems, which link directly to the idea of radiation safety culture. These standards, however, need to be integrated into national regulations. Further, for the regulations to be effective, there also needs to be a suitable body tasked with overseeing compliance with regulations, including a programme of appropriate inspections and sanctions where required.

5.2 Policies and procedures

International standards and national regulations will often be implemented through local policies and procedures in health care facilities where radiation is being used for diagnosis and/treatment; these then need to be developed to address wider issues of radiation safety culture as well. These should become the most essential tool for establishing a good radiation safety culture in an institution. Policies should be established which set out clear lines of responsibility for different aspects of radiation safety, including the responsibilities of the individual user as well as management and advisers. This should cover issues such as equipment management; management of staff exposures; staff training; and referral, justification and optimization of patient exposures. Detailed procedures should then be in place to elaborate on each area and provide guidance on specific aspects of radiation safety culture.

5.3 Education and training programmes

Education and training are key areas for maintaining a good radiation safety culture and need to include both primary and update training for all professional staff groups that are engaged with radiation work and/or the care of patients undergoing radiation exposure. In order to strengthen radiation safety culture, there should be a good foundation in radiation protection principles to build upon. The following aspects should be considered.

- Primary training in radiation protection should ideally be contained within professional education programmes for key staff members of the radiation teams, such as radiologists, radiation oncologists, nuclear medicine physicians, radiographers and medical physicists. It is important that such training is made engaging and relevant to practice.

- There are some staff groups, such as other medical staff and nurses, for whom radiation protection may commonly not be included in basic training, but for whom it should be considered. The evidence for this

comes from numerous studies of referrer knowledge on patient dose and risk (Koutalonis & Horrocks, 2012; Lee et al., 2012), which demonstrate a worrying lack of awareness of radiation issues.

- Specific training focused on radiation safety culture, combining more generic approaches with strategically targeted approaches to include tailored training for leaders, should be considered.

- Training on new radiation-generating equipment is essential for all staff involved in delivering patient exposures, or with responsibility for maintenance or quality assurance of such equipment.

- Routine update training on radiation safety issues should be mandatory for key staff, in order to keep abreast of developments in standards, guidance and regulatory matters, but also for the sharing of best practice.

- New methods of training and continuous education should be explored, including methods such as e-learning, group work, role-play, journal clubs and scenario-based education rather than just attending a course.

- The effectiveness of training programmes should be assessed. This can be done by monitoring compliance with participation and standards, and by reviewing staff performance and seeking feedback on specific training opportunities. This should always focus on how training/education is translated into practice.

- Inclusion of radiation safety culture in conference sessions is an important consideration and is already being addressed by organizations such as IOMP (IOMP, 2020).

The IAEA has developed training material to support the strengthening of radiation safety culture in medicine. The material uses case-based events that correspond to 10 safety traits, providing "real case" scenarios that can be used for facilitated discussion to change individual and organizational culture, thus leading to improvements in safety and quality in radiation medicine (IAEA, 2021b).

5.4 Audit activities

Audit is a well-established tool in many arenas and can be used as a tool for developing a variety of aspects of radiation safety culture. Audits can be carried out against specific policies or procedures, or single aspects of these. Examples might include auditing wearing of personal dosimetry or personal protective equipment; compliance with referral procedures; or checks of pregnancy status for female patients prior to exposure. They may also be used to assess attitudes and knowledge, for example an audit of referrer knowledge of relative doses from different radiological examinations. Audit might also be carried out of directly measurable parameters such as staff or patient doses.

The usefulness of audit as a tool depends on how the results are used. It is necessary to assess the data arising from an audit, and make recommendations for improvement as necessary, including assigning responsibility for these. After implementing the required improvements, the audit should then be repeated to establish the effect of the changes. Examples of resources are the tools developed by the IAEA for implementing quality audits in radiotherapy, diagnostic radiology and nuclear medicine (IAEA, 2007; IAEA, 2010; IAEA, 2015b).

5.5 Communication strategies

Communications on radiation safety is essential to ensure education and awareness, particularly of the public, and to facilitate a multidisciplinary and transparent approach to an improved safety culture. Practical ways of improving communication between professionals include:

- conferences (regional, national and international);

- local (institutional) meetings;

- addressing any conflict between professional groups;

- training specifically on teamwork and communication;

- addressing issues arising from an overly hierarchical structure within an institution;

- education of senior management;

- addressing cohesiveness within an institution by using cross-divisional groups to address specific issues;

- newsletters, email forums and other practical methods of sharing ideas and information;

- keeping human factors at the centre of communication developments.

Other communication strategies that might be used for conveying a particular message – whether to staff or for informing patients and the public – might include attractive posters, flyers or information leaflets and booklets. Choice of communication methods should always depend on the circumstances, the target audience and the message to be conveyed. Often a combination of methods may be the most effective approach.

5.6 Reporting and learning systems

Incident learning refers to the entire feedback loop – reporting an incident and then analysing it for salient detail and developing interventions to prevent it from happening again – that is recognized as a tool for improving quality and safety across a wide range of industries and medical disciplines. The goal in reporting and evaluating safety incidents is to improve awareness by recognizing unsafe conditions and acting on these events before they escalate into severe accidents. Near miss and incident analysis can also be used to identify themes and trends that the radiotherapy centre should focus on to improve patient safety and manage risk. The IAEA Safety in Radiation Oncology (SAFRON) incident learning system is an example of a system that collects information on actual incidents and near misses from participating radiotherapy facilities, regulatory authorities and IAEA published reports. SAFRON was launched in 2012, and currently contains over 1300 incidents reports (IAEA, 2021a). Participating organizations/institutes are encouraged to report near misses since they provide information of the adequacy of the safety infrastructure in place. Corrective actions and causality are also considered in each report, thus the opportunity to learn from the incident or near miss. Participants can use the SAFRON system as their own internal reporting system. Participating institutes also have full access to all reports on the website allowing the participant to benchmark against international reports.

5.7 Checklists

The radiotherapy technology is a highly complex process, requiring a multidisciplinary team to work together to provide efficient, accurate and safe patient treatment. Because of these characteristics, radiotherapy is susceptible to errors in the delivery of treatments. Checklists have proven to be an effective tool in error management and in reducing the risk of mistakes and improving the overall outcome of treatment. Effective checklists provide a basic memory guide and back-up for those tasks that are easily forgotten. In other words, checklists ensure that the basics are not missed (e.g. wrong patient, wrong site, missed bolus, missed electron block), allowing the team to concentrate on the difficult and complex tasks that require full attention (Gawande, 2009). Checklists support effective communication and improved work flow supporting the teams to work together. Checklists need to have purpose and need to be constructed so they have value to the team members; overly complicated checklists and trivial checklists have minimum value. Staff simply will not use such checklists if they see no purpose in the additional task (Dekker, 2011). Guidance for the development of safety checklists has been provided by the American Association of Physicists in Medicine (AAPM) (Box 4). Checklists are facility dependent and need to be adapted to each facility once they have been validated by that facility.

> **Box 4. Example of guidance for the development of safety checklists**
>
> The AAPM provided guidance to develop, implement and maintain **effective checklists** to enhance quality and safety in the medical use of radiation, including guidance on the content as summarized below:
>
> a) Define a clear and unambiguous title that reflects the objective of the checklist.
>
> b) Provide clear guidance on the type of checklist and on what, when and who is responsible for carrying out each action.
>
> c) Know the task and consider all task scenarios.
>
> d) Address the task and how it should be performed.
>
> e) Use standard language and unambiguous language and terms.
>
> f) Consider the minimum number of actions that need to be included on the checklist.
>
> g) Differentiate automated subtasks from those that require attention.
>
> h) Record specific values on the checklist if compatible with the workflow.
>
> i) Clearly identify the date of creation or last revision of the checklist.
>
> j) Identify the originator and approval route.
>
> *Source:* Gong de los Santos et al. (2015).

5.8 Verification procedures

Verification procedures can be applied for the detection of errors at different points along the patient pathway. They allow for the opportunity to confirm data are correct and assess whether data recorded are consistent with source data. There should be specific instructions about what/how/when this should be performed. It is important to identify the criteria to judge the results and define the level of tolerance for deviations. Active verification procedures, eliciting specific detailed responses, are more effective than passive ones (e.g., open questions rather than questions that can be simply responded to by YES/NO). This applies for human interactions, with both professionals and patients, and when interacting with software or computerized data (British Institute of Radiology et al., 2008).

5.9 Time-out procedures

Patient safety research indicates that communication failures contribute to medical error and that interventions to improve inter-professional communication also improve patient outcomes (Thomas & MacDonald, 2016). The time-out is a deliberate pause in the activity to allow for safety communication between the members of a team before starting a critical action/practice. Used initially in the aviation industry, it was adopted by members of surgical teams to ensure that the appropriate steps are taken prior to surgery, and it was later extended to other medical disciplines. Stopping for time-out before a patient undergoes a medical procedure means pausing to ensure that the correct actions are being taken (e.g., whether it is the correct patient, the correct procedure, the correct site, the correct protocol, etc.). Time-outs involve inter-professional communication as well as communication with the patient and are usually linked to the use of step-by-step protocols of evidence-based patient safety measures in the form of a checklist. Checklist models have been developed for radiological medical procedures and may be adopted for use during time-outs. Collaboration and teamwork for the review and adaptation of existing evidence-based guidance to the local setting supports the implementation and uptake of pre-exposure checklists and the effectiveness of time-outs (Berlinger & Dietz, 2016).

5.10 Technological developments

Future technological developments may include innovations such as artificial intelligence. The advances in artificial intelligence and machine learning are such that specially designed and trained systems are now able to think and suggest (or even take action if authorized) at any hour of any day. Many new artificial intelligence opportunities are foreseen in the field of medical use of radiation that may affect the way radiation safety is practiced. This poses a challenge and a need to wait-and-watch, as it is a developing area. The technologies may potentially serve as extra eyes, ears and hands at the job site, automatically capturing data from workers, equipment and the environment in real time – providing more information than could be collected manually. This would make reporting quick and easy. Such technology enables staff to engage with safety as it happens, in real time, which in turn improves reporting rates. The availability of technological resources leads to actionable insights empowering organizations and individuals to make better, more informed decisions (Choudhury & Asan, 2020).

Any technological development comes together with ethical challenges and possible risks for the communities and individuals whose health could be affected by its use (WHO, 2021b). Therefore, it is important to that the radiation protection framework is applied including professional development, regulation and governance, and last but not least safety culture (WHO, 2022b).

> ### ☢ Key message
>
> A combination of optimal tools is required to establish and maintain radiation safety culture. This includes standards and regulations, policies and procedures, education and training, audit activities, communication strategies, reporting and learning systems, checklists, verification procedures and time-out, among others.

6 Assessment of radiation safety culture in health care

The previous chapter has considered tools for developing and maintaining radiation safety culture. A different combination of optimal tools is required to assess the existing level and quality of radiation safety culture, not only to measure the identified criteria of success, but also to stimulate judgments and observations about positive or negative trends. Strong leadership, education and training, establishment of positive behaviour at the workplace and proper communication among all practitioners have a definite impact on radiation protection culture. Similarly, learning from events, incidents and near misses is an important part of culture development. It is therefore important to judge the level of culture and to develop indicators to estimate if the conditions put in place allow it to develop. This can be realized through surveys, interviews, any factual evidence showing that the organization put in place promotes the sustainable construction of a strong culture. There are numerous examples of culture assessment in the literature which may be used for guidance (Nieva & Sorra, 2003; Aboul-Fotouh et al., 2012; Berris et al., 2017; Hogden et al., 2017; Ralston & Yuen, 2018). Some general aspects for selecting the method appropriate to a particular situation are outlined below, along with examples at international, regional and national level.

6.1 Requirements for assessing radiation safety culture in health care

In order to determine the best method for assessing safety culture, it is necessary to first clarify what is required of an assessment system. For instance, should it be considered an assessment or evaluation, and should it be qualitative or quantitative? Assessment might be thought of as being the process, whereas evaluation is the outcome. Assessment criteria might be set up that have numerical values for scoring purposes, or an evaluation might be given in descriptive terms such as low, average, excellent. Whatever methodology is chosen, the essential point is that it is reproducible, so that the process may be repeated at different times to demonstrate progress (or lack of) towards an improved radiation safety culture. When discussing the assessment of radiation safety culture, both tools and indicators are referred to. In this context, a "tool" is a methodology for collecting and/or assessing data whereas an "indicator" is a particular metric – which may be qualitative or quantitative – that can be used as a measure of success.

Several approaches have been proposed for use of assessment tools, and these may be adapted as required for a given situation. A comparison is given in Table 2 between three approaches:

- ☢ the 10 safety culture traits proposed by IAEA (IAEA, 2021b);

- ☢ the 10 basic elements of safety culture proposed by the Ibero-American Forum of Radiological and Nuclear Regulatory Agencies (FORO)[5] (IAEA, 2022);

- ☢ the 10 safety culture factors developed by the Society of Radiological Protection (SRP)[6] (Chapple et al., 2017).

Although these frameworks have been developed in different places, and to meet slightly different requirements, there is a clear common pattern to the elements in each. For illustrative purposes, the two first approaches are depicted in Figs. 11 and 12. All three approaches are detailed further in the Annex.

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[5] FORO comprises the nuclear and radiation safety regulatory authorities from ten Ibero-American countries: Argentina, Brazil, Chile, Colombia, Cuba, Mexico, Paraguay, Peru, Spain and Uruguay.

[6] SRP is one of the associate societies of IRPA in the United Kingdom.

Fig. 11. Ten safety culture traits developed by IAEA (IAEA, 2021b)
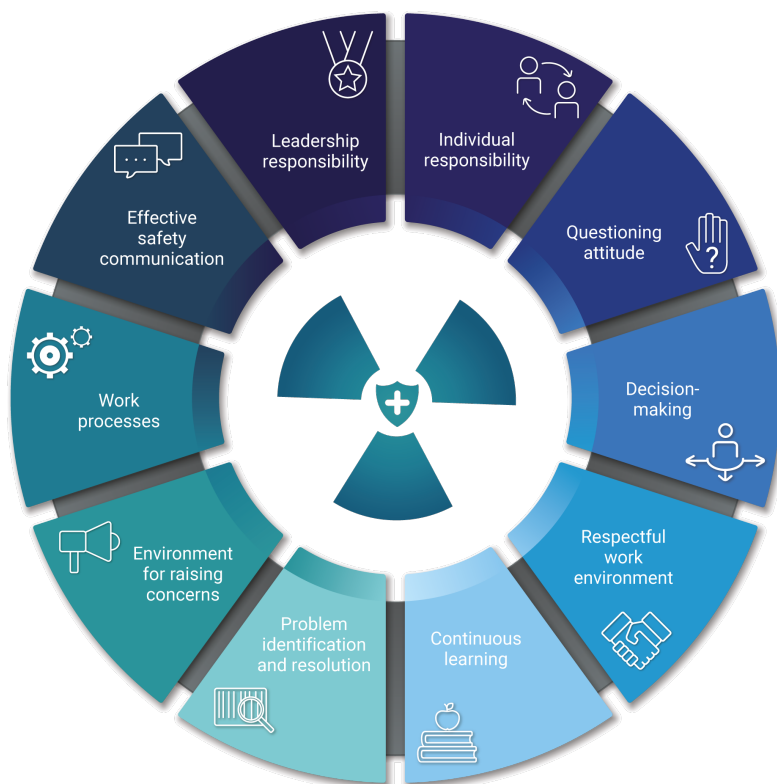
The sequence is not related with priority setting.

Fig. 12. Ten basic elements of safety culture developed by FORO (IAEA, 2022)

Adapted with permission of the publisher. The original figure appears in Spanish and was translated for this publication.

Table 2. Examples of assessment tools for developing radiation safety culture

| Commonalities | Example of a global approach
The IAEA 10 safety culture traits and adopted in this document | Example of a regional approach
The FORO 10 basic elements of safety culture | Example of a national approach
The SRP 10-points assessment of culture factors |
|---|---|---|---|
| Leadership/ management | Leadership responsibility | Visible leadership and commitment with safety from high-level management | Engagement of management |
| | Decision-making | Safety as a priority | Appropriate appointment and use of accredited experts and officers |
| Learning/training | Continuous learning | Continued organizational safety learning | Appropriate training |
| Communication/ relationships | Effective safety communication | Effective communication about safety | Effective communication |
| | Respectful work environment | Environment of trust and collaboration on safety | |
| Handling problems/ incidents | Problem identification and resolution | Timely identification and solution of safety issues | Appropriate incident handling |
| | Environment for raising concerns | Voluntary safety reporting
Just culture for treating individual safety behaviours | |
| Personal/individual responsibility | Individual responsibility | Responsibility, engagement and individual safety behaviour | — |
| Ongoing review/ audit | Questioning attitude | Permanent approach to safety | Regular audit of radiation safety procedures |
| Specific areas of work | Work processes | — | Appropriate use of diagnostic imaging using ionizing radiation
Appropriate management of radiation generating equipment and radioactive materials
Optimization of patient dose
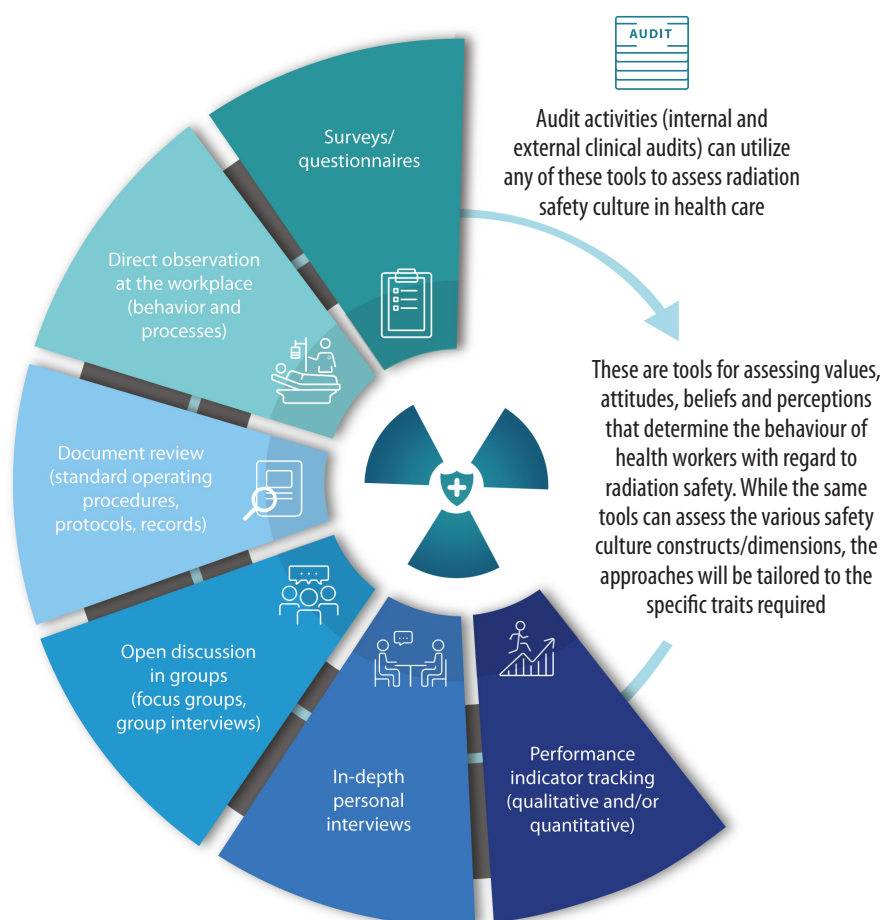Management of staff doses |

☢ **Key message**

A positive safety culture can be defined by 10 traits: leadership responsibility, individual responsibility, continuous learning, effective safety communication, respectful work environment, problem identification and resolution, environment for raising concerns, decision-making, questioning attitude and work processes.

6.2 Tools for assessing radiation safety culture in health care

Tools for collating quantitative data might include collection of national or local data on doses and incidents, for example, or government data. Tools for gathering more qualitative data might include surveys of staff or patient attitudes to radiation safety issues, or knowledge of topics such as typical doses and risks. Assessment tools were discussed at each of the six regional workshops and some of the suggestions are summarized in Fig. 13 (though these are not exhaustive). As a follow up to the Bonn Call for Action, a patient safety toolkit has also been initiated (IAEA, 2020c) some of which may be applicable to radiation safety culture.

Fig. 13. Radiation safety culture assessment tools suggested during the regional workshops

Surveys/questionnaires

Direct observation at the workplace (behavior and processes)

Document review (standard operating procedures, protocols, records)

Open discussion in groups (focus groups, group interviews)

In-depth personal interviews

Performance indicator tracking (qualitative and/or quantitative)

AUDIT

Audit activities (internal and external clinical audits) can utilize any of these tools to assess radiation safety culture in health care

These are tools for assessing values, attitudes, beliefs and perceptions that determine the behaviour of health workers with regard to radiation safety. While the same tools can assess the various safety culture constructs/dimensions, the approaches will be tailored to the specific traits required

6.3 Indicators of the level of radiation safety culture in health care

Indicators or measures can be quantitative as given in Fig. 14, or qualitative (Fig. 15).

Fig. 14. Examples of quantitative indicators that can be related to radiation safety culture traits

EXAMPLES OF INDICATORS	RELATED TRAITS	
Percentage of procedures for which local Diagnostic Reference Levels are in place	• Decision-making • Problem identification and resolution • Work processes	
Percentage of staff included in accreditation programmes for their specific roles	• Continuous learning • Individual responsibility	
Number of services accredited	• Work processes	
Reported errors/incidents	• Problem identification and resolution • Environment for raising concerns	
Number of audits performed	• Problem identification and resolution	
Number of hours training in radiation protection	• Continuous learning	
Number of procedures suspended for safety concerns	• Decision making	
Recorded staff doses	• Leadership responsibility	
Compliance with personal monitoring	• Work processes	
Compliance with wearing PPE	• Individual responsibility	

Fig. 15. Examples of qualitative indicators that can be related to radiation safety culture traits

EXAMPLES OF INDICATORS	RELATED TRAITS
Diagnostic reference levels are in place for the most frequent exams	• Decision-making • Problem identification and resolution • Work processes
Effective communication plan is in place, with policies and procedures for information sharing, regular meetings of radiation safety committees	• Effective safety communication
Peer review of procedures regularly implemented	• Questioning attitude • Problem identification and resolution • Environment for raising concerns
Patient perspective and satisfaction considered	• Environment for raising concerns
Training opportunities in place to simulate learning and improve performance	• Continuous learning
Management involved to ensure engagement	• Leadership responsibility

6.4 Local assessment of radiation safety culture

Each of the assessment frameworks summarized above includes a number of radiation safety culture performance indicators alongside each trait, element, or factor, which may be used or adapted as a basis of audit. Full details of all indicators in each framework are given in the Annex, but the philosophy and application of each are discussed below. The appropriate choice of audit for a specific facility depends on many issues such as aims, locality, persons involved, available data.

The IAEA safety culture traits were used as a basis for a training package in developing radiation safety culture in medicine (IAEA, 2021b). Each trait was accompanied by a detailed description of how that trait may be recognized. An example of this recognition process is given below for the trait of a questioning attitude (Table 3). The traits and

Table 3. Example of an IAEA safety culture trait and its associated description

IAEA trait	Associated description
Questioning attitude	Individuals avoid complacency and continuously challenge existing conditions and activities in order to identify discrepancies that might result in error or inappropriate action. All employees are watchful for assumptions, anomalies, values, conditions or activities that can have an undesirable effect on safety.

descriptions are focused on behaviours, so an audit structured on these would need to be based on either observation over a period of time (specific staff/department) or detailed interview with individuals and recording of specific examples of the behaviours listed. A simple scoring system could be used to indicate the degree to which each behaviour occurs. An audit of this nature requires some skill and time in successful execution but would give an in-depth understanding of the level of radiation safety culture embedded.

The FORO guidelines were launched in 2015 for Latin American countries. Each basic element of radiation safety culture is associated with a number of indicators – an example of those basic elements is given in Table 4. The indicators cover a range of behaviours and expected actions, which again can be audited. Evidence is likely to be more varied than an audit according to IAEA traits, but will often relate to more concrete documents or measurable events. It was developed primarily for regulators to use in assessing health care institutions.

Table 4. Example of FORO basic element and its associated indicator

FORO element	Associated indicator
Safety as a priority	Visibility of the priority of radiation safety in documents.
	Prevention/management of radiation safety issues.
	Time-out due to radiation safety issues.
	Interaction between high-level management and the radiation protection officer/medical practitioner.
	Integration of radiation safety into staff career/promotion/recruitment and service procurement.

The cultural factors in the example from the SRP in the United Kingdom each have associated performance indicators as well, very much designed for assessment of hospitals in the country and covering behaviours along with specific work practices (Table 5). The performance indicators are all intended to be easily quantifiable and thus able to be used for a range of audit purposes, from inspections by competent authorities to local assessment of improvement.

Table 5. Example of SRP culture factors and performance indicators in the United Kingdom

Culture factor	Associated performance indicator
Appropriate incident handling	Documented procedures for handling radiation incidents.
	Evidence of timely reporting and investigation of incidents.
	Evidence of involvement of appropriate managers.
	Actions plans for lessons learned and implementation of any new procedures.
	Evidence of culture of "openness" in reporting.

More details of descriptors and indicators within these frameworks may be found in the Annex. It should be noted that any framework used for assessing radiation safety culture at a local level should be adapted to the specific situation and goals, in order for it to be used effectively. In Chapter 7, the IAEA safety culture traits will be used to illustrate examples of good practice in radiation safety culture in health care.

☢ **Key message**

Existing frameworks proposing assessment tools and performance indicators can be adopted and adapted to the local context to assess level and quality of radiation safety culture.

7 Examples of good practice of radiation safety culture in health care

In the preceding chapters a good radiation safety culture, the factors that influence it, and tools for improving and assessing it were presented. This chapter contains a number of examples of actual situations in which either radiation safety culture has been improved or where poor culture has been analysed to determine an appropriate way forward. Examples are taken from a range of geographical locations and a range of modalities and institutions. It is not exhaustive but illustrate a range of situations of practical application of principles. These real-life experiences/examples were collected during six regional workshops and do not necessarily represent recommendations to follow. Each example is described in terms of the following:

- ☢ The issue/situation involved, including any particular challenges to good radiation safety culture that existed.

- ☢ The sequence of events, including actions, that occurred as a consequence.

- ☢ The resulting situation – what was achieved following intervention, or how a poor outcome arose, if applicable.

- ☢ Analysis of key factors influencing a positive culture outcome, or how a poor outcome could have been transformed.

> ☢ **Key message**
>
> **Good practices to improve safety culture shared by radiation health care providers can be adopted/adapted around the world.**

Example 1.
Assessment of performance of radiation therapy clinic
(work processes)

Type of institution & country	**University hospital, the USA**
Brief summary of existing issue/situation	The Safety Profile Assessment online tool, developed by the AAPM and available free of charge to any individual or clinic (AAPM, 2024), is intended to provide a practical means for assessing performance with respect to key recommendations from the available body of quality and safety literature. The tool is a set of indicators that include measures of radiation safety culture, which probe key elements of quality and safety, intended to provide a straightforward means of documenting and benchmarking the performance of a radiation therapy clinic (Dunscombe et al., 2015).
Any particular challenges to good radiation safety culture	The tool is extremely effective in helping groups to identify both areas of excellence and areas in need of improvement with respect to safety culture. It can be a good way to force difficult conversations and for all members of the team to have a chance to provide their unique perspectives on specific safety culture topics.
Sequence of events (include consequential actions)	The Safety Profile Assessment is comprised of 92 safety indicators and can be used on an annual basis to monitor changes over time. Results can also be benchmarked against other institutions in the same geographic region or of similar size.
Resulting situation (may be positive or negative)	It was found that this tool to be effective in improving and maintaining a positive, constructive safety culture in our department.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	• Use of published tool enabled conversation and action on safety culture. • Ongoing assessment against same indicators possible to identify trends.

AAPM: American Association of Physicists in Medicine.

Example 2.
Empowering all staff to speak up in a radiotherapy department
(questioning attitude)

Type of institution & country	**Cancer center, the USA**
Brief summary of existing issue/situation	Cancer patient was undergoing palliative linear accelerator radiation therapy and reported feeling increasingly nauseous after undergoing several fractions of therapy.
Any particular challenges to good radiation safety culture	All staff are encouraged to speak up freely with any concerns, even if the concern is just a nagging feeling that something is not quite right. Empowering all staff to speak up is a sign of good radiation safety culture.
Sequence of events (include consequential actions)	1. Patient began palliative linear accelerator radiation therapy. 2. Patient received 6 fractions of 10 planned fractions and reported feeling increasingly nauseous. 3. Linear accelerator therapist opted to consult the physician and physicist prior to proceeding with fraction 7; although the patient was nauseated prior to starting therapy, the therapist correctly identified that the increased nausea was not an expected side-effect for the intended treatment area. 4. Physicist and physician discovered that a required shift of the treatment table had not occurred in the first 6 fractions and the intended treatment area was not treated.
Resulting situation (may be positive or negative)	Unfortunately, the patient's primary cancer also progressed aggressively during this time and alternative systemic therapies were pursued rather than continuing with linear accelerator therapies for the intended treatment area. The department retrained all staff on documentation and interpretation of all treatment table movements required for correct therapy administrations. The department decided to no longer use one particular accelerator for spine cases due to inadequate visualization on that accelerator.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	• The key factor in identifying this issue was attentive therapists that felt comfortable questioning the therapy. If the therapist had proceeded without questioning, all 10 fractions could have been delivered without ever identifying that the intended treatment area was not treated. • The entire therapy process was evaluated for all possible contributing factors and corrective actions were established for multiple processes.

Example 3.
Time-out in radiotherapy clinic
(raising concerns)

Type of institution & country	**University hospital, the USA**
Brief summary of existing issue/situation	Patient set up and photos were not documented at the time of CT-simulation.
Any particular challenges to good radiation safety culture	Rushed work; time pressure.
Sequence of events (include consequential actions)	1. Radiation therapy staff running CT-simulation felt time pressure to keep patients on time and forgot to upload photos and put in site set-up instructions in record and verify the system. 2. During the simulation verification process, other radiation therapy staff had to pull staff involved with the simulation away from their work to help reconstruct the set up.
Resulting situation (may be positive or negative)	Delay in verification simulation for patient. Interruption to simulation team's work. Risk of possible errors in setting up patient between CT-simulation and verification/dry run simulation. Near miss report entered into incident learning system.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	Key factors influencing outcomes: • time pressure • unclear roles among team members. Situation has been improved with the following: • Designated time-out prior to and after each CT-simulation (includes set up and photos) established. • Designated CT-simulation team leader (rotating position) established. Of note: due to strong safety culture, staff feel comfortable giving and receiving feedback from one another for example when they initially forget to put in set-up details and photos in the record and verify the system. • CT-simulation team is involved with patient scheduling to reduce risk of over-booking and other contributors to time pressure in CT-simulation work area which contributes to errors.

Example 4.
Formalizing the quality management system in a radiotherapy service
(leadership responsibility)

Type of institution & country	National hospital, South Africa
Brief summary of existing issue/situation	A few years ago, the Radiotherapy and Medical Physics Divisions at this hospital decided to formalize their quality management system and improve the safety culture. The hospital has three linear accelerators, a high-dose rate after-loader and a CT-simulator and treats about 1600 patients per year with radiotherapy.
Any particular challenges to good radiation safety culture	Fortunately, the leadership in the divisions was actively trying to pursue an improvement in the safety culture. The clinical oncologists were very aware of the need for medical physics and radiation therapist engagement, as well as input from all related disciplines, to deliver safer radiotherapy.
Sequence of events (include consequential actions)	1. The hospital put in an official request for a QUATRO audit by the IAEA. The QUATRO audit is a comprehensive audit that provides an independent peer review and evaluation of the quality of all elements of the radiotherapy process, with a view to quality improvement.
	2. Two staff members attended a week-long IAEA training course on the QUATRO audit methodology, which helped with the preparation for a complete internal audit before the actual QUATRO team arrived. Policies and procedures were compiled in areas where they did not exist yet, and incident review meetings were held monthly.
	3. A team also attended an IAEA workshop at the Argonne National Laboratory on prevention of accidents and incidents in radiotherapy. This helped to create awareness for the need to also report near misses, which in turn has led to workflow changes to stop potential errors from slipping through the system. The importance of incident learning systems, such as SAFRON, became very evident. A "time-out" sheet at the last-man-out-button on each linear accelerator was introduced, to double check key treatment parameters before the beam is switched on.
	4. While it was quite tedious at times to get all the documentation in place for the QUATRO audit, it definitely helped to formalize all our procedures and to instil confidence that we are doing everything possible to enhance radiation safety.
Resulting situation (may be positive or negative)	The QUATRO audit team consisted of two medical physicists (from Lund, Sweden and Cairo, Egypt), a senior radiotherapy technologist (from Delhi, India) and a radiation oncologist (from Rabat, Morocco).
	The team spent a week in the department observing procedures, studying documentation, policies and procedures, interviewing staff members, following the workflow in the department and doing independent dosimetry checks. While the final audit report is not available yet at the time of this submission, they stated in their exit briefing that they observed a "culture of quality in radiotherapy", which is high praise for the hard work that has gone into improving services. Independent absolute dosimetry was within $\pm$ 1% for all beams except one, where a 1.7% difference was observed. The team specifically commended the "time-out" check sheets at each machine, which was only recently introduced in the department.
	The recommendations were to continue using Volumetric Modulated Arc Therapy (VMAT) for cases where patients will benefit from it, and to introduce 3D brachytherapy, which is an ongoing project already. VMAT is not done routinely yet, and this was mentioned as a great opportunity to do a failure mode and effects analysis. Other recommendations included a log-book in the mould room and a proper container for the clearing of the slag of the low-melting point alloy that is used in the manufacture of electron inserts. A larger water bath was recommended for the head & neck masks, which was also an issue that we were aware of already. Another recommendation was to create avenues for radiotherapy technologists with a research interest to do research.
	It was very encouraging to see that the department is on the right track with no major shortcomings.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	• The internal audit according to QUATRO guidelines was very well received by the auditors, who now had a great starting point for their audit. This should be a recommendation for all centres requesting a QUATRO audit from the IAEA.
	• With hindsight, it would have been good to have had better communication with the audit team before the audit. At short notice the attendance at some of the multidisciplinary team meetings might not always be possible; however, the audit team mentioned in the exit briefing that they were made very welcome, worked in a friendly atmosphere, staff members were "most co-operative and open in providing information" and that the team was able to carry out their tasks very well.
	• A QUATRO audit is recommended as best practice.

QUATRO: Quality Improvement Quality Assurance Team for Radiation Oncology

Example 5.
Redesigning care and improving safety culture in medical imaging
(respectful work environment)

Type of institution & country	**University school of medicine, cancer institute, the USA**
Brief summary of existing issue/situation	A decade ago, an army colonel underwent a State Department physical exam that revealed a lump in his throat. He would not be going abroad for contract employment as planned, but instead would be fighting an unexpected foe: head and neck cancer.
Any particular challenges to good radiation safety culture	Visualization of the head and neck region is a complex and challenging area for imaging, according to the director of head and neck radiology at this cancer institute. "The lesions are small, the anatomy is difficult to navigate, and everything is in close proximity to the brain. The risks are huge."
Sequence of events (include consequential actions)	Given the complexity of the case, the patient wanted to learn about his squamous cell carcinoma from the person who could best see it — the radiologist. "Initially, my doctor talked to the radiologist and then relayed the information to me, but I wanted to talk to the radiologist directly," he says. "I wanted to ask, 'What's that?' on the images."
Resulting situation (may be positive or negative)	The patient's concerns were respected and addressed. The patient was informed, and this also had a positive impact on the safety communication and dialogue between the members of the team involved in the patient's care.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	• Engagement and empowerment of patients contributes to quality and safety of care, facilitates communication between health professionals in a respectful working environment and improves dialogue with patients and families – all attributes of a positive safety culture.

Example 6.
Radiologists supporting communication across care continuum
(effective safety communication)

Type of institution & country	**Medical center, the USA**
Brief summary of existing issue/situation	A patient visited the emergency department for a rib injury. A CT scan showed no broken bones, but the radiologist noted a pulmonary nodule in the patient's left lung and recommended follow-up imaging. At discharge, the emergency physician suggested that the patient follow up on the nodule with his primary care physician — but that did not happen. Now, a year later, the patient is having another CT, and this time the radiologist suspects and a biopsy confirms the presence of lung cancer. The patient finally begins treatment, but the chances of a positive outcome have significantly diminished.
Any particular challenges to good radiation safety culture	Lack of teamwork, lack of dialogue/communication between health-care providers resulted in fragmentation of care, the diagnosis made only after a second CT.
Sequence of events (include consequential actions)	Radiologists have taken the lead to address the issue with "Failsafe". Programme uses letters and phone calls to inform patients about incidental findings discovered in the emergency department and encourages them to follow up with their primary care physician.
Resulting situation (may be positive or negative)	Positive impact, as patients are now more likely to follow up incidental findings with potential life-saving benefits.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	• Identification of an issue that was affecting patient outcomes. • Recognition of ability to influence outcome. • Initiation of appropriate action. • Improved communication.

Example 7.
Patient-friendly summaries of appropriateness criteria
(effective safety communication)

Type of institution & country	**Radiology department, the USA**
Brief summary of existing issue/situation	Large number of unnecessary radiology referrals.
Any particular challenges to good radiation safety culture	Pressure from patients for radiology referral.
Sequence of events (include consequential actions)	Patient-friendly summaries of the American College of Radiology Appropriateness Criteria produced: e.g. Acute Chest Pain—Suspected Pulmonary Embolism.
Resulting situation (may be positive or negative)	The purpose of these summaries is to provide an entry point for patients and referring clinicians to information designed to reduce low-value imaging, which may result in reduced radiation dose to the patient.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	• Imaging tests are not necessary for many patients suspected of having a blood clot in the lungs known as a pulmonary embolism. For medically stable patients, the risk of a pulmonary embolism should be assessed first by asking standard questions about the patient and his or her symptoms. If the answers to the questions result in a low-risk score, no further testing is required. • If the answers indicate the possibility of pulmonary embolism, a blood test (D-dimer) to check for a substance released when a blood clot breaks up is recommended. If the test comes back negative, no further testing is required. (The D-dimer test should not be used for anybody expected to have blood clots due to other things, such as recent surgery or trauma, or for pregnant women.) • If the answers to the standard questions indicate a high risk of pulmonary embolism and the D-dimer test is positive, in most cases a pulmonary CT angiography – a CT scan to look at the blood vessels in the lungs – is the next step. For people with symptoms of a blood clot in the lower legs, especially for pregnant women, an ultrasound Doppler of the legs is often the first choice to reduce radiation exposure. Eighty per cent of pulmonary embolisms are associated with blood clots in the lower legs. In addition, a chest X-ray may be performed to rule out other causes such as pneumonia or fluid in the lungs. Ventilation and perfusion nuclear medicine scans are sometimes used in place of CT angiography.

Example 8.
Improving knowledge and skills in radiation protection
(continuous learning)

Type of institution & country	**Radiation protection regulatory body, the United Republic of Tanzania**
Brief summary of existing issue/situation	Radiation protection is part of curriculum for all radiation workers, but the knowledge may be inadequate, irrelevant, theoretical and does not translate into competency. Relevant knowledge, competence and skills may be missing in some end users of radiation in health care.
Any particular challenges to good radiation safety culture	There is no safety requirement for updating/refreshing radiation protection knowledge and skills in radiation health workers.
Sequence of events (include consequential actions)	It was proposed to take the following actions. 1. Include radiation safety culture training in the medical curricula and at specialist training level (including orthopaedics, gastroenterology, cardiology, referrers and other users). 2. Make mandatory continuing medical education/continuing professional development to strengthen safety culture. 3. Support education on safety culture at professional meetings. 4. Develop training packages for trainers.
Resulting situation (may be positive or negative)	Education and training of end users of radiation in health care will positively impact on their safety attitude and behaviour thus enhancing their radiation safety culture
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	• The situation might have been improved earlier by developing and implementing policies and actions for ensuring education and training on radiation protection and safety culture, and training and continuous learning of health professionals dealing with medical use of radiation.

Example 9.
Engagement of management in radiation safety
(individual responsibility)

Type of institution & country	**Hospital, the United Kingdom**
Brief summary of existing issue/situation	Although radiation safety awareness and practice were generally very good within the main radiology and radiotherapy departments, frequent issues were arising in areas such as interventional radiology theatres where responsibilities were less clearly defined, e.g. lack of quality assurance on the use of some equipment; poor compliance with wearing personal dosimetry and PPE; lack of awareness of local safety rules.
Any particular challenges to good radiation safety culture	Perception that "someone else" was looking after radiation protection.
Sequence of events (include consequential actions)	• Summary of responsibilities of managers for radiation safety sent out to all relevant personnel. • Radiology practitioner assistant and radiologist presentations scheduled during Directorate Managers meetings. • Representatives of all Directorates invited to Radiation Protection Committee meetings. • Online radiation safety training provided at different levels (managers, (occasional) radiation workers, all other staff).
Resulting situation (may be positive or negative)	Increased awareness among departmental managers of radiation issues and safety requirements. More frequent contact sought with radiology practitioner assistants. Improved compliance of staff with safe practice.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	• Lead taken at highest management level and information cascaded to department managers. • Structure established to facilitate communication between and across levels in the organization. • Support and cooperation fostered between departments rather than competition or blame.

PPE: personal protective equipment.

Example 10.
Enhancing safety culture in digital radiology
(work processes)

Type of institution & country	Hospital, Chile
Brief summary of existing issue/situation	New digital X-ray equipment was installed for the first time in the Radiology department. The 10 or so medical technologists with many years of experience (but not in digital imaging) received rapid training and immediately began taking images due to the load of work. The new equipment immediately became the most demanded equipment. Months later the chief technologist and the radiological safety officer carried out an analysis in the database of the patients of how many images were taken, compared to those which were transferred to the radiologists for reporting. It was found that more than 20% of images, including paediatric images, were not transferred. Because of a shared password used by all staff, it was not possible to analyse which specific operators were responsible for non-transfer.
Any particular challenges to good radiation safety culture	Work load: a large number of patients waiting for one device meant time pressure during unit operation. False sense of experience with an unknown new technology. Worries among staff about punitive actions resulting from the poor-quality images taken. No clear lines of responsibility among operators. Lack of leadership.
Sequence of events (include consequential actions)	1. Extended meeting with all technologists to analyse the results of the analysis of the database. 2. Training and education in the safe use of this technology. 3. Unique password assignment for each operator. 4. All images are sent to the picture archiving and communication system (PACS) system. 5. The option to delete images is disabled. 6. A note should be left as to why the images are repeating. 7. Tracking the frequency of imaging repetition over time. 8. Lessons on safety culture issues for all staff given by the radiation safety officer.
Resulting situation (may be positive or negative)	After some time of implementing the corrective actions, a decrease in the repetition rate was observed, to below 10%. Many patients benefited from lower radiation doses in their diagnosis. The operators began to work with more safety and responsibility, but also with more knowledge.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	Key factors influencing outcomes: • renovation of the diagnostic imaging department and acquisition of five additional digital X-ray devices; • managers now involved in technical and security aspects; • willingness of all staff to work together. Situation has been improved with the following: • active and present leadership; • clearly stated personal responsibilities; • continuous training and learning of new technologies.

Example 11.
Enhancing safety culture in nuclear medicine
(problem identification and resolution)

Type of institution & country	**Hospital, Chile**
Brief summary of existing issue/situation	On certain occasions, different identification errors were made in the nuclear medicine department: a) when patients were called in for the injection appointment their name was not used, just "please come in"; b) some patients were identified by only a single name (making it hard to track the patient and their records); c) doses destined for one patient were injected into another patient; d) images were taken using a protocol other than prescribed for the patient. It was then that changes were implemented to reverse these errors.
Any particular challenges to good radiation safety culture	False assurance that everything was fine. Working pressure; number of patients. Lack of communication within the work team. Very old equipment. Lack of motivation. Only one nuclear medicine physician for all patients.
Sequence of events (include consequential actions)	1. Error in the correct identification of patients: actions are taken by all clinical staff. 2. Scheduling of the examination by written request of the referring physician and consultation with the nuclear physician. The examination request is scanned and uploaded on the electronic medical record. 3. On day of the examination, secretary requests the full name and what type of test, informing technologist who prepares the dose to be injected, in case of paediatric patient it is taken into account age, weight and consultation with the nuclear physician. 4. Before injecting, the full name, date of birth and the reason for the test are asked; these same data are asked a second time before starting the acquisition of the images. 5. The technologist compares the patient data with those described in the medical order and selects the protocol on the equipment, notifying the nuclear physician in case additional images are requested.
Resulting situation (may be positive or negative)	As a result of the corrective actions, the quality and safety of the nuclear medicine examinations are guaranteed, reducing the possibility of errors or mistakes. The "4R rule" is followed: correct radiopharmaceutical, correct dose, correct patient, correct test and double check identification is applied.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	Key factors influencing outcomes: - acquisition of a new SPECT/CT and a new laboratory (for radiopharmaceuticals) as part of the nuclear medicine department improvement project; - hiring more staff (nuclear doctor, secretary, technologist); - implementing suggestions from the Joint Commission Accreditation and the IAEA-ORPAS mission. Situation has been improved with the following: - analysis of the procedures that led to the errors; - defined responsibilities within the processes; - holding training and talks (even informal) on how to improve safety procedures; - increasing and enhancing communication between members of the nuclear medicine department; - involving all staff in some decisions, including the Radiation Safety Officer.

Example 12.
Radiation safety culture in nuclear medicine
(decision-making)

Type of institution & country	**Nuclear medicine department, Argentina**
Brief summary of existing issue/situation	Some technicians and physicians working in a nuclear medicine department are reluctant to comply with radiation-safety procedures, such as: routine area control, labelling of syringes (radiopharmaceutical/activity) prior to patient injection, reporting errors (contaminations, acquisition misses, etc.).
Any particular challenges to good radiation safety culture	These procedure-deviations occur mainly with experienced personnel and new members of staff. No continuous-education programme is available in the institution.
Sequence of events (include consequential actions)	• Absence of area-control compliance: technicians are asked to perform daily controls. • Absence of syringe labelling compliance: Technicians are asked to perform it regularly. • Inadequate/unequal level of engagement by senior management: physicians schedule meetings to review ways of improving communication, but senior management does not attend.
Resulting situation (may be positive or negative)	There were some issues on room-contamination unawareness, which were discovered by chance when an open unlabelled vial was found, and area-control was performed. On three occasions, patients had to be rescheduled and re-injected because of the incorrect radiopharmaceutical being injected.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	• Radiation-protection continuous education programme to be put in place for all staff. • Blame-free policy: for people to be able to report errors or procedure deviations without fear of punishment. • Consistency in following rules and obligations by senior management (Chief-Higher rank personnel).

Example 13.
Equipment failure affecting patients and workers in interventional procedures (problem identification and resolution)

Type of institution & country	**Catheterization laboratory, Argentina**
Brief summary of existing issue/situation	In a catheterization laboratory, a patient with a possible radiation-induced skin injury on the back was identified after performing an interventional radiology procedure. The injury was identified by the radiologist after a routine control of the patient for the treated pathology. After that, the radiologist consulted with his colleagues and referred the patient to a specialized medical centre for the treatment of localized radio-induced injuries. Approximately four months after the event, another patient who underwent an electrophysiology procedure in the catheterization laboratory in the same week as the previous patient (four months ago) also presented an apparently radiation-induced skin injury on the back.
Any particular challenges to good radiation safety culture	Detecting two similar adverse events in two different patients treated in the same facility/service during the same week may have a common root cause, possibly related with radiation safety, thus suggesting a radiation safety culture issue.
Sequence of events (include consequential actions)	The radiologist requested support from a reference institution to perform quality control of the angiography equipment and review the dosimetric reports. Results obtained: • The assessed dose for fluoroscopy coronary protocol was 198 mGy/minute and for cine coronary protocol 15 frames/second; dose: 830 mGy/minute = 0.92 mGy/frame. • Those values exceeded significantly the recommended values by international protocols (fluoroscopy: 50 mGy/minute; Cine: 0.25 mGy/frame). • The head of department decided to suspend further procedures while the manufacturer of the equipment was contacted but declined to solve the problems. The catheterization laboratory received institutional support to make this decision. • Additionally, there was an absence of a lead screen (suspended from the ceiling) and a lead table shield for protection of lower limbs, both protections for the staff. • The manufacturer then made the necessary repairs, and the reference institution re-performed the quality control of the angiography system after 4 months, resulting in a 40% dose reduction but still exceeding the recommended values. • The catheterization laboratory restarted performing interventional procedures, but later professionals detected an increase in the values of the dosimetric reports over several months. • Once again, quality control of the equipment was requested, but it was not possible to carry out the measurements.
Resulting situation (may be positive or negative)	Two overexposed patients, with radiation-induced skin damage in the back were referred to a specialized centre for treatment of their localized radiation induced injuries. Overexposed staff (physicians and technicians). The angiography system was temporarily suspended from service and then a final removal and change of equipment was made, affecting patients' health care for months, as patients had to be referred to other health institutions for imaging.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	Positive point: • The radiologist took actions and received institutional support for suspension of activities in the catheterization laboratory and equipment change request. Key factors influencing the outcome included the following: • Lack of implementation of a radiological protection manual. • Lack of periodic quality assurance of the equipment. • Poor analysis of personal dosimetry reports. • Lack of a protocol for monitoring patients for detection and treatment of possible radio-induced injuries. • Lack of registration of doses received by patients. • Lack of controls by the regulatory body for staff and patient safety. • Lack of adequate controls by the manufacturer. Points to improve: • Review the case study to learn from this experience.

Example 14.
Unintended exposure of a pregnant patient during an interventional procedure (working processes)

Type of institution & country	**Catheterization laboratory, Argentina**
Brief summary of existing issue/situation	An iliac vein angiography procedure (pelvic region) was performed on a 30-year-old female patient. At all times the patient dismissed the possibility of being pregnant. One month after the study, the patient communicated to the radiologist who performed the intervention that she was pregnant. The patient indicated last menstrual period 3 weeks prior to the interventional procedure, estimating a pregnancy of 7–10 days at the time of the study.
Any particular challenges to good radiation safety culture	The health care facility did not make provisions to rule out possible pregnancy of a female patient of reproductive age before performing a radiological medical procedure involving a significant pelvic dose and this challenged radiation safety culture.
Sequence of events (include consequential actions)	The head of the service requests support from specialized reference institutions for analysis of the case. According to the report, the procedure lasted approximately 6 minutes with only antero-posterior projections. The patient received a total dose of 210 mGy at the interventional reference point and Dose-Area Product 4063 cGy.cm^2.
	Given the length of pregnancy at the time of the study (less than 10 days i.e. pre-implantation stage) the so called "all or none effect" could have occurred, which might have led to a miscarriage; however the patient presented to the physician with 6–8 weeks of pregnancy with normal development of the embryo. The physician was informed that the dose received by the fetus did not exceed the threshold for deterministic effects.
	The specialized reference institutions recommend the establishment of a pregnancy verification protocol for studies that involve high doses of radiation in the abdomen-pelvis region and the inclusion of the dose report in the medical history of the patient.
Resulting situation (may be positive or negative)	The patient continued the normal course of pregnancy without problems.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	Negative point: • Pregnancy verification was not performed. Positive point: • The radiologist requested support from specialized reference institutions to assess the situation. Points to improve: • Review the case study to learn from this experience.

Example 15.
Improving working procedures in paediatric interventional cardiology
(working procedures)

Type of institution & country	Hospital, Chile
Brief summary of existing issue/situation	A paediatric interventional cardiologist of a hospital received radiation protection education and training for the first time in 2007, during an IAEA radiation safety training course. Among other topics, this training was an opportunity to learn about existing tools for implementing optimization of protection and safety of patients during the procedures, while at the same time improving occupational radiation protection of operators. In fluoroscopy-guided interventions there are two main types of image acquisition commonly available: cine-angiography and fluoroscopy. The cine images deliver doses significantly higher than fluoroscopy. The optimization strategy referred to in this case utilizes the possibility offered by some interventional fluoroscopy systems to perform fluoroscopy sequences and save them as if they were cine.
Any particular challenges to good radiation safety culture	In this case, the challenge was not only exploring whether this optimization tool was available in the equipment being used at the hospital but also learning how to utilize it. It was also a challenge to assess whether this strategy was helpful and safe to perform paediatric interventional procedures such as pulmonary and aortic valvuloplasty (e.g. transcatheter balloon dilation of the valve); pulmonary artery branch angioplasty (e.g. in native stenosis, post-surgery or post stent narrowing) and aortic angioplasty (e.g. transcatheter balloon dilation of a re-coarctation or narrowing of a surgically repaired coarctation).
Sequence of events (include consequential actions)	1. To investigate whether the equipment being used had the possibility of saving fluoroscopy sequences. 2. Once confirmed that the equipment offered that possibility, to learn how to use it. 3. While learning how to use it, to confirm whether this would fulfil the requirements to ensure patient safety and efficacy of the procedure. 4. To demonstrate the utility of this change to the rest of the team members when using the fluoroscopy sequence in the abovementioned procedures, not only to lower patient doses, but also for substantially reducing the scattered radiation received by the operator. 5. To disseminate the Information to the other operators. 6. To implement the use of this optimization tool by all the operators of the service. 7. To incorporate the use of the fluoroscopy sequence as a service by the health facility.
Resulting situation (may be positive or negative)	Finally, the objective was achieved: all the operators working at the time in this service used the fluoroscopy sequence instead of using cine-angiography in image-guided procedures for pulmonary and aortic valvuloplasty, pulmonary artery branch angioplasty and aortic angioplasty.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	Key factors influencing outcomes include the following: • The involvement of the operator probably helped to look for, and identify more quickly, the pros and cons of the tool to be used for optimization. • Another facility with two operators started using this approach. While one of the operators immediately adopted the tool, the other one expressed that he did not feel safe with the fluoroscopy image at the end of the balloon inflation during pulmonary artery branch angioplasties. In this case it was suggested performing and recording the fluoroscopy sequence and taking a picture (i.e. a single image with cine quality) in order to get a better representation of the balloon during peak inflation. Situation has been improved with: • Approximately a 10-fold reduction of the patient dose was achieved for these procedures, based on experimental dose measurements using fluoroscopy sequences (10 frames/second) versus cine-angiography sequences (15 frames/second) using polymethyl methacrylate phantoms with different thicknesses. The patient dose reduction is approximately equivalent to the operator dose reduction due to the decrease in the backscatter radiation, which means a significant dual benefit from the use of this optimization tool available in all new systems (and also in many of the old systems).

Example 16.
Improvement in dose record keeping
(decision-making)

Type of institution & country	Cancer centre, Australia
Brief summary of existing issue/situation	Centralized registers of occupational radiation dose records provide the ability of workers to access their career radiation dose records from multiple employers. They also provide long-term data security, and data for research, particularly in the risk of long-term low dose radiation exposure.
	The ANRDR was implemented in consultation with the Australian uranium mining industry to allow mining workers to access their career dose record from multiple employers. Participation in the ANRDR was mandated by the mining and radiation protection regulatory frameworks in each jurisdiction.
	Data on radiation doses to workers in medicine, particularly over long-time scales is limited. This is despite medical workers representing by far the largest number of people occupationally exposed to radiation in Australia. Medical radiation workers are likely to have multiple employers, and in the Australian context work in multiple regulatory jurisdictions. The pace of technological advances and applications of ionizing radiation is rapid, increasing the importance of dose assessment and record keeping.
	In 2018, ARPANSA which administers the ANRDR, sought to expand participation in the ANRDR to the medical sector. This cancer centre was invited by ARPANSA to pilot the use of the ANRDR for medical workers.
Any particular challenges to good radiation safety culture	Radiation dose records are provided from multiple commercial dosimetry vendors in different data formats.
	There are no regulatory standards for radiation dose record keeping (e.g., units of dose, personal data requirements).
	There is no regulatory requirement to participate in the ANRDR unlike the mining sector. Few hospitals have the resources to compile large datasets.
	The ANRDR uses a set data-reporting format. This may require to reformat data prior to submission.
	Dedicated professional IT services or commercial software packages are required to participate in the ANRDR, which require resourcing.
	Senior hospital administrators require education in the value of national dose registers and privacy regulations must be complied with.
Sequence of events (include consequential actions)	A business case was presented to the hospital executive to procure a commercial radiation dose record software package compatible with secure data transfer between multiple dosimetry vendors and the ANRDR.
	Once the software was installed, all radiation dose records were compiled into a single database. The data was then assessed for quality, for example missing personal information, duplications, and correct handling of different dose quantities (e.g. HP10 and HP0.7).
	A register of all occupational dose records from 1987 in a single format was eventually created.
	Permission was sought and received from the relevant bodies to transfer data to the ANRDR.
	Education was provided to staff in the ANRDR and the value it represents to them. A sub section of test data was successfully transferred to the ANRDR in late 2018. This cancer centre became the first hospital in Australia to do this.

Resulting situation (may be positive or negative)	It was demonstrated that radiation dose records from medical workers could be transferred into the ANRDR.
	The pilot study identified opportunities to improve the ANRDR to facilitate greater participation from the medical sector. This cancer centre demonstrated its objective of leading radiation protection culture in health care and participation with stakeholders that allow for enhancing outcomes for medical workers. The visibility of the project by senior management was an additional advantage.
	The pilot study suggested that participation in the ANRDR could be limited by the resources required to manage large databases on complex platforms.
	As a side issue, differences in dose recording between a TLD- and an OSL-based system were explored and reported on at two scientific conferences.
	It is also expected that the increased visibility of personal dose monitoring will improve compliance and awareness of workers about their radiation risks.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	• The project was supported by senior management which enabled the procurement of software and project resourcing. • This cancer centre has a good relationship with ARPANSA which may have influenced participation in the project. • This cancer centre strives to be a leader in the use of ionizing radiation in health care and at the forefront in radiation protection in health care. • Challenges remain in the participation of the medical sector in the ANRDR. These include lack of regulatory requirements to participate, limited radiation protection resources in most hospitals and the relatively complex nature of the transfer of data to the ANRDR.

ANRDR: Australian National Radiation Dose Register.
ARPANSA: the Australian Radiation Protection and Nuclear Safety Agency.

Example 17.
Unplanned working hours
(problem identification and resolution)

Type of institution & country	**General oncological hospital, Greece**
Brief summary of existing issue/situation	Radiation therapy session scheduling in our department often causes tension among team members. Machine down times, emergency cases or various unexpected delays frequently resulted in extended and unplanned working hours causing anxiety among radiotherapy radiographers. Stressful situations may lead to unsafe working conditions and potentially jeopardize patient safety.
Any particular challenges to good radiation safety culture	This situation raised concerns among radiotherapy radiographers who had to continue working beyond their regular shift as they realized the negative impact of this practice on departmental teamwork. The identification of the issue by staff members of all levels including leadership and management was the first step to finding a solution. Actions were taken to effectively communicate the necessity of additional working hours without pressuring those involved while recognizing radiographers' efforts.
Sequence of events (include consequential actions)	1. Organizing the daily staff shift. 2. Radiographers are notified in advance of the potential extended working hours of a particular shift. 3. The days of extended work are rotated among staff. 4. The additional working hours are acknowledged and may be subtracted from an upcoming shift or accumulated to annual leave, or overtime compensation could also be considered.
Resulting situation (may be positive or negative)	The situation was improved. Before: extended working hours were underestimated causing confusion among radiographers due to the absence of radiographer designation for potential overtime work, and the lack of recognition of their effort in working extra hours. Now: there is a stress-free working environment with personnel feeling respected and accountable.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	Key factors influencing outcomes: • identifying the problem by leadership • effective communication • appraisal of personnel's efforts. Situation may be further improved with: • hiring of additional staff.

Communication in a radiotherapy service
(effective safety communication)

Type of institution & country	**General oncological hospital, Greece**
Brief summary of existing issue/situation	Effective safety communication among members within the radiotherapy team is fundamental. With regard to treatments, patients' chart and checklists are essential tools for communicating therapy information safely. Yet, teams interact and communicate on various issues every day. Repeatedly, poor communication leads to confusion and tension, which in turn have a negative impact in our practice.
	Initially, the COVID-19 pandemic triggered misunderstandings which escalated disputes in our workplace. Limited recourses of PPE and the rapid exchange of information were causes of several conflicts. These increased the burden of the department since radiographers exhausted their energy in resolving communication issues.
Any particular challenges to good radiation safety culture	The outset of the pandemic was unprecedented. Communication became rather challenging. We realized that we had to act early to resolve areas of misunderstanding in order to remain focused on our daily responsibilities of safe and high-quality delivery of treatment.
Sequence of events (include consequential actions)	1. We established an event logbook for effective communication. 2. Radiographers of all levels were obligated to report/record any relevant information or event (other than patients' treatments) in the logbook including date, time and their signature to verify their entry. 3. Every radiographer on shift is updated via the event logbook in addition to the regular personal communication and institution's official documents.
Resulting situation (may be positive or negative)	The situation was improved resulting in: • effective communication and teamwork • peaceful work environment • trust.
Your analysis of key factors influencing outcome (bullet points) or how the situation might have been improved	Key factors influencing outcomes: • identification of the situation (unprecedented situations cause confusion at the workplace); • reporting and recording information and actions were necessary to avoid misunderstandings. Situation has been improved with the following: • Use of a communication tool (event logbook). • An event logbook can further be used in cases where transmission of information is challenging or in cases of patient handoffs.

PPE: personal protective equipment.

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Annex. Key resources for radiation safety culture

A.1 The Bonn Call for Action: 10 priority actions to improve radiation protection in medicine (IAEA, WHO, 2014)

1. Enhance the implementation of the principle of justification

2. Enhance the implementation of the principle of optimization of protection and safety

3. Strengthen manufacturers' role in contributing to the overall safety regime

4. Strengthen radiation protection education and training of health professionals

5. Shape and promote a strategic research agenda for radiation protection in medicine

6. Increase availability of improved global information on medical exposures and occupational exposures in medicine

7. Improve prevention of medical radiation incidents and accidents

8. Strengthen radiation safety culture in health care

9. Foster an improved radiation benefit-risk-dialogue

10. Strengthen the implementation of safety requirements globally

A.2 The IRPA Guiding Principles for Radiation Protection Professionals on Stakeholder Engagement (IRPA, 2014)

1. Identify opportunities for engagement and ensure the level of engagement is proportional to the nature of the radiation protection issues at stake and their context.

2. Initiate the process as early as possible and develop a sustainable implementation plan.

3. Enable an open, inclusive and transparent stakeholder engagement process.

4. Seek out and involve relevant stakeholders and experts.

5. Ensure that the roles and responsibilities of all participants, and the rules for cooperation are clearly defined.

6. Collectively develop objectives for the stakeholder engagement process, based on a shared understanding of issues and boundaries.

7. Develop a culture which values a shared language and understanding, and favours collective learning.

8. Respect and value the expression of different perspectives.

9. Ensure a regular feedback mechanism is in place to inform and improve current and future stakeholder engagement processes.

10. Apply the IRPA Code of Ethics in their actions within these processes to the best of their knowledge.

A.3 International safety culture traits, adapted from IAEA (IAEA, 2021b)

Trait	Description
Individual responsibility	All individuals take personal responsibility for safety. Responsibility and authority for safety are well defined and clearly understood. Reporting relationships, positional authority, and team responsibilities emphasize the overriding importance of safety.
Questioning attitude	Individuals avoid complacency and continuously challenge existing conditions and activities in order to identify discrepancies that might result in error or inappropriate action. All employees are watchful for assumptions, anomalies, values, conditions, or activities that can have an undesirable effect on facility safety.
Effective safety communication	Communications maintain a focus on safety. Safety communication is broad and includes facility level communication, job-related communication, worker-level communication, equipment labelling, operating experience and documentation. Leaders use formal and informal communication to convey the importance of safety. The flow of information up the organization is seen as important as the flow of information down the organization.
Leadership responsibility	Leaders demonstrate a commitment to safety in their decisions and behaviours. Executive and senior managers are the leading advocates of nuclear safety and demonstrate their commitment both in word and action. The safety message is communicated frequently and consistently, occasionally as a stand-alone theme. Leaders throughout the organization set an example for safety. Corporate policies emphasize the overriding importance of safety.
Decision-making	Decisions that support or affect safety are systematic, rigorous and thorough. Workers are vested with the authority and understand the expectation, when faced with unexpected or uncertain conditions, to place the facility in a safe condition. Senior leaders support and reinforce conservative decisions.
Respectful work environment	Trust and respect permeate the organization. A high level of trust is established in the organization, fostered, in part, through timely and accurate communication. Differing professional opinions are encouraged, discussed, and resolved in a timely manner. Employees are informed of steps taken in response to their concerns.
Continuous learning	Opportunities to learn about ways to ensure safety are sought out and implemented. Operating experience is highly valued, and the capacity to learn from experience is well developed. Training, self-assessments and benchmarking are used to stimulate learning and improve performance. Safety is kept under constant scrutiny through a variety of monitoring techniques, some of which provide an independent "fresh look".
Problem identification and resolution	Issues potentially impacting safety are promptly identified, fully evaluated and promptly addressed and corrected commensurate with their significance. Identification and resolution of a broad spectrum of problems, including organizational issues, are used to strengthen safety and improve performance.
Environment for raising concerns	A safety-conscious work environment is maintained where personnel feel free to raise safety concerns without fear of retaliation, intimidation, harassment or discrimination. The facility creates, maintains and evaluates policies and processes that allow personnel to freely raise concerns.
Work processes	The process of planning and controlling work activities is implemented so that safety is maintained. Work management is a deliberate process in which work is identified, selected, planned, scheduled, executed, closed and critiqued. The entire organization is involved in and fully supports the process.

A.4 Regional safety culture elements, adapted from FORO (IAEA, 2022)

Safety culture basic elements	Related radiation safety culture indicators
Safety as a priority	• Visibility of the priority of radiation safety in documents. • Prevention/management of radiation safety issues. • Time-out due to radiation safety issues. • Interaction between the high-level management (HLM) and the radiation protection officer/medical physicist. • Integration of radiation safety into staff career/promotion/recruitment, service procurement.
Visible leadership and commitment with safety from HLM	• Visibility of the radiation safety commitment of HLM in documents and in the organization. • Education of HLM on radiation safety leadership and on other radiation safety-related topics. • Assignment of human and financial resources to radiation safety • Periodic assessment of radiation safety by HLM. • Internal actions to promote/develop radiation safety culture.
Timely identification and solution of safety issues	• Timely identification of radiation safety issues. • Timely evaluation of radiation safety issues. • Timely solution of radiation safety issues.
Permanent approach to safety	• Consideration of radiation safety issues at the planning and control levels • Daily organizational mechanisms for proactive radiation safety evaluation. • Evaluation of the impact of changes to radiation safety. • Dialogue between HLM and the regulatory bodies and stakeholders.
Responsibility, engagement and individual safety behaviour	• Responsibility for radiation safety at the organization. • Radiation safety engagement of staff. • Attention paid by HLM to radiation safety suggestions/ recommendations from staff. • Dialogue between HLM and the workers to analyse safety behaviours. • Incentives/rewards for the engagement/contribution to safety. • Workers' training to enhance their radiation safety culture. • Workers' questioning attitude, accurate and prudent approach.
Effective communication about safety	• Acknowledgement of the importance of/culture of effective communication about safety in the organization. • Communication between the organization and stakeholders.
Free (voluntary) safety reporting	• Acknowledgement of the importance of free safety reporting. • Staff engagement in safety reporting. • Nature of the reports about safety issues/concerns. • Mechanism utilized for safety reporting. • Attention paid by HLM to the safety reports. • Incidents or events not hidden by the staff.[7]
Just culture for treating individual safety behaviours	• Acknowledgement of the importance of just treatment of individual safety behaviours. • Investigation of events, incidents and other safety issues.
Continued organizational safety learning	• Acknowledgement of the importance of continued organizational safety learning. • Scope of the continued organizational safety learning. • Effectiveness of the improvement resulting from the lessons learned from safety events. • Institutional transparency. • Treatment of (external) reports. • Acceptance of the social responsibility of potential radiological harms.

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7   This element, originally presented by the FORO as "Incidents or events hidden by staff", would indicate stronger safety culture if its frequency is lower (or null), which would mean that incidents are reported by staff. To avoid misunderstanding the text was adapted here to refer to incidents or events not hidden by staff.

Safety culture basic elements	Related radiation safety culture indicators
Trust and collaboration safety environment	• Collaboration between staff regarding radiation safety. • Trust environment between staff. • Positive relationships between management and staff. • Staff mobility. • Organizational policies to promote safety as a lifestyle.

HLM: high-level management.

A.5 SRP safety culture factors, adapted from IRPA (IRPA, 2014)

Culture factor	Performance indicator
Engagement of management	• Senior management understand their role and responsibility in relation to radiation safety. • There exists a clear management structure for radiation safety with link to Executive Board (or equivalent). • The radiation safety policy contains clear descriptions of management responsibilities and how these are audited. • Evidence of clear communication between staff on radiation safety issues.
Appropriate training	• Appropriate radiation safety training/qualifications are included in relevant job descriptions. • Induction training contains appropriate level of radiation safety training – including general awareness training for non-radiation workers. • Radiation workers and individuals recognized under the Ionising Radiation (Medical Exposure) Regulations (IR(ME)R) have documented update training at specified intervals. • Evidence that training complies with best practice guidelines if/when available from professional bodies.
Regular audit of radiation safety procedures	• Schedule of audits including internal compliance audits with local rules and (IR(ME)R). • Recent audit results of local rule compliance (IR(ME)R). • Independent schedule of radiation safety audits (e.g. as per Ionising Radiation Regulations 2017 (IRR17) or the Environmental Permitting (England and Wales) Regulations 2016 (EPR16), etc.).
Appropriate use of diagnostic imaging using ionizing radiation	• Documented use of appropriate referral guidelines • Evidence of culture where radiologists and radiographers can challenge inappropriate requests • Availability of non-ionizing imaging modalities
Appropriate management of radiation generating equipment and radioactive materials	• Documented management system in place. • Evidence of equipment replacement programme. • Evidence of service/maintenance contracts. • Evidence of quality assurance (both equipment and standard operating procedures). • Evidence of action on quality assurance results. • Evidence of audit of radioactive material policy and procedures. • Disposal records. • Compliance with permits.
Appropriate appointment and use of accredited experts and officers	• Policy level statement of their appointment and proper consultation with them. • Evidence of appointment of suitable numbers of qualified experts. • Evidence of action following reports from experts. • Evidence of appointment of Radiation Protection Committee. • Appointment of suitable number of Radiation Protection Supervisors.
Optimization of patient dose	• Formation of multidisciplinary "Dose Champion" teams • Local diagnostic reference levels in place. • Results of audit against diagnostic reference levels. • Documented result of optimization activity.

Culture factor	Performance indicator
Management of staff doses	• There exists a defined management system for personal dosimetry. • Number of incomplete dose records (i.e. lost/damaged dosimetry) is recorded and acted upon. • Evidence of routine checking of doses against investigation levels. • Typical and maximum doses for different staff roles. • Results of audit of use, checking and storage of PPE. • Audit of compliance with local rules.
Appropriate incident handling	• Documented procedures for handling radiation incidents. • Evidence of timely reporting and investigation of incidents. • Evidence of involvement of appropriate managers. • Actions plans for lessons learned and implementation of any new procedures. • Evidence of culture of "openness" in reporting.
Effective communication	• Radiation protection issues are on agenda of staff meetings. • Staff have access to managers to raise concerns. • Staff have access to union safety officers to raise concerns. • Staff have access to "mentors/guardians" to raise concerns. • Management and advisers regularly communicate radiation protection performance to relevant staff.

IR(ME)R: Ionising Radiation (Medical Exposure) Regulations.
PPE: personal protective equipment.

A.6 Links to online resources

Agency for Healthcare, Research & Quality (AHRQ)

https://www.ahrq.gov/patient-safety/index.html

Operational Safety Review Team (OSART)

https://www.iaea.org/services/review-missions/operational-safety-review-team-osart

Retrospective Evaluation of Lens Injuries and Dose study (RELID study)

https://www.iaea.org/resources/rpop/resources/relid-study

Safety in Radiation Oncology (SAFRON)

https://www.iaea.org/resources/rpop/resources/databases-and-learning-systems/safron