

## Chapter

# The Role of the Radiation Safety Officer in Patient Safety

*Thomas L. Morgan and Sandy Konerth*

## Abstract

The role of the Radiation Safety Officer (RSO) is to prevent unnecessary exposure to ionizing radiation and maintain necessary exposures as low as reasonably achievable (ALARA). The RSO is delegated broad authority throughout the organization by senior management. This authority includes permission to stop unsafe practices and identifying radiation protection problems, initiating, recommending, or providing corrective actions and verifying implementation of these actions. For the most part, these efforts are focused on maintaining radiation doses to employees and the public ALARA. Regulations do not address a role for the RSO in reducing radiation exposure to patients, except when unnecessary exposure is suspected due to equipment malfunction or human error. There is increasing concern about the risks of cancer and other effects from the use of medical imaging procedures. This chapter will discuss the tools and resources available to the RSO to educate members of the medical community and senior management on the need to manage radiation doses to patients so that the physician is able to obtain information necessary to properly diagnose and treat patients while avoiding unnecessary exposure.

**Keywords:** ALARA for patients, radiation safety, justification, optimization

## 1. Introduction

Patients are exposed to ionizing radiation from individual radiographic or nuclear medicine procedures and from multiple procedures. In 1987, the National Council on Radiation Protection and Measurements (NCRP) published a report that evaluated the radiation doses to the U.S. population from all sources of ionizing radiation [1]. Report No. 93 estimated the annual dose to an individual at 3.6 mSv. The amount caused by medical diagnostic x-rays and nuclear medicine procedures was estimated at 0.53 mSv or 14.7% of the total dose. Doses from computed tomography (CT) scans were not listed separately. In 2006, an updated report, No. 160, estimated the average annual dose at 6.2 mSv [2]. Doses from medical procedures increased 5.7-fold to 3.0 mSv or 48.4% of the total exposure. CT scans were responsible for 1.47 mSv or 24% of the total dose. This was based on an estimated 62 million CT procedures and a U.S. population of 300 million. Doses from ubiquitous natural sources remained largely unchanged – 3.0 mSv in Report No. 93 and 3.1 mSv in Report No. 160. In 2019, a follow-on report, No. 184, evaluated medical radiation exposure alone. For 2016, an estimated 74 million CT procedures (20% increase from 2006) in a population of 323 million resulted in an average dose that was essentially unchanged from 2006–1.4 to 1.5 mSv [3]. However, the report noted an overall decrease in the average medical exposure from 3.0 mSv in 2006 to 2.2 to

2.3 mSv, due largely to a 68% decrease in dose from nuclear medicine procedures, a 25% decrease from diagnostic radiography and fluoroscopy procedures and a 39% decrease from cardiac interventional fluoroscopy procedures. These reductions were due to a variety of factors, including increased patient, physician, and manufacturer awareness (CT scans), changes in the standards of practice resulting in fewer nuclear medicine procedures and changes in technology (replacement of film-screen units to digital receptors in radiography) and standards of practice (fluoroscopy).

Several studies have chronicled the utilization of radiographic and nuclear medicine procedures in detail. For example, a retrospective cohort study of 952,420 nonelderly patients enrolled in healthcare plans across five U.S. health care markets for three years (2005 through 2007) was conducted to evaluate the pattern and source of radiation exposure [4]. Analysis of utilization data found that 68.8% (655,613) underwent at least one imaging procedure during this time frame. A total of more than 3.44 million imaging procedures were associated with these enrollees. Nuclear medicine myocardial perfusion studies accounted for more than 22% of the total radiation dose to this population and CTs of the chest, abdomen, and pelvis accounted for almost 38%. CT scans and nuclear medicine procedures accounted for only 21% of the procedures but were responsible for 75.4% of the total dose to the population. Plain radiographs made up 71.4% of the procedures but accounted for only 10.6% of the total dose. More than 80% (81.8%) of the dose was delivered in an outpatient setting, most often in physicians' offices. As a second example, a study of patients admitted to a level 1 trauma facility found 10,504 radiographic studies were performed on 465 patients who suffered spinal injuries [5]. A total of 6,720 X-ray studies and 3,606 CT scans were performed which translates to an average of 14.5 X-ray studies and 7.75 CT scans per admitted patient.

Neither of these studies criticized the decisions to refer the patients for medical imaging studies. However, in the case of the utilization review study, the authors commented "that in some patients worrisome radiation doses from imaging procedures can accumulate over time underscores the need improve their use." In the second study, the authors expressed concern about cumulative radiation exposure. They urged colleagues to "be astutely aware of the implications of different imaging studies and weigh these against the benefits when ordering any study".

Elsewhere in the medical literature, there is increasing concern expressed about the potential risks of exposing patients to ionizing radiation from medical imaging procedures. In 1994, the United States Food and Drug Administration published an advisory notice to physicians and other health care professionals about serious x-ray-induced injuries to the skin from fluoroscopically guided radiographic procedures [6]. This advisory listed the types of procedures that often involve extended fluoroscopy time (e.g., 50 to 60 minutes or more) that could cause injury and discussed ways to minimize the risk of injury.

Computed tomography (CT) scanners became commercially available in 1972 and their use quickly took off. In 2000, attention was called to the potential increased lifetime risk of cancer mortality attributable to radiation from CT scan use in children [7]. More recently, in 2012 and 2013, two large retrospective cohort studies evaluated the risk of cancer from CT scans delivered in childhood and adolescence. The first study reviewed results from more than 175,000 patients scanned from 1985 to 2002 in Great Britain. For patients who received a cumulative dose of at least 30 mGy, the risk of leukemia was increased 3.18-fold; for brain cancer the risk was increased 2.82-fold for patients whose cumulative dose was 50 to 74 mGy [8]. The second study assessed the cancer risk in more than 680,000 patients, aged 0 to 19 years, who received a CT scan from 1985 to 2005 in Australia. The overall

cancer risk was 24% greater for exposed versus unexposed people, after accounting for age, sex, and date of birth [9].

## 2. Methodology

This chapter is intended as a literature review. Search parameters included: medical indications for imaging procedures, hazards and risks of radiation exposure, risk analysis, responsibilities of a Radiation Safety Officer (RSO), laws and regulations governing use of radiation, industry best practices for prescribing medical imaging procedures. The author used his more than 25 years of experience in radiation protection to guide this search.

## 3. Concepts

The following concepts and principles are presented in this chapter:

Concept	Principle	Responsibility
Identify high dose imaging procedures	Risk analysis	RSO, medical physicists
Reduce radiation exposure	Justify imaging procedure; optimize dose	Referring provider, medical physicists
Educate providers on best practices	Identify and provide resources	RSO
Change practices	Implement best practices	RSO, providers, management

## 4. The Radiation Safety Officer

The RSO is charged with the responsibility to monitor and/or estimate the radiation exposure of staff, visitors, and the public from the use of ionizing radiation sources within the facility. In the U.S., Federal and State regulations require that these doses be maintained below certain maximum limits. From a safety perspective, best practices suggest that the RSO should take action to achieve and maintain doses as low as reasonably achievable (ALARA). This concept has been adopted as a regulatory requirement. As defined by the U.S. Nuclear Regulatory Commission (NRC) in Title 10 Code of Federal Regulation Section 20.1003 [10], ALARA means

*“making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socio-economic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.”*

While NRC regulations focus only on the use of radioactive materials (“licensed materials” above), state agencies that regulate the use of x-ray-generating equipment have incorporated the NRC ALARA policy and dose limits into their own radiation protection regulations.

However, neither federal nor state regulations address or require ALARA principles be applied to patients undergoing medical imaging procedures. At best, these regulations require the equipment be inspected to ensure it is operating in compliance with regulations, manufacturers' recommendations and best industry practices. In addition, the RSO is required investigate unnecessary or excessive exposures to determine the root cause and provide corrective and preventative actions to reduce or eliminate the risk of similar event.

These practices, while appropriate, are reactive, not proactive. They do not mandate a process of risk management – i.e., identifying, monitoring, and managing potential risks in order to minimize the negative impact they may have on patients.

The usefulness of medical imaging procedures is not in dispute. Clearly, an accurate diagnosis that leads to appropriate treatment outweighs the low risks of cancer or injury. However, given the large number of procedures carried out each year, a patient advocate is needed. This advocate will educate medical providers and management about the risks of excessive radiation exposure, identify areas or procedures within the organization where the potential for high doses to patients exists, and provide oversight of a process to apply ALARA principles medical imaging.

It can be argued that while the RSO is one of many individuals in a healthcare organization who have roles to play in the responsible use of these modalities, the RSO has a unique mission—that of leading the healthcare team in maintaining radiation doses ALARA. This allows for a different perspective than the provider who orders the imaging studies, the radiologic technologist who performs the studies, or the medical physicist who ensures the equipment is performing properly.

The RSO has broad responsibility for ensuring the organization achieves and maintains compliance with applicable laws, regulations and standards. This requires in-depth knowledge of equipment, personnel, facilities and operating procedures. It also requires the RSO to develop and maintain collaborative relationships with senior medical and non-medical managers as well as line managers and where feasible, the individuals who are responsible for operating the imaging equipment. Thus, the RSO is in a position bring together important stakeholders to focus efforts on reducing patient radiation doses. This puts the RSO in a unique position to become the patient advocate or to be part of the patient advocate team.

## **5. ALARA concepts**

The principles of ALARA introduced above are based on three fundamental concepts: justification, optimization, and dose limits [11]. Justification means doing more good than harm. The benefit to the exposed individual exceeds the detriment the radiation dose causes. If the procedure is justified, it should be optimized and performed to maximize the good over the harm. Finally, the use of dose limits implies an adequate standard of protection, even for the most highly exposed individual. These three concepts will be discussed in Sections 7.1 and 7.2 below.

## **6. Risk analysis**

Risk analysis is a prospective, structured method for assessing the likelihood of an adverse event occurring. This is followed by the design of a new procedure or modification of an existing procedure to reduce the likelihood [12]. Briefly, the process involves identifying the hazards (i.e., what could go wrong) and estimating the risk of the hazard occurring. This process requires a deep dive into policies, procedures, and equipment performance at the institution.

For the purposes of this discussion, the major hazard to be evaluated is radiation dose to patients during medical imaging procedures.

The RSO should be aware of those areas within the institution where there is potential for high radiation exposures. The hazards and risks will change and scale as the size and complexity of the institution increases. Taking a risk-informed approach, the RSO can survey the various medical imaging departments or areas to become informed about the type and number of procedures routinely performed. This will allow the RSO to focus efforts on the highest risk areas first.

Radiation dose is governed by several factors. First, the radiation output of an X-ray tube is determined by beam energy (applied voltage) (kVp), applied current (mA) and beam on time. The output is typically preset by computer, based on patient size, weight and scan length in case of plain radiographs and CT scans. With fluoroscopy, the output is determined automatically by a computer, based on the ability of the X rays to penetrate the patient. In these cases, the RSO's efforts can be focused on directing providers to educational resources that identify appropriate procedure(s) for a given medical condition and training fluoroscopy users on how to properly operate the fluoroscopy unit to achieve a good quality image at an appropriate dose.

Some patients have complex medical conditions that require fluoroscopy for both diagnosis and treatment. In these cases, a fluoroscopically guided interventional (FGI) procedure is indicated. These procedures have the potential to deliver high doses to localized areas of the skin. However, due to the diverse nature of these procedures, variation in patient size and anatomy, and other confounding factors, it is not possible set a standard technique or beam-on time. Reductions in patient doses can be achieved through specialized operator training and machine settings as described in Section 7.2.2.3 below.

Second, for nuclear medicine and nuclear cardiology procedures, radiation dose is a function of the type and amount of the radiopharmaceutical administered to the patient. The amounts are usually standardized for each radiopharmaceutical and procedure, although some may vary based on the patient's weight. There are four major hazards: administration (i) to the wrong patient; (ii) of the wrong radiopharmaceutical; (iii) in the wrong amount; or (iv) by the wrong route.

## **7. Policies and procedures for the RSO**

Once the RSO has cataloged the institution's hazards, the next step is to prioritize dose reduction efforts. For example, an outpatient clinic or urgent care center may have only one or a few X-ray machines and perform studies limited to plain films of the head and neck, torso and extremities. In this case, the RSO's focus would be on ensuring the equipment is functioning properly, personnel are properly licensed and trained, standard imaging protocols are used, and patient identification procedures are in place to prevent unnecessary exposures (i.e., wrong patient or wrong site imaged).

In a hospital setting, the imaging needs, equipment, and modalities offered can range from a small facility with only X-ray imaging equipment, including CT scanners to a large regional medical or teaching hospital center that provides the full spectrum of imaging modalities from X-ray machines, portable fluoroscopy units, nuclear medicine and nuclear cardiology cameras, and complex fixed fluoroscopy units in the interventional radiology and cardiology areas.

In the small hospital, the RSO's efforts would be similar to the outpatient clinic example above, with the additional need to monitor CT protocols (see below). In a large hospital setting, the risk of high doses increases substantially because of



the number and complexity of the cases. In this case, the RSO risk analysis efforts should be focusing on evaluating the patient workload, number and general types of procedures performed, and the state of training, certification and credentialing of the personnel involved in the imaging procedures. In general, the highest radiation doses occur in the following departments/areas [4]: nuclear cardiology, radiology, interventional cardiology, nuclear medicine, positron emission tomography (PET)/CT scans.

Patient dose reduction efforts begin with developing and implementing policies and procedures based on the three basic principles of ALARA described in Section 5 above.

## **7.1 Justifying imaging procedures**

### *7.1.1 Appropriateness criteria*

In the United States, the Protecting Access to Medicare Act (PARMA) of 2014 established a new program to increase the rate of appropriate advanced diagnostic imaging services provided to Medicare beneficiaries [13]. Examples of such advanced imaging services include CT, PET, nuclear medicine, and magnetic resonance imaging (MRI).

Under this program, at the time a provider orders an advanced diagnostic imaging service for a Medicare beneficiary, he/she, or clinical staff acting under his/her direction, will be required to consult a qualified Clinical Decision Support Mechanism (CDSM). CDSMs are electronic portals through which appropriate use criteria (AUC) can be accessed. This program is set to be fully implemented on January 1, 2022.

The American College of Radiology (ACR), the Society of Nuclear Medicine and Molecular Imaging (SNMMI), and the American Society of Nuclear Cardiology (ASNC) have published evidence-based guidelines to assist providers in making appropriate imaging or treatment decisions for specific clinical conditions [14–16].

Consulting and applying the AUC will help reduce the number of inappropriate and duplicative medical imaging studies ordered, thus reducing radiation dose to patients and staff if fluoroscopy is used. The role of the RSO in this process would be to educate providers about this resource and the upcoming requirement and where appropriate, assist in its implementation.

### *7.1.2 Credentialing of providers who use fluoroscopy*

According to the Joint Commission, licensed practitioners who provide care and services without direction or supervision within the scope of their license must undergo a process of called credentialing by the organization where they provide care. This helps protect patients from unethical or untrained practitioners by recognizing the competency of a professional. This is a process of obtaining, verifying and assessing the qualifications of a practitioner to provide specific care or services within the organization. This process involves examination of the applicant's education, training, licensure, experience and other appropriate qualifications. Once these have been evaluated, the practitioner may be granted privileges to perform a specific scope and content of patient care services by the organization. A "privilege" is defined as an advantage, right or benefit not available to everyone; the rights and advantages enjoyed by a relatively small group of people, usually as a result of education, training and/or experience [17].

The Accreditation Council for Graduate Medical Education (ACGME) sets and monitors the professional education standards essential in preparing physicians to

deliver safe, high-quality medical care in the U.S. [18]. To demonstrate competency in a specific discipline, a practitioner must complete an ACGME-accredited training program and pass an examination in the discipline administered by an independent medical specialty board (e.g., American Board of Radiology, American Board of Surgery, etc.).

Not all graduate medical training programs provide training in the safe use of fluoroscopy. Thus, a practitioner may have used fluoroscopy during his/her residency training and may be technically proficient in its use but have little or no knowledge of how X rays are produced and the hazards they present to the patient, the operator, and other personnel in the room. This can result in the overuse of radiation during a procedure, resulting in unnecessary exposure to both the patient and the practitioner.

A solution is to require training and credentialing of practitioners for the use of fluoroscopy. The FDA advisory discussed above included the following recommendations for operators [6]

- Be trained and understand system operation, including implications for radiation exposure from each mode of operation;
- Be educated so that, on case-by-case basis, assess the risks and benefits for individual patients;
- Counsel patients on symptoms and risks of large radiation exposures and address risks from radiation in the consent form; and
- Be able to justify and limit the use of high dose rate modes of operation.

Some regulatory agencies have mandated training for operators. The State of California Department of Public Health requires practitioners who use or supervise the use of fluoroscopy to obtain a separate license as a Fluoroscopy Supervisor and Operator [19]. Continuing education is required to maintain this license. The City of New York Department of Health regulations require training of all persons operating, or supervising the operation of, fluoroscopy systems (see below) [20].

AAPM Task Group Report No. 124 provides guidelines for establishing a credentialing and privileging program for users of fluoroscopy [21]. This effort will require close coordination with and approval of the organization's Chief Medical Officer (CMO) and the office that oversees the process. The RSO can collaborate with this office to evaluate the provider's credentials and advise the credentialing office on the appropriateness of the request, arrange for training, issue radiation monitoring devices, and ensure appropriate personal protective equipment (i.e., lead or lead equivalent protective aprons and eye wear) is available for the individual.

## **7.2 Optimizing equipment and processes**

### *7.2.1 Role of the Radiation Safety Officer*

As the chief radiological compliance officer of the institution, the RSO oversees the quality assurance program for medical imaging equipment. As such, when regulators inspect the facility the RSO will be held to account for any findings or violations. Therefore, while not directly responsible for performance evaluations, the RSO should audit the program to ensure that they were performed on time and in compliance with regulations, standards, and best practices. The RSO should have

the authority to remove from service any equipment that is a radiological safety hazard to patients, staff, or the public. This will ensure the equipment is functioning as designed and will not overexpose patients or staff.

The RSO is also responsible for overseeing the training in radiation safety that is mandated by many regulatory agencies. Training should include

- Awareness of the magnitude of the radiation dose delivered by imaging equipment
- Location of scattered radiation around the patient and in the imaging suite;
- Features of imaging equipment, particularly fluoroscopy units, whose use may reduce patient exposure
- Requirements for monitoring radiation dose to staff and use of personal protective equipment when appropriate
- Policies and procedures relevant to equipment selection and use.

However, this is the minimum expected of the RSO. As an advocate for patient safety, the RSO should proactively seek out ways to optimize processes to reduce patient dose.

### *7.2.2 Management of patient doses*

#### *7.2.2.1 Benchmarking radiation doses*

It is well known that there is substantial variation in radiation dose between procedures within an institution and for the same procedure between healthcare facilities [22]. Efforts to apply ALARA principles to medical imaging and interventional procedures need to appreciate that patient size, region to be imaged and the clinical indications for the study will affect the radiographic technique(s) and hence, patient dose. Collecting information about radiation doses from potentially high dose procedures will assist the RSO to determine where to prioritize dose reduction efforts. Comparing these results to published data (i.e., benchmarking) will help the RSO to identify best practices and help uncover gaps in knowledge or processes in the institution that can be addressed. These published data are known as diagnostic reference levels (DRLs). For example, in 1999 the European Commission published a guide to member states on the establishment of DRLs [23]. Once established, these levels are “...not to be exceeded for standard procedures when good and normal practice regarding diagnostic and technical performance is applied.” This publication also includes example DRLs collected from multiple institutions in 10 member countries.

In the United States, the ACR offers accreditation for a variety of imaging modalities, include CT and mammography. Accreditation ensures the facility is providing the highest level of image quality and safety. For example, as part of the CT accreditation application process, the facility must provide examples of CT protocols for specific procedures with measured and calculated radiation doses [24]. These doses can be used by the facility to benchmark its CT scanners against similar scanners at other sites.

Once DRLs have been established, the RSO can work collaboratively to implement routine collection and reporting of patient doses. This data can be used to develop and implement standard protocols for typical imaging procedures. These



protocols should be reviewed routinely to ensure that the institution is taking advantage of the most recently published best practices. If a DRL is consistently exceeded, an investigation should be initiated, and appropriate action taken.

#### *7.2.2.2 Regulatory changes*

Changes in regulations may mandate closer supervision of patient radiation doses. For example, the City of New York Department Health and Mental Hygiene completely repealed and re-enacted the radiation control regulations (Article 175 of the New York City Health Code [20]). The changes are numerous and of a broad scope and will significantly increase the administrative and safety oversight burden on the imaging facility. Although many of these changes are focused on occupational exposure to ionizing radiation, several – including requirements for initial and ongoing training of fluoroscopy users – are focused on patient safety.

These regulations do not apply to facilities outside of New York City, but they provide a road map for future regulations in other state jurisdictions. They also provide a list of suggestions for the RSO to consider for the patient radiation dose reduction efforts.

#### *7.2.2.3 Optimization of patient dose*

A limited review of the literature suggests that there are steps that can be taken to reduce patient dose, over and above simply ensuring that imaging equipment functions as designed and is operated within standards and regulations.

In a study of radiation dose reduction measures in a busy invasive cardiovascular laboratory [25], investigators achieved a 40% reduction in the mean cumulative skin dose to patients over a three-year period by

- Educating staff about properly adjusting imaging equipment and minimizing duration of beam activation
- Verbally announcing air-kerma values at specific levels with the expectation that further strategies for dose management would be implemented
- Adding air-kerma values to the final report of each procedure
- Investigating relationship between image quality and radiation dose and implementing strategies to maintain acceptable image quality while keeping patient dose to the minimum necessary to achieve the goals of the imaging procedure
- Increased use of copper x-ray beam spectral filters
- Reducing the fluoroscopy frame rate from 15 frames/s to 7.5 frames/s
- Recording and maintain on file radiation dose records by procedure and provider

The U.S. Veterans Administration National Center for Patient Safety (NCPS) (Ann Arbor, MI) funded a study to apply the principles of Healthcare Failure Mode and Effect Analysis (HFMEA), developed by NCPS, to identify systematic gaps associated with potentially high-radiation dose fluoroscopic procedures, to assess the relative importance of different interventions to reduce dose, and to identify areas to improve patient safety [26]. As an example high-radiation dose

intervention, they chose to evaluate a pacemaker or implantable cardioverter defibrillator lead extraction procedure. A total of 29 actions were devised of which 5 were determined to be of the highest priority for implementation to reduce patient dose

- Develop a checklist that includes assessment and documentation of clinical risk factors for radiation injury to patients
- Incorporate review of these risk factors into procedural time-outs
- Assign a staff member to verbally notify the operator at medically appropriate times when dose thresholds have been reached. The operator must verbally acknowledge each notification.
- Monitor the skin radiation dose or, if the peak skin dose is not displayed, the reference point air kerma (in milligrays)
- For each type of procedure typically performed, develop an imaging protocol that specifies the machine settings (technique factors); require physicists periodically perform a protocol review, with collection of data, such as radiation outputs for fluoroscopy and image recording.

These are but two examples of efforts by institutions to conduct a detailed analysis of their processes, procedures and equipment function to understand where, why, and how high radiation doses occur and what measures can be implemented to effect reductions. The RSO can bring these and other studies to the attention of both physicians and managers of the interventional cardiology department in their institution.

### **7.3 Resources for the RSO**

There are several resources available to the RSO on the internet. They can be used to educate providers, managers, and medical physicists and focus attention on the need to manage radiation dose to patients. These resources provide guidance and suggestions for implementing change.

#### *7.3.1 Image Gently® campaign*

Formed in 2006, Image Gently® is a physician-led initiative begun as a committee within the Society for Pediatric Radiology (SPR). Today, more than 50 medical, dental, and allied professional societies from across the globe have joined as alliance organizations [27]. Like the Image Wisely® campaign discussed below, the goal of this initiative is to change practice by raising awareness of opportunities to reduce radiation dose with a focus on imaging of children. Implementation includes providing information and free educational materials.

#### *7.3.2 Image Wisely® campaign*

Image Wisely® is a joint initiative of the American College of Radiology (ACR), Radiological Society of North America (RSNA), American Society of Radiologic Technologists (ASRT) and American Association of Physicists in Medicine (AAPM). Formed to address concerns about the surge of public exposure to ionizing radiation from medical imaging, its objective is to lower the amount of

radiation used in medically necessary imaging studies and eliminating unnecessary procedures [28]. The campaign is focused on adult patients. It provides radiation safety information by imaging modality for patients and providers. A free series of online and mobile-compatible education modules are available that include case-based questions that allow the viewer to improve, and then assess, understanding of important safety concepts in medical imaging.

Imaging professionals, referring providers, image facilities, and associations and educational programs are encouraged to sign a pledge to educate themselves on radiation doses from imaging procedures, consulting with professionals prior to ordering studies, optimize dose to ensure only necessary amounts are used to produce images tailored to patient size and the diagnostic task, prevent duplication of exams, and to actively promote these goals among colleagues, staff, members and students.

### *7.3.3 Bonn Call for Action*

In 2012, the IAEA issued the Call for Action at an international conference on radiation protection in medicine in Bonn, Germany [29]. The goal of the conference was to

- Indicate gaps in current approaches to radiation protection in medicine;
- Identify tools for improving radiation protection in medicine;
- Review advances, challenges, and opportunities in this field; and
- Assess the impact of the Call for Action in order to prepare new recommendations.

The Bonn Call for Action Implementation Toolkit is an online platform offering resources for improving radiation protection in medicine that was created as a result of a follow-on conference in 2017. It includes educational resources for referring physicians, radiology and nuclear medicine providers and other professionals, medical physicists, manufacturers, and regulators [30].

## **Author details**

Thomas L. Morgan\* and Sandy Konerth  
Versant Medical Physics and Radiation Safety, Kalamazoo, MI, USA

\*Address all correspondence to: [morgantl@aol.com](mailto:morgantl@aol.com)

## **IntechOpen**

---

© 2021 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

## References

- [1] National Council on Radiation Protection and Measurements (NCRP). Ionizing radiation exposure of the population of the United States. NCRP Report 93, Bethesda, MD, 1987.
- [2] National Council on Radiation Protection and Measurements (NCRP). Ionizing radiation exposure of the population of the United States. NCRP Report 160, Bethesda, MD, 2009.
- [3] National Council on Radiation Protection and Measurements (NCRP). Medical radiation exposure of patients in the United States. NCRP Report 184, Bethesda, MD, 2019.
- [4] Fazel R, Krumholtz KM, Wang Y, Ross JS, Chen J, Ting HH, Shah ND, Nasir K, Einstein AJ, Nallamothu BK. Exposure to low-dose ionizing radiation from medical imaging procedures. *New Eng J Med* 2009;361:849-857. DOI: 10.1056/NEJMoa0901249.
- [5] Martin E, Prasarn M, Coyne E, Giordano B, Morgan T, Westessen P-L, Wright J, Rehtine II G. Inpatient radiation exposure in patients with spinal trauma. *J Spin Cord Med* 2013;36:112-117. DOI: 10.1179/2045772312Y.0000000054.
- [6] Food and Drug Administration. Important information for physicians and other health care professionals. Avoidance of serious x-ray-induced skin injuries to patients during fluoroscopically-guided procedures. September 9, 1994 [Internet]. Available from: <https://www.fda.gov/downloads/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/MedicalImaging/MedicalX-Rays/ucm116677.pdf>. [Accessed: 2021-02-24]
- [7] Brenner DJ, Elliston CD, Hall, EJ, Berdon WE. Estimated risk of radiation-induced fatal cancer from pediatric CT. *Amer J Radiol* 2001;176:289-296. DOI:10.2214/ajr.176.2.1760289.
- [8] Pearce MS, Salotti JA, Little MP, McHugh K, Lee C, Kim PK, Howe NL, Ronckers CM, Rajaraman P, Craft AW, Parker L, Berrington de Gonzalez A. Radiation exposure from CT scans in childhood and subsequent risk of leukemia and brain tumors: a retrospective cohort study. *Lancet* 2012;380:499-505. DOI:10.1016/S0140-6736(12)60815-0.
- [9] Mathews JD, Forsythe AV, Brady Z, Butler MW, Goergen SK, Byrnes GB, Giles GG, Wallace AB, Anderson PR, Guiver TA, McGale P, Cain TM, Dowty JG, Bickerstaffe AC, Darby SC. Cancer risk in 680,000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians. *Brit Med J* 2013;346:f2360. DOI: 10.1136/bmj.f2360.
- [10] United States Nuclear Regulatory Commission regulation 10 CFR 20.1003. Definitions [Internet]. Available from: <https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1003.html> [Accessed: 2021-02-24]
- [11] International Council on Radiation Protection (ICRP). Radiological protection and safety in Medicine. ICRP Publication 73. *Ann ICRP* 1996;26(2). Elsevier Science Inc., Tarrytown, NY.
- [12] American Association of Physicists in Medicine (AAPM). The report of Task Group 100 of the AAPM: Application of risk analysis methods to radiation therapy quality management [Internet]. Available from: <https://aapm.onlinelibrary.wiley.com/doi/full/10.1118/1.4947547> [Accessed: 2020-12-26]

- [13] Centers for Medicare & Medicaid Services. Appropriate use criteria program [Internet]. Available from: <https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/Appropriate-Use-Criteria-Program> [Accessed: 2021-02-24]
- [14] American College of Radiology. ACR Appropriateness Criteria [Internet]. Available from: <https://www.acr.org/Clinical-Resources/ACR-Appropriateness-Criteria> [Accessed: 2021-02-24]
- [15] American Society of Nuclear Cardiology. Appropriate use criteria [Internet]. Available from: <https://www.asnc.org/guidelinesandstandards> [Accessed: 2021-02-24]
- [16] Society of Nuclear Medicine and Molecular Imaging. Appropriate use criteria [Internet]. Available from: <https://www.snm-imsi.org/ClinicalPractice/content.aspx?ItemNumber=15666&navItemNumber=10791> [Accessed: 2021-02-24]
- [17] Ambulatory Care Program: The who, what, when, and where's of credentialing and privileging [Internet]. Available from: [https://www.jointcommission.org/-/media/depated-unorganized/imported-assets/tjc/system-folders/blogs/ahc\\_who\\_what\\_when\\_and\\_where\\_credentiaing\\_bookletpdf.pdf?db=web&hash=CD838EB80D69FE2FA517285B4F3A0537](https://www.jointcommission.org/-/media/depated-unorganized/imported-assets/tjc/system-folders/blogs/ahc_who_what_when_and_where_credentiaing_bookletpdf.pdf?db=web&hash=CD838EB80D69FE2FA517285B4F3A0537) [Accessed: 2021-02-24]
- [18] Accreditation Council for Graduate Medical Education. About Us [Internet]. Available from: <https://www.acgme.org/About-Us/Overview> [Accessed: 2021-02-24]
- [19] Title 17 California Code of Regulations Section 30464. Requirements for radiography permits [Internet]. Available from: [https://govt.westlaw.com/calregs/Document/I8C393B90391E11E3A497C9CEC9EBAB68?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=\(sc.Default\)](https://govt.westlaw.com/calregs/Document/I8C393B90391E11E3A497C9CEC9EBAB68?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)) [Accessed: 2021-02-24]
- [20] New York City Health Code Section 175.53. Fluoroscopic equipment [Internet]. Available from: <https://www1.nyc.gov/assets/doh/downloads/pdf/about/healthcode/health-code-article175.pdf> [Accessed: 2021-02-24]
- [21] American Association of Physicists in Medicine. A guide for establishing a credentialing and privileging program for users of fluoroscopic equipment in healthcare organizations [Internet]. Available from: [https://www.aapm.org/pubs/reports/RPT\\_124.pdf](https://www.aapm.org/pubs/reports/RPT_124.pdf) [Accessed: 2021-02-24]
- [22] International Atomic Energy Agency. Radiation Protection of Patients: Justification and optimization [Internet]. Available from: <https://www.iaea.org/resources/rpop/resources/international-safety-standards/justification-and-optimization#4> [Accessed: 2021-02-24]
- [23] European Commission. Radiation Protection 109: Guidance on diagnostic reference levels (DRLs) for medical exposures [Internet]. Available from: [https://ec.europa.eu/energy/sites/ener/files/documents/109\\_en.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/109_en.pdf) [Accessed 2021-02-24]
- [24] American College of Radiology. Accreditation information for CT [Internet]. Available from: <https://www.acr.org/Modalities/CT> [Accessed: 2021-02-24]
- [25] Fetterly KA, Matthew V, Lennon R, Bell MR, Holmes Jr DR, Rihal CS. Radiation dose reduction in the invasive cardiovascular laboratory: Implementing a culture and philosophy of radiation Safety. *JACC: Cardiovas Interv* 2012;5:866-873. DOI: 10.1016/j.jcin.2012.05.0



[26] Justinvil GN, Leidholdt Jr EM, Balter S, Graves, LL, Loring BA, Brenner AC, Boyle NG, Srinivasa RN, Moran JM. Preventing harm from fluoroscopically guided interventional procedures with a risk-based analysis approach. *J Am Coll Radiol* 2019;16:1144-1152. DOI: 10.1016/j.jacr.2019.02.047

[27] Image Gently [Internet]. Available from: <https://www.imagegently.org/> [Accessed: 2021-02-24]

[28] Image Wisely [Internet]. Available from: <https://www.imagewisely.org/> [Accessed: 2021-02-24]

[29] Bonn Call for Action [Internet]. Available from: <https://www.iaea.org/resources/rpop/resources/bonn-call-for-action-platform> [Accessed: 2021-02-24]

[30] Bonn Call for Action implementation toolkit [Internet]. Available from: <https://gnssn.iaea.org/main/bonn-toolkit/SitePages/Home.aspx> [Accessed: 2021-02-24]