

Compendium of Resources for Radiation Safety in Medical Imaging Using Ionizing Radiation

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Purpose: Diagnostic imaging, including ionizing radiation modalities, maintains a prominent role in the medical evaluation of patients. There is increasing awareness and need for information across varied sectors about low-level radiation and potential risks. Many medical and scientific organizations have resources discussing radiation risk and management. However, there is no single resource compiling this information.

Methods: Websites, including those of national and international medical organizations, were reviewed for information on radiation dose, risk, justification, optimization, guidelines (including general information about improvement in quality and dose reduction without specific mention of optimization techniques), appropriateness criteria, and general principles of radiation safety for CT, fluoroscopy or angiography, and radiography. This information was organized into 8 tables, categorized by modality, and separated for adult and pediatric populations. Websites with training modules were noted as well.

Results: Twenty-nine websites were explored. Overall, less information is available about medical radiation safety in children compared with adults. Across both groups, most information is available on CT, then fluoroscopy, and finally radiography. Across all groups and modalities, there is no information available for patients or parents on optimization, appropriateness, or guidelines, with the exception of adult radiography, for which there are some guidelines.

Conclusions: This compendium serves as a collective resource for communities including the public and regulatory organizations. Additionally, the compendium can be used to determine redundant or deficient areas, providing opportunities for more comprehensive resources and efficient efforts in accessing medical radiation patient safety information.

Key Words: Compendium, radiation safety, diagnostic medical imaging

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INTRODUCTION

Diagnostic imaging plays a major role in the diagnosis and management of many adult and pediatric medical conditions. However, ionizing radiation from diagnostic imaging is associated with potential risks [1-6]. Continued concerns regarding potential risks have created a need for broad awareness of issues surrounding radiation safety, such as education for physicians, training, and protocols for equipment [7]. Many major medical and scientific organizations currently have information regarding radiation dose and risk, justification for use, appropriateness criteria, optimization techniques, and other guidelines. Despite the presence

of this information, to the best of our knowledge, there is no single resource compiling the available information regarding radiation safety for diagnostic medical imaging. There is a need for a unified resource to provide patients, health care providers, radiologists, and technologists with a collection of the currently available resources in order to identify potential redundancies as well as deficiencies, enabling expeditious access to available information as a resource for various purposes, such as for educational materials or a medical radiation safety program. Therefore, the purpose of this investigation was to develop a compendium as a single resource for what is currently available for radiation safety in diagnostic medical imaging.

METHODS

Inclusion Criteria

To be included in this compendium, documents had to be available through the websites of the following selected medical organizations or organized campaigns we

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felt were major medical resources, and in keeping with prior compendiums [8,9]: the RSNA [10], the ACR [11], Image Wisely[®] (a program of the ACR, the RSNA, and the American Association of Physicists in Medicine, and the American Society of Radiologic Technologists) [12], Image Gently[®] (the Alliance for Radiation Safety in Pediatric Imaging) [13], the Society of Pediatric Radiology [14], the American Academy of Pediatrics [15], the American College of Emergency Physicians [16], the American College of Surgeons [17], the American Congress of Obstetricians and Gynecologists [18], the American College of Physicians [19], the AMA [20], the American Association of Physicists in Medicine [21], The Joint Commission [22], Joint Commission Resources [23], the Health Physics Society [24], and the American Academy of Family Physicians [25]. We also included RadiologyInfo.org, a website developed jointly by the RSNA and the ACR [26]. The websites of federal government agencies, such as the National Cancer Institute [27], the National Council on Radiation Protection and Measurements [28], the FDA [29], the National Guideline Clearinghouse [30], the Agency for Healthcare Research and Quality [31], the National Institutes of Health [32], the Centers for Disease Control and Prevention [33], and the National Quality Forum [34], were also included. Lastly, the websites of the following international organizations that include membership from the United States were also included: the International Commission on Radiological Protection [35], the International Atomic Energy Agency [36], the World Health Organization [37], the International Society of Radiology [38], and the International Radiation Protection Agency [39].

Our search included all web pages and documents available directly on the websites of each organization, without need to access specific journals, and excluded information from conferences and symposiums. If the website of an organization provided a link to a particular article or document from the website of another organization, the information was included for both the original website and the website making a reference to it. For example, information found on RadiologyInfo.org was included for both the RSNA and the ACR.

Information searched for was primarily related to radiation safety in diagnostic medical imaging of patients. Information about radiation dosing was included under the heading “radiation dose” only if specific doses were mentioned, such as a particular modality delivering a certain amount of radiation dose or dose estimate. Information about risk factors was included if any risks from radiation were mentioned, at a cellular or tissue level or related to cancer risk in general. Management and radiation reduction concerns were divided into justification, optimization, appropriateness, and guidelines. Justification included any information related to rationale for performing diagnostic imaging or any statements deter-

ring the use of excessive imaging. Optimization information included specific techniques for improving quality and dose reduction. Information was included under appropriateness only if appropriateness criteria were explicitly provided, to separate it from justification. Guidelines arbitrarily included information about improving quality and dose reduction (without specific techniques) and about improving patient safety. An additional category, called principles of radiation safety and regulation, included any information related to radiation safety in general (ie, information that did not fit into the other categories) or to the regulation of radiation use, such as information for patients regarding the importance of discussing their imaging histories with physicians.

The audience for all articles and documents was also determined. To the best of our ability, the audience was divided into 4 groups: the public (including patients, parents, and the general public); nonimaging health care professionals; imaging health care professionals, consisting of radiologists, radiology technicians, and medical physicists; and the “general” audience, or when the audience was unclear. These divisions were determined by a target audience as stated on the website or by our judgment of the group to which the content of the information best related.

All information found was classified into tables by modality, consisting of CT, fluoroscopy, and radiography. We elected not to include nuclear imaging in this compendium. If information regarded radiation safety in general without reference to a specific modality, it was included in a separate table titled “unspecified modality.” Information was also divided into separate tables for adult and pediatric patient populations. This distinction was based on the nomenclature in the resource; no age was used for inclusion or exclusion. All information was considered to be for adults unless specifically listed for children.

A table was included that contained any training modules or protocols for the imaging community. These were not assessed for quality but simply noted as potentially informative sites. We noted if the information was directed to a particular group, such as radiologists, technologists, physicists, or nonimaging health care providers. If it was unclear which specific audience was targeted within the imaging community, we considered it to be for the imaging community in general.

Search Methods

The websites of the major medical organizations and national and international organizations were searched. Initially, all sites were searched by following links from the home page. When an appropriate indicator was not found simply by navigating the site, the search engines on the sites were used. The websites of the Agency for Healthcare Research and Quality, the National Institutes of Health, the American Academy of Pediatrics, the American College of Surgeons, the American Academy

of Family Physicians, the American Congress of Obstetricians and Gynecologists, and the American College of Physicians were further searched in this way. The terms *imaging*, *diagnostic imaging*, *radiology*, *radiation safety*, and *radiation dose* were searched for at these sites via the search box located on the home page.

Further, some organizations were contacted if the previous two search methods did not yield significant information. These included the National Cancer Institute, the National Guideline Clearinghouse, the Centers for Disease Control and Prevention, the National Quality Forum, The Joint Commission, and the Joint Commission Resources. The National Cancer Institute was interrogated using an online chat feature, with subsequent review of the links that were provided. The National Guideline Clearinghouse was contacted by leaving a comment in the "comment box," and a representative responded via e-mail with helpful links. The Centers for Disease Control and Prevention was contacted by telephone, and a representative searched the website as well but agreed that not much information pertinent to radiation safety could be found. The National Quality Forum was contacted via telephone. The Joint Commission and Joint Commission Resources were contacted by leaving a voice mail, and a representative responded via e-mail with information.

RESULTS

A total of 29 websites were searched. These included 8 federal organizations, 5 international organizations, and 16 other medical organizations, which are listed in Table 1. With this information, 8 additional tables were created. There are 4 tables for each modality for adults (Tables 2 and 3 for CT and fluoroscopy, respectively, and Tables 4 and 5 [available online at <http://dx.doi.org/10.1016/j.jacr.2012.10.005>] for x-ray and unspecified modality, respectively) and 4 corresponding tables for pediatric patients (Tables 6 and 7 for CT and fluoroscopy, respectively, and Tables 8 and 9 [available online at <http://dx.doi.org/10.1016/j.jacr.2012.10.005>] for x-ray and unspecified modality, respectively). Each table is organized to show which websites have information about dose, risk, justification, optimization, appropriateness, guidelines, accreditation or certification, and principles of radiation safety and regulation. Each table also notes whether this information is indicated for the public (including patients, parents, and the general public), for health care providers, for the imaging community (including radiologists and technologists), or for an unspecified audience.

An additional table was created that includes information on training modules and protocols available on the respective websites and for whom within the imaging community (radiologists, technologists, physicists, or the imaging community in general) the information is intended (Table 10).

Table 1. Organizations included in the compendium

Medical Organizations	
RSNA	
ACR	
Image Wisely (program of the ACR, the RSNA, the American Association of Physicists in Medicine, and the American Society of Radiologic Technologists) (IW)	
Image Gently (Alliance for Radiation Safety in Pediatric Imaging) (IG)	
Society of Pediatric Radiology (SPR)	
American Academy of Pediatrics (AAP)	
American College of Emergency Physicians (ACEP)	
American College of Surgeons (ACS)	
American Congress of Obstetricians and Gynecologists (ACOG)	
American College of Physicians (ACP)	
AMA	
American Association of Physicists in Medicine (AAPM)	
The Joint Commission (TJC)	
Joint Commission Resources (JCR)	
Health Physics Society (HPS)	
American Academy of Family Physicians (AAFP)	
National Organizations	
National Cancer Institute (NCI)	
National Council on Radiation Protection and Measurements (NCRP)	
FDA	
National Guideline Clearinghouse (NGC)	
Agency for Healthcare Research and Quality (AHRQ)	
National Institutes of Health (NIH)	
Centers for Disease Control and Prevention (CDC)	
National Quality Forum (NQF)	
International Organizations	
International Commission on Radiological Protection (ICRP)	
International Atomic Energy Agency (IAEA)	
World Health Organization (WHO)	
International Society of Radiology (ISR)	
International Radiation Protection Agency (IRPA)	

DISCUSSION

As a collective resource, this compendium can be used by physicians and other health care providers or those in need of information on medical radiation for several objectives, including providing information to patients and their families and for serving as background for scientific publications and diagnostic imaging programs. Additionally, it can be used by regulatory and legislative organizations to increase awareness of medical radiation safety. One central objective is to determine redundant or deficient areas, so that recommendations can be made for appropriate channeling of resources. For example, we found that, overall, more information is available regarding medical radiation safety in adults compared with children. Within both groups, the highest volume of information found pertains to CT, followed by fluoroscopy, and then radiography. Across both the adult and pediatric populations, no information for patients and families was found regarding optimization, appropriateness, and guidelines, with the exception of adult radiog-

Table 2. Adult: CT

Parameters								
Audience	Dose	Risk	Management/Reduction				Accreditation/ Certification	Principles of Radiation Safety/ Regulation
			Justification	Optimization	Appropriateness	Guidelines		
Public	RSNA, IAEA, NIH, HPS	RSNA, IAEA, NIH	RSNA, IAEA				RSNA, ACR	RSNA
Health care providers	ACR, IW, ICRP, IAEA, AHRQ, NIH, IRPA	ACR, IAEA, AHRQ, ACS, ACP, JCR, IRPA	ACR, IAEA, NIH, ACS, ACP, IRPA	ACR	ACR	ACR, ACP	ACR, AHRQ, JCR	ACR, NIH, ACS, IRPA
Imaging community	ACR, IW, ICRP, IAEA, AHRQ, NIH, IRPA	ACR, IW, ICRP, IAEA, AHRQ, ACP, JCR, IRPA	ACR, ICRP, IAEA, NIH, ACP, IRPA	ACR, IW, ICRP, IAEA, NIH	ACR, IW	ACR, IW, ICRP, IAEA, NIH, ACP, AAPM	ACR, IW, AHRQ, JCR	ACR, ICRP, NIH, IRPA
General		WHO					ACR	

Note: See Table 1 for definitions of abbreviations.

Table 3. Adult: fluoroscopy

Parameters								
Audience	Dose	Risk	Management/Reduction				Accreditation/ Certification	Principles of Radiation Safety/ Regulation
			Justification	Optimization	Appropriateness	Guidelines		
Public	RSNA, IAEA, HPS	RSNA, NIH	RSNA, NIH				RSNA, ACR	RSNA
Health care providers	ACR, NCI, NGC, AHRQ, NIH, ACP	ACR, NCI, NGC, AHRQ	ACR, NIH	ACR, NGC	ACR	ACR, NCI, NGC	ACR	ACR, NIH, NGC
Imaging community	ACR, IW, NCRP, ICRP, IAEA, NGC, AHRQ, NIH, ACP	ACR, ICRP, IAEA, NGC, AHRQ	ACR, ICRP, IAEA, NIH	ACR, NCRP, IAEA, NGC	ACR	ACR, ICRP, IAEA, NGC	ACR	ACR, NIH, NGC
General		WHO						

Note: See Table 1 for definitions of abbreviations.

Table 6. Pediatric: CT

Parameters								
Audience	Dose	Risk	Management/Reduction				Accreditation/ Certification	Principles of Radiation Safety/ Regulation
			Justification	Optimization	Appropriateness	Guidelines		
Public	IG	RSNA, IG	RSNA, IG				RSNA, IG	RSNA
Health care providers	IG, SPR, NCI, AHRQ, NIH, AAP	IG, SPR, NCI, AHRQ, NIH, AAP	ACR, IG, AAP	ACR, AAP	ACR	ACR, IG, SPR, NCI, NIH, AAP	ACR, IG	ACR, NCI, AAP
Imaging community	IW, IG, SPR, ICRP, IAEA, AHRQ, NIH, AAP	IW, IG, SPR, AHRQ, NIH, AAP	ACR, IG, ICRP	ACR, IW, IG, ICRP, IAEA, NIH, AAP	ACR	ACR, IW, IG, SPR, ICRP, IAEA, NIH, AAP	ACR	ACR, IG, ICRP, AAP
General								

Note: See Table 1 for definitions of abbreviations.

Table 7. Pediatric: fluoroscopy

Parameters								
Audience	Dose	Risk	Management/Reduction				Accreditation/ Certification	Principles of Radiation Safety/ Regulation
			Justification	Optimization	Appropriateness	Guidelines		
Public	IG	RSNA, IG	RSNA, IG				RSNA, IG	RSNA
Health care providers	IG, AAP	IG	ACR, IG	ACR	ACR	ACR, IG	ACR	ACR, IG
Imaging community	IG, ICRP, IAEA	IG, ICRP	ACR, ICRP, IG	IG, ACR, ICRP	ACR	ACR, IG, ICRP	ACR	ACR, IG, ICRP
General								

Note: See Table 1 for definitions of abbreviations.

Table 10. Modules and protocols

Audience	Website
Radiologists	RSNA, IW, IG, IAEA, IRPA
Technologists	IW, IG, IRPA
Physicists	IW, IG, IAEA, AAPM
Imaging community	SPR, WHO
Nonimaging health care providers	IAEA, IRPA

Note: See Table 1 for definitions of abbreviations.

raphy, for which some guidelines are available. It can be argued, however, that perhaps it is of little benefit to develop information for patients and families in these more technical areas.

This compendium can also be used to enable easier access to resources containing the desired information. For instance, in the adult population, across all modalities, the RSNA seemed to offer the most comprehensive spectrum of information for patients, parents, and the general public, while the ACR provided the most comprehensive spectrum of information for health care providers and the imaging community. For the pediatric population, the RSNA and the Alliance for Radiation Safety in Pediatric Imaging provided the most information for patients, families, and the general public regarding radiation risk for CT and fluoroscopy, while the ACR and the Alliance for Radiation Safety in Pediatric Imaging provided the most for health care providers and the imaging community. Regarding pediatric radiography, the Alliance for Radiation Safety in Pediatric Imaging is the only source investigated that provided information for patients, parents, and the public, while the ACR and the American Academy of Pediatrics provided the most comprehensive information for health care providers and the imaging community.

The goal of this study was to generate a collective resource for those interested in radiation safety in medical imaging. However, there are several limitations. First, we were unable to include all possible organizations with information regarding the topic. In particular, this information relates primarily to US organizations. We chose to focus on organizations at the national level. We also arbitrarily chose to include major international organizations that had membership from the United States. Additionally, although we used many search strategies to minimize any documents that may have been overlooked, we acknowledge that there may be some information we were not able to locate. It is also possible that since the time of our search, more information has been made available on these websites regarding the topic. Furthermore, the purpose of this study was only to find information. Documents were not analyzed for their individual value.

CONCLUSIONS

This compendium can be used as a comprehensive resource for information related to radiation safety in medical imaging for patients and their families, health care providers, radiologists and technologists, and regulatory and legislative organizations. It can also be used to identify areas of redundancy and deficiency and to provide recommendations for areas needing more information. Furthermore, it can be used as an educational tool for the imaging community.

TAKE-HOME POINTS

- This compendium can serve as a single resource for patients, health care providers, radiologists, and technologists with reference to the currently available resources regarding radiation safety in medical imaging.
- We found that overall, more information is available regarding medical radiation safety in adults compared with children.
- This compendium can further be used to identify other deficiencies as well as redundancies.
- This compendium can also be used as an educational tool and can assist regulatory and legislative organizations in increasing awareness of medical radiation safety.

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Table 4. Adult: radiography

Parameters									
Audience	Dose	Risk	Management/Reduction				Accreditation/ Certification	Principles of Radiation Safety/ Regulation	
			Justification	Optimization	Appropriateness	Guidelines			
Public	RSNA, IAEA, NIH, HPS	RSNA, IAEA, NIH	RSNA, IAEA				IAEA, NIH	RSNA, ACR, IAEA	RSNA
Health care providers	ACR, AHRQ, NIH, ACP	ACR, AHRQ, NIH, JCR	ACR, AHRQ	ACR		ACR	ACR, AHRQ, NIH	ACR	ACR, AHRQ
Imaging community	ACR, IW, NCRP, IAEA, AHRQ, NIH, ACP	ACR, IAEA, AHRQ, NIH, JCR	ACR, IAEA, AHRQ	ACR, IAEA		ACR	ACR, NCRP, IAEA, AHRQ, NIH	ACR	ACR, AHRQ
General		WHO						WHO	

Note: See Table 1 for definitions of abbreviations.

Table 5. Adult: unspecified modality

Parameters									
Audience	Dose	Risk	Management/Reduction				Accreditation/ Certification	Principles of Radiation Safety/Regulation	
			Justification	Optimization	Appropriateness	Guidelines			
Public			HPS						ACR, IW
Health care providers	ICRP	ICRP, AHRQ	AHRQ, WHO, JCR				ICRP, AHRQ, JCR	ICRP	ICRP, AHRQ, JCR
Imaging community	ICRP, NIH	IW, ICRP, AHRQ, NIH	IW, AHRQ, WHO, JCR				ICRP, AHRQ, JCR	ICRP	ICRP, AHRQ, JCR
General	IAEA, NIH, HPS	IAEA, NIH, HPS	IAEA				ACR		IAEA, NCRP, ICRP, FDA, JCR, HPS

Note: See Table 1 for definitions of abbreviations.

Table 8. Pediatric: radiography

Parameters								
Audience	Dose	Risk	Management/Reduction				Accreditation/ Certification	Principles of Radiation Safety/ Regulation
			Justification	Optimization	Appropriateness	Guidelines		
Public	IG	IG						
Health care providers	NCI, AAP	AAP	ACR, AAP	ACR, AAP	ACR	ACR, AAP		
Imaging community	ICRP, IAEA	AAP	ACR, ICRP, AAP	ACR, ICRP, AAP	ACR	ACR, ICRP, IAEA, AAP		ICRP
General								

Note: See Table 1 for definitions of abbreviations.

Table 9. Pediatric: unspecified modality

Parameters								
Audience	Dose	Risk	Management/Reduction				Accreditation/ Certification	Principles of Radiation Safety/ Regulation
			Justification	Optimization	Appropriateness	Guidelines		
Public		AAP	AAP					
Health care providers		AAP	AAP		AAP	AAP	AAP	
Imaging community		ICRP						
General								

Note: See Table 1 for definitions of abbreviations.