MEETING THE NEEDS FOR RADIATION PROTECTION: DIAGNOSTIC IMAGING

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Abstract—Radiation and potential risk during medical imaging is one of the foremost issues for the imaging community. Because of this, there are growing demands for accountability, including appropriate use of ionizing radiation in diagnostic and image-guided procedures. Factors contributing to this include increasing use of medical imaging; increased scrutiny (from awareness to alarm) by patients/caregivers and the public over radiation risk; and mounting calls for accountability from regulatory, accrediting, healthcare coverage (e.g., Centers for Medicare and Medicaid Services), and advisory agencies and organizations as well as industry (e.g., NEMA XR-29, Standard Attributes on CT Equipment Related to Dose Optimization and Management). Current challenges include debates over uncertainty with low-level radiation; lack of fully developed and targeted products for diagnostic imaging and radiation dose monitoring; lack of resources for and clarity surrounding dose monitoring programs; inconsistencies across and between practices for design, implementation and audit of dose monitoring programs; lack of interdisciplinary programs for radiation protection of patients; potential shortages in personnel for these and other consensus efforts; and training concerns as well as inconsistencies for competencies throughout medical providers’ careers for radiation protection of patients. Medical care providers are currently in a purgatory between quality- and value-based imaging paradigms, a state that has yet to mature to reward this move to quality-based performance. There are also deficits in radiation expertise personnel in medicine. For example, health physics academic programs and graduates have recently declined, and medical physics residency openings are currently at a third of the number of graduates. However, leveraging solutions to the medical needs will require money and resources, beyond personnel alone. Energy and capital will need to be directed to:

• innovative and cooperative cross-disciplinary institutional/practice oversight of and guidance for the use of diagnostic imaging (e.g., radiology, surgical specialties, cardiologists, and intensivists);
• initiatives providing practical benchmarks (e.g., dose index registries);
• comprehensive (consisting of access, integrity, metrology, analytics, informatics) and effective and efficient dose monitoring programs;
• collaboration with industry;
• improved use of imaging, such as through decision support combined with evidence-based appropriateness for imaging use;
• integration with e-health such as medical records;
• education, including information extending beyond the medical imaging community that is relevant to patients, public, and providers and administration;
• identification of opportunities for alignment with salient media and advocacy organizations to deliver balanced information regarding medical radiation and risk;
• open lines of communication between medical radiation experts and appropriate bodies such as the U.S. Environmental Protection Agency, the U.S. Food and Drug Administration, and the Joint Commission to assure appropriate guidance on documents and actions originating from these organizations; and
• increased grant funding to foster translational work that advances understanding of low-level radiation and biological effects.

Key words: National Council on Radiation Protection and Measurements; diagnostic imaging; education; radiation protection

INTRODUCTION

SOMewhat recently, a colleague very familiar with the broad scientific landscape of ionizing radiation, such as that embraced by the National Council on Radiation Protection and Measurements (NCRP), tangentially mentioned following a discussion on the topic of “Where have all the radiation professionals gone?” He wasn’t sure that there was much relevance for the medical community. We discussed this briefly, and after relaying several critical areas of importance (and of need) in the medical community, his reply essentially distilled to the equivalent of, “Oh, my.”

So we will go from “Oh, my” to hopefully “Yes; of course” in addressing the relevance of radiation expertise for the medical field (excluding radiation oncology). In doing so, I will invite an expanded view on the acronym of WARP (Where Are All the Radiation Professionals?) to WARPP (Where Are All the Radiation Professionals and Professionalism?). Being a professional does not necessarily
imply prudent perspectives on radiation and risk in medical imaging. I believe that even through medical pathways, agendas have motivated how risk is portrayed, and that professionals and professionalism will not be inherently coupled until nonselective, balanced content is forthcoming and enduring. This is not a numbers game only. The “man” power of the “professionals” element of WARP must translate into effective and informed practices.

In an endeavor for clarity, the following material will be divided into sections of specific needs. These are not intended to be prioritized, although the content of each section may convey some sense of relative importance. There will also be some overlap, although most discussion is intended to be uniquely related to the stated need. At the end of each need, there will be a recommendation or other considerations in addressing this need. The format will be loosely based on a familiar communication strategy in medicine known as SBAR: subject, background (both in initial text in the following points), followed by sections on assessment and recommendations. In day-to-day medical care, this strategy is intended to improve communication and understanding (and outcomes), for example, with hand-off care for patients or in a consultative (i.e., emergency) circumstance, but it serves an equally resourceful and hopefully effective purpose here.

Increased public scrutiny and often alarm with ionizing radiation in medical imaging

This public scrutiny and alarm (Sternberg 2001; Redberg and Smith-Bindman 2014; Cohen 2015) over getting cancer from medical imaging is not related to computed tomography (CT) alone (Redberg and Smith-Bindman 2014) and not limited to physicians, as the use of cone beam CT and radiation risk for dental practice has also been publicized (Bogdanich and McGinty 2010; Bogdanich and Rebelo 2011).

Assessment. Current modes of communication often favor a “harm and alarm” perspective, as this is an easier sell than the more balanced understanding of the use of ionizing radiation in medical practice and potential cancer risks. Public media outlets have not been interested in contrary opinions or on the value of imaging as a rule (Cohen 2015). This might not be rational, but it is a reality.

Recommendations. Imaging professionals need to keep on message (present the known value of imaging as well as informed uncertainty with risk), direct to organizational resources (e.g., NCRP) that offer unbiased content and websites such as Image Gently® (ARSPI 2016), Image Wisely® (ACR 2016a), and radiologyinfo.org (RSNA 2016) for more balanced perspectives on cancer risk, especially in response to misinformation. In addition, partnerships should be fostered with patient advocate groups for appropriate content, content formatting, and dissemination strategies [e.g., social media (Prabhu and Rosenkrantz 2015)] for target information and information delivery.

Incomplete understanding of radiation and medical imaging

The public in general as well as patients and their families and other caregivers have an incomplete understanding of radiation and medical imaging, often due to unbalanced media reporting. However, health professionals are also included in this group, as they can have a poor understanding of radiation doses and potential risks (Puri et al. 2012; Rehani and Berris 2012; Boutis et al. 2013; Sadigh et al. 2014; Lam et al. 2015; Prabhu and Rosenkrantz 2015). For example, in the recent meta-analysis by Lam et al. (2015), depending on the publication, from 5-15% of physicians thought ultrasound emitted ionizing radiation and 8-28% of physicians thought the same thing about magnetic resonance imaging. The degree of misunderstanding among those other healthcare providers that use ionizing radiation is unclear but is likely also present in cardiology (where imaging may be performed by CT, nuclear imaging, or angiography/fluoroscopy) (Carpeggiani et al. 2012); urology [i.e., operating room (OR) fluoroscopy]; orthopedic surgery (OR and emergency department fluoroscopy and intra-operative CT); vascular, general, and pediatric surgery, (OR fluoroscopy); gastroenterology (endoscopic retrograde cholangiopancreatography); and intensive care settings (C-arm fluoroscopy), among other settings.

Assessment. There is a need for improved and consistent understanding of low-level radiation and risks across patients, their caregivers and healthcare providers (Lam et al. 2015). This applies to the wide variety of specialties and subspecialties that use and depend on ionizing radiation examinations in the care of their patients. In addition, there is variability state-to-state with credentialing for use of ionizing radiation imaging by practitioners that can convey to differences between medical practices.

Recommendation. Multi-disciplinary programs should be created at medical practices and institutions to provide guidance for education/training and credentialing. This should begin in medical school as part of the compulsory curriculum, preferably as part of diagnostic imaging content addressing appropriateness as well. These then can better represent the tenets of justification and optimization in diagnostic imaging. All relevant practitioners should have a voice in developing and monitoring this practice, and the group should include health physicists (e.g., radiation safety officers), medical physicists, administrative personnel (e.g., credentialing guidance), and personnel with information technology expertise. This will cost money and time and will likely be resisted, as it will be seen as another
bureaucratic impediment. The implementation process will need to consider ways to make this effective and accepted as part of the culture of quality and safety.

**Increasing regulatory requirements and accreditation requirements**

In 2012, the State of California enacted SB 1237 (CA 2010) requiring dose metrics for CT and nuclear medicine studies to be included in patient reports based largely on indiscriminate CT performance at several centers (Zarembo 2009). This requirement (some have offered that this is a punishment for radiologists) may increase radiologists’ recognition of radiation doses, potentially identifying high exposures as well as variabilities. The value to (or even simpler, understanding by) the patient is more tenuous. Awareness and accountability for doses delivered should have been the radiologists’ responsibility from the outset.

I believe, though, that inserting a dose metric (e.g., dose length product for CT) in the report was reactive and myopic, and it does little if anything for the overwhelming majority of patients. I would expect the report to be ignored at best, or confusing, which may prompt a conversation with the referring healthcare provider (such as a family practitioner, pediatrician, or internist) who would likely also have little understanding of what, for example, 50 mGy CTDIvol for a head CT means. To date, no other state has imposed such a regulation. There is also no federal oversight for the use of equipment-produced radiation (e.g., CT scans, fluoroscopic equipment); this is generally up to states to regulate (Harvey and Pandharipande 2012). The U.S. Nuclear Regulatory Commission does regulate the medical use of byproduct material (USNRC 2013). In July 2015, The Joint Commission (TJC) released *Diagnostic Imaging Requirements*, which included in the accreditation requirements establishment of dose monitoring programs (TJC 2015). In May 2015, the Center for Medicare and Medicaid Services released *Revised Hospital Radiologic and Nuclear Medicine Services Interpretive Guidelines—State Operations Manual (SOM) Appendix A* that included requirements also aimed at increased accountability for use of ionizing radiation in medical imaging (CMS 2015).

**Assessment.** In addition to (and arguably in response to) increased public scrutiny, there is increasing regulation/accreditation/guidance for performance of diagnostic imaging using ionizing radiation.

**Recommendations.** Consensus review and input for such organizational specifications is essential through professional organizations and societies such as NCRP, the American Association of Physicists in Medicine and various radiology organizations including the American College of Radiology (ACR). Input could also be through the leadership of the Image Gently® Alliance as well as the Image Wisely® Program. There should be established networking, which could include or be based on existing communication network models, such as the Imaging Communication Network for Radiology [steering committee: the ACR, the Radiological Society of North America (RSNA), the American Roentgen Ray Society, the American Board of Radiology, and the American Board of Radiology Foundation]. Such a network model can be effective in identifying, discussing, and when appropriate, delegating responsibility for appropriate actions, including those with some urgency.

**Increasing use of medical imaging that uses ionizing radiation**

This has been established and is the foundation of NCRP (2009). While there is ample evidence that use of CT in children has leveled or decreased over the past several years (Korley et al. 2010; Kocher et al. 2011; Larson et al. 2011; Raja et al. 2011; Miglioretti et al. 2013; Roudsari et al. 2013), the net increase for this population as well as that for adults is evident over the past two to three decades (NCRP 2009). This is not to say that some increase is not warranted, but there are myriad factors that influence the use of imaging. These have been reviewed recently (Frush 2014).

**Assessment.** Medical imaging is valuable (Hricak et al. 2011; Rubin 2014; Pandharipande et al. 2016), but not all use is clearly medically justified (Cascade et al. 1998; Studdert et al. 2005; Levin and Rao 2008, 2011; Hendee et al. 2010; Bhargavan et al. 2011; Linscott et al. 2013; Kanzaria et al. 2015).

**Recommendation.** Decision support is one major tool for improving appropriate use of diagnostic imaging examinations, and efforts at providing assistance at point-of-care are growing (e.g., ACR Select™) (ACR 2016b). Developing and monitoring decision support are time consuming and expensive. Developing and implementing helpful products, inherently commercial (in the United States), will cost money. Administration will need to budget for this. This is not solely a radiology department responsibility since the justification/appropriateness when requesting an imaging examination is a shared responsibility and necessarily includes the healthcare providers at the point-of-care, as well as information technology resources. The technology community and vendors together must develop appropriate products that serve the need of the patient in this respect and are efficient for use by medical providers.

**Dose monitoring**

It is required now that patient radiation dose monitoring programs are in place for radiology practices/institutions (TJC 2015).

**Assessment.** There are evolving requirements for monitoring radiation doses to patients with likely highly variable...
compliance in part due to complexity and lack of clarity with current requirements.

**Recommendation.** Given multiple stakeholders, multidisciplinary committees should be formed for the current state of dose monitoring, emphasizing gaps and including what is needed for compliance. While radiologists can assist in helping to define what might be the best measures to assess (such as common examinations to monitor, examination ontology, technique/protocol refining, and auditing), radiation expertise is necessary in deciding which if any product is best, what metrics to measure (and what they mean), implementing the program and reviewing success as well as identifying and addressing deficiencies. Details for program development as well as challenges have been recently reviewed (Frush and Samei 2015). Stakeholders include radiologists, medical and health physicists, information technology professionals, and technologists and hospital administration.

**Emergency Response**

Radiologists need to be part of emergency response/disaster preparedness/mass casualty programs. This is more familiar for scenarios such as mass transit accidents, or even biological (i.e., anthrax or ebola) events. However, this must also include chemical and, most relevant here, radiation exposure that can come in several forms such as ingested/inhaled material exposure or from explosive devices that may contain radioactive material; i.e., an improvised explosive device or other dispersal medium with either external contamination or imbedded foreign bodies that may be radioactive. This topic was presented at the 2015 RSNA Annual Meeting, in part supported by the NCRP. This session was very well attended as a virtual broadcast meeting and received very positive reviews. Following this, I began to explore what our preparedness was for such an event locally and what may be potential gaps in our program. For example, where is the decontamination area? Who is labeled “hot” and who is not? Who screens - are they health physicists (the answer to this was “yes”)? What equipment should they use? Is there enough? How available is this equipment? Where does decontamination fluid go, and is storage acceptable for radioactive fluid? What about embedded radioactive material in a patient who needs an emergent imaging study or interventional radiology procedure? It is likely that through word-of-mouth during a radioactive disaster, there will be a great deal of confusion about risk and risk mitigation outside the triage areas such as in the radiology department. Radiologists, too, may be called upon as content experts in such a scenario, and the assistance of radiation expertise in preparing for this is paramount.

**Assessment.** It is unclear what universal preparedness there is for nuclear/radioactive mass casualty by members of the imaging team.

**Recommendation.** The NCRP Annual Meeting in 2017, “Emergency Preparedness for Nuclear Terrorism: Where Are Remaining Gaps and Is There Need for Realignment of National Efforts,” will address this and hopefully clarify programmatic needs and strategies. A publication specifically targeting the imaging community would be of value, outlining types of exposures, risks, operational management including accreditation requirements and other available resources, such as the Radiation Emergency Assistance Center/Training Site (ORISE 2016). Individual radiologists should consider contacting their disaster preparedness teams, and arranging a radiation casualty response drill.

**Is low level radiation harmful?**

Healthcare providers depend on scientists such as epidemiologists for clarification of the risks of low level radiation, such as that used in diagnostic imaging. An NCRP report in process is reviewing existing models for low level radiation and cancer risk.

**Assessment.** There is a need for consensus clarity here.

**Recommendation.** Additional balanced information such as through NCRP will be very helpful in guiding our approach with each other as imaging professionals with other non-imaging colleagues, our patients, their caregivers, and the public. We, including technologists, are often frontline in this patient contact.

**Communication**

This point touches on many if not all previous items addressed above. Improved content and effective delivery strategies are needed.

**Assessment.** As already noted, information coming through public media is often biased (Cohen 2015). The medical community, our patients, and members of the public often do not understand fully what is and what isn’t known about ionizing radiation and medical imaging with respect to cancer risks, and there is increasing pressure for accountability (Frush et al. 2013; CMS 2015; TJC 2015). There are increasing global efforts in radiation protection awareness to address this lack of understanding. Starting with Image Gently® and subsequently with Image Wisely®, with programs now in Europe, (EuroSafe), Africa (AFROSAFE), Asia (Japan Safe Imaging), Canada Safe Imaging, and most recently the LatinSAFE program, there is a global recognition of the need for information and communication related to use of medical radiation. Recently, the World Health Organization released a risk communication tool that underscores many of the communication needs and strategies (WHO 2016).

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Recommendations. NCRP should take the lead and activate the relatively nascent PAC 7, Radiation Education, Risk Communication, Outreach, and Policy, which is responsible for communication. There are so many stakeholders that are impacted and so much value that will be gained. Industry must provide adequate training and follow-up education on equipment use because technology is increasingly complicated. If they cannot self-regulate, then efforts for professional imaging communities through the U.S. Food and Drug Administration or the Medical Imaging and Technology Alliance should address this issue. Early and authoritative efforts in addressing information on equipment use because technology is increasingly complicated. If they cannot self-regulate, then efforts for professional imaging communities through the U.S. Food and Drug Administration or the Medical Imaging and Technology Alliance should address this issue. Early and authoritative efforts in addressing information on equipment use because technology is increasingly complicated. If they cannot self-regulate, then efforts for professional imaging communities through the U.S. Food and Drug Administration or the Medical Imaging and Technology Alliance should address this issue.

Other items

- Radiation professionals are extremely valuable in helping with consent language and other patient educational content and in developing departmental policies. Such policies might include the use of ionizing radiation in pregnancy, as well as dosimetry for complex high exposure procedures for interventional radiology, cardiology, or conceivably orthopedic interventions. Expertise is also helpful in settings of inadvertent or relatively high exposures during pregnancy; and
- Educational needs: There will likely be a shortage of those medical physicists who have met required residency training with available residency positions. There are many more applications than available positions, and it is currently unclear if the projected numbers will meet growing medical needs.

CONCLUSION

The medical community is critically dependent on radiation professionals, indeed all relevant professional groups, from basic sciences including epidemiologists to those with expertise in information technology, media, and communication. Identifying needs while emphasizing opportunities will be of benefit as a unified and compelling voice for increased radiation professionals and professionalism. This will change “Oh my” to “yes; of course.”

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