Radiology

Challenges in Dosimetry and Radiation Dose Trends

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The number of fluoroscopically guided interventional (FGI) procedures has been steadily increasing. This is due in part to improved radiographic imaging technology and innovations in catheters, guidewires, stents, and biomaterials. Many of the FGI procedures are alternatives or replacements to surgical procedures. Some complex FGI procedures require prolonged imaging time and radiation exposure. Appropriately, concern has been expressed about the radiation dose patients receive because of the high levels of radiation typically associated with some of these procedures (eg, placement of transjugular intrahepatic portosystemic shunts and cerebrovascular embolization) (1–3). Although the protection and safety of patients during FGI procedures is of utmost importance, the radiation dose to medical staff who perform or assist in these procedures is also an important and timely concern.

In this issue of *Radiology*, Borrego and colleagues (4), in a survey of over 1500 institutions, reported that the occupational dose to staff performing or assisting with FGI procedures was generally below U.S. regulatory limits. However, in 15% of the readings in their study, the equivalent dose to the lens of the eye was above the limits recommended by the International Commission of Radiation Protection (ICRP) (5). Of note, the annual lens equivalent dose for staff wearing a single radiation monitoring badge was similar to that of individuals who wore two badges.

The authors retrospectively collected over 2 000 000 entries from radiation monitoring badges for medical workers across 3 years (2009, 2012, and 2015). The badge entries of staff believed to have performed or assisted in FGI procedures were evaluated. Consideration was given to inclusion and exclusion criteria, particularly for the instances where it was not possible to determine the effective dose equivalent. An effort was also made to gain insight into the practice of using the one-badge protocol compared with the two-badge protocol. This information can be important for radiation safety to determine which approach is more appropriate for the needs of a particular practice.

The risk for radiation-induced cataractogenesis with high chronic or acute exposure is well known. Current regulatory limits for the lens of the eye–equivalent dose in the United States are not the same as the ICRP recommendations (5). On the basis of more recent epidemiologic evidence, the ICRP has recommended lower dose limits for the lens of the eye. Although these limits have not been universally adopted, they have drawn attention from professional groups and advisory organizations (6). Adoption of lower equivalent dose limits is worthy of consideration, but this process involves many stakeholders, including health care institutions, scientific and professional organizations, and regulatory agencies. As noted in the discussion by Borrego et al, the reported badge readings may overestimate the actual equivalent dose to the lens of the eye in those who use properly designed protective eyewear such as lead or lead acrylic glasses. If properly used, such protective eyewear is effective in reducing the radiation dose to the lens, which is considered the most radiosensitive part of the eye. In view of the aforementioned concerns—particularly with regard to potential overestimation of the equivalent dose to the eye with current techniques—universal consensus on adopting a lower equivalent dose limit is likely to be gradual.

Historically, radiation-induced lens opacification has not been considered likely to develop below some threshold of radiation dose. This threshold mechanism is called a deterministic effect of radiation. However, review of more recent epidemiologic data suggests that cataract formation may occur with much lower radiation than previously assumed. The concept of a dose threshold below which lens opacification or cataracts may not be induced is currently in question (5–9). If any dose threshold exists, it may be at a lower dose than previously assumed (5–9). The radiation effects to the lens of the eye are more complex than previously assumed and genetic susceptibility, age, and tissue sensitivity at the molecular level may contribute to the process of opacification (5,9). Radiation-induced lens opacification appears to have certain characteristics of the random or probabilistic, also called stochastic, effect of radiation where with no threshold and theoretically any amount of radiation (even small) there is potential for biologic damage.

The ICRP now assumes that 0.5 Gy for acute or protracted exposure dose to the lens of the eye is a practical threshold for radiation-induced opacification effects in the

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See also the article by Borrego et al in this issue.

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lens. This can be used as a practical guideline in radiation protection. Moreover, for occupational radiation protection, ICRP has changed its recommendation for protection of the lens of the eye from the previous equivalent dose limit of 150 mSv per year to 20 mSv per year averaged over 5 years and a limit of 50 mSv in a single year (5). By comparison, in the United States, the current occupational annual radiation dose limit to the lens of the eye is 150 mSv and for the public the limit is 15 mSv (7,9). In the United States, however, reduction of the currently recommended annual radiation dose limit to the lens of the eye is being considered (9). In expressing radiation dose for tissue effects, as in lens opacification, the use of absorbed dose in units in milligray instead of equivalent dose in units of millisieverts is recommended (7,9).

The results of the study by Borrego and colleagues (4) are important to those who have a role in the management of occupational radiation in medical imaging practices. Their findings on the use of a single- versus two-badge protocol for radiation dose monitoring may motivate health care organizations to reconsider or modify their practice at least for part of their occupationally exposed personnel. The use of a two-badge protocol creates more work, and the associated cost to cover a large number of personnel can be substantial. In situations where a two-badge protocol is deemed essential, it may be used in a more restricted approach for those who are more likely to be exposed above a certain level, such as those who are involved in FGI procedures.

Defining and recommending limits to occupational radiation exposure is a complex process that requires careful review and analysis of the scientific evidence on the basis of epidemiologic and radiobiological science and radiation dosimetry and physics. Improved understanding of the radiobiological mechanistic processes in radiation-induced lens opacification is especially important, particularly at the dose range at or below current limits. The report by Borrego et al (4) is timely because scientific advisory organizations and regulatory agencies are working toward harmonization of occupational radiation limits at the international level. Their study provides strong evidence on general compliance with current regulatory limits for effective dose equivalent, but also suggests that some improvements may be needed in data collection and in equivalent dose reduction to the lens of the eye for staff who perform or assist in FGI procedures.

Borrego et al (4) also demonstrate the operational challenges associated with extracting relevant information from large data sets. Badges that are not returned or that are inconsistently or improperly worn can interfere with the accuracy of dosimetry and data analysis in this process. According to Borrego et al, only about one-third of the badges were deemed to be informative. This is a concern if this finding is typical of a general trend. The authors found problems in the two-badge group, in which a large number of badges were deemed incomplete and many others had readings that suggested a technical problem with the badge.

The authors acknowledged the limitations in this study, which included the inability to include all data because of failure to return badges, to consider missing data when only one badge from a set of two badges was received, and to resolve problems with reversed or improperly placed badges on the body. Despite these limitations, the strength of this study (4) is in the large sample and in exploring the potential to improve accuracy in occupational dose assessment, potentially with a simplified approach. The use of a two-badge monitoring protocol has its challenges (4,6), and the dose reading obtained with radiation monitoring badges close to the eye may not be as accurate as anticipated because of the changing position of the exposed person from the radiation source (typically the patient) during the FGI procedure.

The establishment of a nationwide comprehensive database on occupational dosimetry data has great potential. Although advanced computational techniques such as artificial intelligence can help identify dose trends and problems, the effectiveness of such techniques will be dependent on the quality of data, as indicated by Borrego et al (4). Proper use of dose-measuring badges and compliance with institutional radiation safety procedures are essential for reducing occupational radiation dose and advancing the state of the art in radiation dosimetry.

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