The interventional cardiologist practices internal medicine, cardiology, and critical care medicine in the setting of multiple, often complex, patient care scenarios. Beyond the cognitive challenges, significant technical skills are required, covering a wide range of equipment options necessary for the broad field of invasive cardiovascular diagnosis and therapy. Quality improvement programs track procedure outcomes as well as provide processes for best practices, such as contrast reduction and radiation safety (1). Publications are available to address the various radiation issues in the cardiac catheterization laboratory (2–4). Radiation safety education is a defined requirement for the cardiology fellowship, with 15% of the questions on the interventional cardiology board examination pertaining to radiation safety and/or physics (5). The deterministic effects for skin injury are recognized, and the stochastic effects for potential cancer concerns have been published (6,7). Aging interventional cardiologists illustrate the consequences of both prolonged radiation exposure and radiation protective attire, with cataracts, premature cancer risks, spinal injury, pain, and surgery (8). Without question, radiation safety is an important issue for patient, staff, and physician safety, but what priority is it for the busy interventionalist?

In this issue of JACC: Cardiovascular Interventions, Kuon et al. (9) publish their results for the implementation of a 90-min interactive radiation dose reduction workshop offered to 177 trained interventional cardiologists at 32 cardiac centers in Germany. Cine runs, frame rate, collimation, filtering, angulation effect on dose, and proper techniques of table/receptor heights were covered as an updated, concentrated, focused review. This minicourse was provided as an adjunct to the national German regulations for radiation protection, which are required for all interventionalists. This includes 20 h of both basic and advanced theoretical concepts in radiation protection with an 8-h special course in fluoroscopy-guided interventions (required to be repeated every 5 years). A yearly mandatory fundamental 1-h refresher course in the principles of radiation protection in clinical routine is also required. Using the dose area product (DAP) for diagnostic catheterizations, Kuon et al. (9) identified the significant success of implementing this program, with a 48% reduction in patient radiation dose for the 154 operators who completed this voluntary minicourse.

As seen in this study, the assessment of radiation dose requires more than fluoroscopy time (10). Steeper angulations, larger patients, varying frame rate, ignoring store fluoroscopy mode, and patient extremities in the field of view all will significantly increase the dose without affecting fluoroscopy time. Fluoroscopic equipment sold in the United States since 2006 is required to measure and display radiation dose parameters. These measures include: total air kerma at the interventional reference point (units: Gy), also referred to as cumulative air kerma; and air kerma area product (units: Gy × cm²), also known as DAP. Total air kerma at the interventional reference point is the x-ray energy delivered to the air at the interventional reference point; this is used to estimate potential deterministic skin effects. Air kerma area product is the product of air kerma and the x-ray field size; this is affected by collimation.

The National Council for Radiation Protection published radiation safety training recommendations that it feels should be mandatory for all operators of fluoroscopic imaging equipment (3). This has been sporadically instituted among the states (11). This training includes general knowledge for all users and more advanced information for the operators where “high patient dose” may be administered, >2 Gy for total air kerma at the interventional reference point. This radiation safety education program should be coordinated with the hospital radiation safety officer, hospital medical or health physicist, or an outside consultant. The essential components of this program are listed in Table 1. This training, approximately 8 h, should include both didactic and hands-on tutorials, with annual updates provided. The didactic program can be a series of online and/or standard classroom lectures with the focus on content, not hours, with written examination as deemed appropriate. Hands-on equipment training is essential for all operators, both initially and with new equipment purchases. Documentation of course completion is necessary, with fellows receiving verification of fluoroscopic training.

In addition to the required radiation safety training in Germany, an additional minicourse significantly affected...
patient procedural radiation dose (9). However, an essential component to this study, as it applies to mandatory training for the interventional cardiologist, lies in the operators that "chose" not to take the course. Twenty-three cardiologists at 13 of the centers were invited but did not attend the course due to "daily duties, illness, vacation, and so on—or assumedly owing to the fact that they considered themselves already experienced enough in dose-optimized interventional practice" (9). Based on the study design and statistical limitations, formal analysis of this group was not possible. The baseline radiation dose (DAP) for the nonparticipating operator was approximately 15% lower than that of the group participating in the course. However, whereas the 23 nonparticipants did not improve their radiation dose, the 154 participants showed a 48% improvement in DAP. After the course, the course participants had approximately a 35% lower procedure radiation dose than did those not taking the minicourse. The potential benefits for all operators, no matter what skill level (achieved or perceived), to be thoroughly trained in radiation safety with regular updates should not be understated. Fetterly et al. (12) at the Mayo Clinic succeeded in a 40% radiation dose reduction (cumulative air kerma) over a 3-year period by implementing a culture and philosophy of radiation safety in the catheterization laboratory. The goal of interventional cardiologists is to do the best for their patients, and in so doing, protect the staff and themselves. In the multitask environment of the cardiac catheterization laboratory, mandatory radiation safety training, with annual updates, will allow all operators, new and experienced, to achieve this goal throughout their career.

The annual patient radiation dose from medical imaging has increased 3-fold since 1982, with cardiovascular dose alone increasing approximately 20% (13). This dramatic increase in radiation from medical imaging has appropriately heightened concerns for radiation safety. Radiation safety must be a priority in the cardiac catheterization laboratory, in the setting of multiple priorities. The interventional cardiologist is required to take the leadership role to:

- Establish a radiation safety program for the laboratory, incorporating the physicist for radiation training, equipment purchase, and safe maintenance;
- Require and document the appropriate radiation safety training both upon employment and with annual updates;
- Purchase and properly operate imaging equipment with dose-limiting capabilities and appropriate dose notification;
- Use all available above and below table shielding as well as personal protective garments and glasses;
- Mandate the wearing of the dosimetry badge(s) by incorporating badge use as a component of the pre-procedure "time out;"
- Manage radiation dose throughout the case, not just upon high dose notification; and
- Establish follow-up parameters with policies for those patients receiving high radiation doses.

When a radiation-conscious environment has been established in the cardiac catheterization laboratory, the patients, staff, and physicians will all benefit.

Reprint requests and correspondence: Dr. Charles E. Chambers, Penn State Hershey Medical Center, 500 University Drive, MCHO47, Hershey, Pennsylvania 17036. E-mail: cchambers@psu.edu.

REFERENCES


Key Words: coronary angiography ■ dose reduction ■ education ■ invasive cardiology ■ radiation exposure.