Editorial

Radiation Exposure in Cardiovascular Medicine
How Do We Protect Our Patients and Ourselves?

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How important is the issue of radiation exposure in cardiovascular medicine? What constitutes best medical practice with respect to patient medical exposure and personnel occupational exposure?

During the past 2 decades, we have enjoyed a remarkable development and refinement of diagnostic and therapeutic cardiovascular procedures. Concomitantly, there has been substantial growth in the number of procedures performed. Of these widely used modalities, x-ray fluoroscopically guided invasive cardiovascular procedures, x-ray CT, and nuclear medicine studies all involve exposure to ionizing radiation. In addition to exposing patients, invasive cardiovascular procedures expose physician-operators and laboratory personnel. The initial infatuation with the capabilities of these diagnostic and therapeutic modalities has been tempered by a growing awareness of their potential, inapparent hazards both to patients and to medical personnel. It is important that we devote attention to assessing the hazard more accurately and to minimizing everyone’s exposure.

Patients and medical personnel present different radiation exposure issues. For both groups, the principal hazard is the stochastic risk of radiation-induced neoplasm. Patients generally undergo a modest number of comparatively large exposures, whereas medical personnel incur a long-term, continual low-level occupational exposure. Practitioner occupational exposure for invasive cardiovascular procedures is becoming a more prominent concern because these procedures increasingly are concentrated in a group of highly active practitioners whose careers span ≥30 years.1,2 Thus, these physicians may receive a substantial lifetime occupational exposure.

The large prevalence of spontaneously occurring neoplastic disease confounds attempts to draw a cause-and-effect connection between a particular neoplasm and the associated occupational or medical radiation exposures. Thus, exposure-neoplasm relationships can be detected only through population-based studies.

There are many challenges to estimating the attributable risk of a radiation exposure. Existing models are likely more accurate when applied to intermittent large medical exposures than to long-term low-level occupational exposures. Nonetheless, estimates of the stochastic risk of medical radiation exposure are disquieting.2 Exposure for cardiovascular CT and x-ray fluoroscopically guided procedures is concentrated in the chest. Thus, the lungs and bone marrow are the most exposed radiosensitive organs, and women carry an additional risk of breast exposure.

The attributable risk declines with age at the time of exposure. The age relationship is logical given the delay between exposure and presentation of an induced neoplasm. Women have a greater risk than men largely because of breast cancer risk. For example, Einstein et al3 estimated a lifetime cancer-attributable risk of 0.7% in a 20-year-old woman undergoing a standard coronary CT angiography scan, including the thoracic aorta. On the other hand, they estimated the lifetime attributable risk of the same examination in a 60-year-old man at 0.081%.

Our profession should have a high awareness of the medical radiation exposure hazard and make an earnest effort to minimize it. Minimizing exposure requires both thoughtful case selection and attention to parameters that modulate exposure. Case selection should include assessment of the appropriateness and clinical value of a procedure as well as choice of imaging modality (stress nuclear study versus stress echocardiography, x-ray CT versus MRI). Nuclear cardiology and cardiovascular x-ray CT studies should use exposure-reducing image acquisition protocols, including stress-only nuclear studies when the stress images are normal and electrocardiographically modulated tube current protocols for x-ray CT.

X-ray fluoroscopically guided procedures have substantial potential for exposure variation because numerous variable parameters (some of which are under operator control) affect exposure. Consequently, physicians are responsible for understanding these parameters and modulating them appropriately to achieve the minimal exposure consistent with satisfactory procedure execution. Unfortunately, 1 major determinant of patient and operator exposure—patient size—is not modifiable.4

Fluoroscopic equipment calibration and configuration should be optimized to minimize exposure rate during fluoroscopy and cine acquisition.5 There is an obligatory trade-off between dose rate and image quality. An x-ray fluoroscopic facility is responsible for ensuring that its equipment is optimally calibrated to produce diagnostic quality images at the smallest acceptable dose. Physician-operators are respon-
sible for understanding how to configure and position equipment optimally to achieve minimal exposure rates.

The dose-area product is a measure of the total amount of radiation energy deposited in the patient during an x-ray fluoroscopic procedure. This parameter, calculated by the x-ray unit, is expressed as Gy·cm². It determines the patient’s stochastic risk of future neoplasms. In addition to patient exposure, operator and personnel exposure are directly related to the dose-area product. Naturally, a safety and quality goal for invasive cardiovascular procedures is to minimize the dose-area product delivered during a procedure.

The effective dose, expressed in milliSv, is a measure of the stochastic risk impact of a radiation exposure that allows comparison across exposure modalities. For x-ray fluoroscopic exposure, as an approximation, the conversion factor 0.26 may be used to convert the dose-area product to milliSv.²⁻⁸

Many variables combine and interact to determine a procedure’s aggregate dose-area product. Variables under the operator’s procedure conduct control include fluoroscopy time, cine acquisition time, and certain fluoroscopic parameters such as framing rate and dose rate selection. Highly skilled operators are able to complete a procedure with shorter fluoroscopy times than less experienced and skilled operators. In addition, system positioning and collimator positioning (image field size) also influence the dose-area product.⁶

Because the cine acquisition dose rate typically is 6 to 10 times greater than the fluoroscopy dose rate, the cine acquisition dose may exceed the fluoroscopy dose. An ideal cardiovascular angiographic examination contains neither too many nor too few angiographic runs. Each run acquired should have a specific purpose and should be selected to provide important incremental diagnostic information that complements the information obtained by the prior runs. A study is complete when a comprehensive diagnosis has been achieved. Thus, another important operator skill in cardiovascular angiography is to optimize the number of cineangiographic runs acquired and to achieve perfect execution of each run. Typically, for coronary arteriography, this can be achieved with 4 well-selected angiographic views of the left coronary and 2 views of the right coronary, requiring ∼36 seconds of cine acquisition time.

Although fluoroscopy time and cine acquisition time are the most important modifiable parameters that determine patient and operator exposure, the operator’s position with respect to the x-ray source is also an important determinant of operator exposure. These issues are addressed in the study by Sciahbasi et al⁹ reported in this issue of *Circulation: Cardiovascular Interventions*. The study addresses the question of whether vascular access by 1 radial artery is superior to access through the other. Although the study finds no difference between the 2 approaches, its more important contribution is that it provides one of the most comprehensive measurements of both patient and operator radiation exposure published to date and demonstrates exemplary exposure control.

The procedures reported in the Sciahbasi et al⁹ article, all performed using radial artery vascular access, had a mean fluoroscopy time of 132 seconds for coronary arteriography, yielding a mean dose-area product of 30 Gy·cm² and a mean effective dose of 7.8 mSv, which is considerably smaller than typical doses for nuclear cardiology studies and cardiovascular CT angiography. The values for percutaneous coronary intervention procedures were similarly low: mean fluoroscopy time, 365 seconds; mean dose-area product, 59 Gy·cm²; mean effective dose, 15.3 mSv. These values are substantially lower than values reported by Jolly et al¹⁰ in the recently reported Radial vs Femoral Access for Coronary Intervention trial, which was a randomized comparison of femoral versus radial access for percutaneous coronary intervention (mean fluoroscopy time, 588 seconds).

Jolly et al¹⁰ reported that fluoroscopy times and patient exposures were 20% less when the femoral route was used, suggesting that the femoral route has an advantage over the radial route in terms of both patient and operator exposure. However, the fluoroscopy times through the radial route reported by Sciahbasi et al⁹ were substantially shorter than either the radial or the femoral route fluoroscopy times reported by Jolly et al. The femoral access fluoroscopy times reported by Jolly et al were longer than the radial access fluoroscopy times reported by Sciahbasi et al. These findings indicate that physician-operator experience and skill are the principal exposure-determining variables. The physicians who performed the procedures reported by Sciahbasi et al were highly proficient. Their fluoroscopy times and procedure doses are among the lowest values reported and likely represent the best values achievable with current technology.

Sciahbasi et al⁹ also made rigorous measurements of operator radiation exposure. Operators were monitored with dosimeters located at the left wrist, the left shoulder, the middle thorax outside the lead apron, the middle thorax under the lead apron, and the thyroid level outside the lead collar. This measurement protocol assessed the radiation dose incident to the operator outside the protective lead garments as well as the exposure to the thorax underneath the protective garments. Happily, the operator exposures were small, and exposure underneath the protective garments was undetectable. It is noteworthy that the operators used all available radiation protection strategies, the most important of which probably is the ceiling-suspended radiation shield.¹¹ These findings are reassuring, indicating that exemplary technique and careful attention to radiation protection practices can achieve acceptably low physician-operator occupational exposures.

Sciahbasi et al⁹ demonstrate that exemplary operator technique and assiduous attention to radiation protection practices enable cardiovascular angiography to be performed with gratifyingly small magnitudes of patient and operator radiation exposure. These practices optimize the potential patient benefit of these procedures by minimizing the radiation exposure risk. Their accomplishments constitute a standard to which all practitioners should aspire.

**Disclosures**

None.
References


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