The ever-increasing global concerns for environmental threats, among which is public radiation exposure, are quite appropriate. Medical applications of radiation appear to contribute significantly to the overall radiation-related hazard. Kaul et al.1 remind us that the collective radiation dose from medical imaging has increased by a factor 7 over the last 2 decades. Skeptics have observed that this evolution in practice is not matched by a proportionate improvement in outcomes. Each time another critical study on radiation-induced projected risk of cancer appears in the scientific literature, this publication triggers commentaries, position statements, and reports of all kinds, including in the lay press, eventually fueling the growing concerns in the community. The understandable emotional nature of the issue may amplify the perceived risk and cause irrational behaviors. Patients may refuse to undergo radiation-based diagnostic or therapeutic procedures out of fear, underestimating the risk they are presently exposed to and failing to fully appreciate the consequences of not being diagnosed or treated properly right now.

**Radiation Exposure in Patients With Myocardial Infarction**

The present analysis of radiation exposure to patients treated for acute myocardial infarction1 by the Duke Clinical Research Institute and the University Health System Consortium provides useful insights and illustrates a novel way forward in addressing this essential issue. The authors have identified >275,000 radiation-based procedures performed in nearly 65,000 patients with acute myocardial infarction treated in 49 academic hospitals over a 3-year period. The average in-hospital stay was 6 days, and the cumulative radiation dose was \( \approx 15 \) mSv, which is 5 times the annual background level and a third of the annual limit for radiation workers. Few patients (2% of all cases) received a 50-mSv dose, which is the tolerated yearly maximum for radiation workers. In addition to modest local and regional variations, the main independent predictors of higher exposure were in-hospital complications, especially procedure-related bleeding events, resulting in increased use of noncardiac computed tomography scans. Findings were adjusted for clinical complexity through the use of the severity of illness score. Higher exposure was associated with increased severity of illness scores and increased mortality rates at 1 month, except for invasive angiography and percutaneous intervention. Indeed, patients undergoing revascularization had higher exposure but lower mortality.

The authors recognize 2 potentially significant limitations to their study. The factual data were collected retrospectively and are based on billing claims and International Classification of Diseases, ninth revision, codes, with no verification of source data applied. Effective radiation dose was estimated, not measured, assigning to each test an estimated mean exposure value from the literature. This approach is commonly used and seems appropriate. Large variations in radiation exposure have been reported mostly for cardiac computed tomography, representing only 1% of the total number of examinations and used in 2.6% of patients in this study. The authors also mention that their findings pertain only to academic institutions and their affiliated hospitals.

The study results are largely reassuring. Radiation exposure was justified by and in proportion to the severity of the illness. Increased radiation exposure is driven primarily by the treatment of complications. In this high-risk subset of patients, the measurable short-term benefit that results from adequate diagnosis and therapy, even if radiation based, outweighs by far the projected incremental risk of cancer caused by radiation exposure.

Thus, in patients with severe disease, an overly cautious attitude that would prevent doctors from prescribing and patients from undergoing the appropriate tests and therapies might be deleterious by exposing the patient to immediate danger out of fear for a potential, distant side effect. A similar extreme situation refers to cardiac transplantation for terminal heart failure. We know that the likelihood of developing malignancies and lymphomas as a result of long-term immune suppression is very high, yet nobody questions the appropriateness of cardiac replacement therapy.

**Moving Forward**

In keeping with the “as low as reasonably achievable” principles that recommend reducing radiation burden as much as possible without compromising the delivery of proper diagnosis or care, the authors are proposing a new, very innovative, proactive approach: assessing the total cumulative radiation exposure per episode of care.

Several valuable strategies have been recommended so far, aiming at increasing the awareness of the various stakeholders who are involved in the process: the industry constantly striving to introduce technological developments that reduce radiation doses; the doctor who prescribes the test or therapy,
who can rely on published appropriateness criteria of use; the doctor who performs the test or therapy, who should make best possible use of available technology and implement technological advances that reduce radiation exposure; and the patient or subject undergoing the test or therapy, who should be accurately informed about the balance between benefit and risks.

In addition to the above mentioned strategies, the authors are proposing that the cumulative exposure that is delivered at the occasion of a finite episode of care should be assessed. The limitations of focusing exclusively on reducing the radiation delivered at the occasion of a single examination are obvious. Physicians are often unaware of similar tests being performed earlier or elsewhere. Comorbidities or complications often require the involvement of specialists in other disciplines, who may also be prescribing radiation-based procedures. To apply the proposed new metric prospectively, contributions from all caregivers will be required as the patient tracks on the pathway that addresses his or her condition. In addition, priority will be given to nonionizing approaches when equally effective options are available.

For instance, when treating a patient presenting with acute myocardial infarction, the proposed approach will require the team to consider choices between radiation-based and radiation-free methods for evaluation of ventricular function. It is surprising that a multigated acquisition blood pool scan was used in 5.8% of patients, accounting for 4% of all tests, when left ventricular angiography can be performed during the initial catheterization or noninvasively at any time period using radiation-free echocardiography. In patients with multivessel disease, revascularization during the initial catheterization is usually restricted to the culprit coronary stenosis. Stress testing, often combined with nuclear imaging (3% of all tests and 4.8% of patients in this study), is used to identify residual ischemia that may require treatment of additional stenoses during a secondary invasive procedure, performed at an interval. As an alternative, hemodynamically significant stenoses can be easily identified by applying pressure-derived fractional flow reserve measurements at the end of the initial invasive procedure. For measuring up to 3 additional stenoses, the fractional flow reserve approach requires the use of an additional 50 mL contrast, prolongs the catheterization by 9 minutes, and adds 4 mSv of patient exposure (one third of the exposure required for a nuclear stress test). Most important, the team will be encouraged to develop strategies that reduce bleeding complications and the domino effects that are associated with such complications in terms of worsening outcomes but also increased radiation exposure.

The same reasoning can be applied to other care pathways addressing various clinical presentations and shows great potential for changing practices and true implementation of the “as low as reasonably achievable” principles.

**Patient Information, Monitoring Individual Cumulative Exposure, and Late Effects**

As mentioned, adequate patient information is essential to guarantee proper delivery of care to the critically ill patient or any patient whose disease carries significant risk. The balance between benefit and risks becomes potentially less favorable when addressing radiation-based therapies such as ablative procedures for paroxysmal atrial fibrillation, diagnostic testing in subjects with suspected coronary artery disease, and coronary and chest computed tomography scanning for “ruling out” purposes or, certainly, screening for coronary artery disease in the worried, well, normal subject.

Although Kaul et al discuss only the situation of acute myocardial infarction, one could certainly apply the analysis model they are proposing to the above-mentioned care or diagnostic pathways, among others.

When benefit becomes less immediate, large and long-term outcome studies addressing both efficacy and safety endpoints will be required to justify any level of radiation exposure. At present, information on radiation-induced cancer is available from the study of populations exposed to external radiation or to incorporated radionuclides. We should remember that the childhood thyroid gland, premenopausal female breast, and bone marrow are the most radiosensitive organs in the body.

The Japanese atomic bomb survivor data are relevant to the present study. Indeed, the majority of survivors were exposed to low doses of radiation. Close to 70% of the 86 572 individuals was exposed to <50 mSv. After exposure to 100 mSv, the risk of radiation-induced cancer is predicted to be 1.05 or an excess of 5%. An increased risk of dying of cancer was still seen after exposure to <50 mSv, which is somewhat comparable to the range of doses delivered to patients in the present survey. There has been considerable debate on the possibility of a threshold dose below which there is no excess risk. The supposed threshold being 0 Sv led to an upper limit to the confidence interval of 60 mSv in the latest survey. Although Kaul et al discuss only the situation of acute myocardial infarction, one could certainly apply the analysis model they are proposing to the above-mentioned care or diagnostic pathways, among others.

Beside the doses, other factors need to be considered. Among Japanese survivors of atomic bombings, the highest risk of thyroid cancer was found among those exposed before 10 years of age. There was a significant delay between exposure and cancer onset; the highest risk was 15 to 29 years after exposure but still increased after 40 years. Individuals >20 years of age at the time of the blast had no excess of thyroid cancer. In the survey by Kaul et al, only 0.5% of the patient population was <30 years of age; 85% of the population was >50 years of age. Because the risk of cancer would possibly appear 15 to 30 years after radiation exposure, the excess of cancer onset could be difficult to detect.

The only way to obtain an objective assessment of the issue of radiation-induced cancers in cardiology practice would be to combine systematic dosimetric measurements with an epidemiological survey. Keeping track of cumulative exposure of individual subjects, especially those of young age and female gender, through the use of smart cards or electronically available records may prove useful. In the absence of such tangible data, patient and public information will continue to rely on estimates of cancer risk obtained from current epidemiological data.

In closing, we would like to emphasize the concluding statements by Kaul et al:

“We propose that rather than considering effective radiation exposure in isolation for a given imaging test, efforts should be made at documenting real-time total exposure per episode of care for a given diagnosis, such as acute myocar-
dial infarction. This paradigm has the greatest potential to inform decisions and change the care of AMI patients. Finally, effective radiation exposure per episode of care represents a potential safety metric for patients with common clinical conditions.”

This proposition is an essential contribution that scientific societies and regulatory bodies should carefully consider for incorporation into their guidelines and advisory documents. Physicians may want to consider applying the proposed approach to disease presentations involving radiation for diagnosis, treatment, or both. In this way, patients suffering from cardiovascular disease can be reassured that the radiation doses to which they are exposed are relatively low, bearing a low risk of radiation-induced cancer; that technological developments constantly aim at reducing the radiation burden; and that physicians are actively seeking to minimize radiation exposure levels to their patients.

Disclosures

None.

References


Key Words: Editorials ■ myocardial infarction ■ radiation risk ■ revascularization