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EDITORIAL COMMENT

Women Image Wisely

The 3 mSv Challenge for Nuclear Cardiology*

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In 2009, the National Council on Radiation Protection and Measurements report 160 on ionizing radiation exposure in the United States made a striking observation that the population exposure from medical diagnostic procedures had increased by nearly a factor of 6 since 1982, due largely to the increased use of x-ray computed tomography (CT) and nuclear medicine imaging, mainly in cardiac patients with known or suspected coronary artery disease (CAD) (1). As a result of the increase from approximately 0.5 to 3.0 mSv/year, the average adult living in the United States was receiving a total annual radiation dose approximately double that of the natural background value of 3 mSv/year (~50% from x-ray CT and 25% from nuclear medicine imaging). This prompted a large number of public awareness, educational, and dose reduction campaigns such as the Image Wisely program by professional societies, standards organizations, and health care regulators. The paper by Shi et al. (2), in this issue of *iJACC* is the fourth in a series of reports from the International Atomic Energy Agency-sponsored INCAPS (IAEA Nuclear Cardiology Protocols Cross-Sectional Study) study, which surveyed the use of stress myocardial perfusion imaging (MPI) at nuclear cardiology laboratories in 65 countries during a 1-month period in 2013 (2). The primary outcomes paper reported on the regional variations in stress MPI practice, including the fact that women typically received a slightly lower radiation dose than men (−0.3 mSv), after adjusting for factors such as age and body weight. On a global scale, it is very encouraging to see that the observed radiation doses are not very different in women than in men and indeed may be slightly lower.

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WHERE ARE WE NOW?

The study by Shi et al. (2) sought to uncover the factors contributing to this apparent sex difference in the use of stress MPI across 6 regions of the world, given that there are some known sex-specific effects on patient referrals to MPI, image quality, and radiation sensitivity. In all regions, the proportion of women referred for MPI was approximately 40% (38% to 45%), but in some individual countries the proportion was below 25%. This is generally consistent with the known lower risk of cardiovascular diseases in women than in men but also suggests that women in some countries, who might otherwise benefit, are not being referred for this valuable test.

There were significant geographical variations in radiation dose, demonstrating the largest differences between women and men in Europe, Africa, and Asia (−1 mSv) and the smallest differences (−0.3 mSv) in North America and Oceana. However, in some individual countries, again, doses were actually higher in women, contrary to the global trend. There is some evidence to suggest that the risk of cancer may be higher in women, particularly with the use of Tc-99m single-photon emission CT (SPECT) MPI in younger patients (**Figure 1**) as reported in the recent American Heart Association (AHA) scientific statement on Approaches to Enhancing Radiation Safety in Cardiovascular Imaging (3). Continued efforts to reduce these risks should be pursued, in line with the universally accepted dogma to decrease patient radiation doses to levels that are as low as reasonably achievable (ALARA). The authors are commended

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From the Department of Cardiac Imaging, University of Ottawa Heart Institute, Ottawa, Ontario, Canada. Dr. deKemp has licensed Rubidium PET technology to Jubilant DraxImage; and has received technology license revenues from Jubilant DraxImage and INVIA Medical. Dr. Wells has had a research collaboration with and received honoraria for speaking at user meetings from GE Healthcare; and has conducted a research study for Advanced Accelerator Applications. Dr. Beanlands has served as a Consultant for Lantheus Medical Imaging and Jubilant DRAXImage; and has received research grants from GE Healthcare, Lantheus Medical Imaging, and Jubilant DRAXImage.

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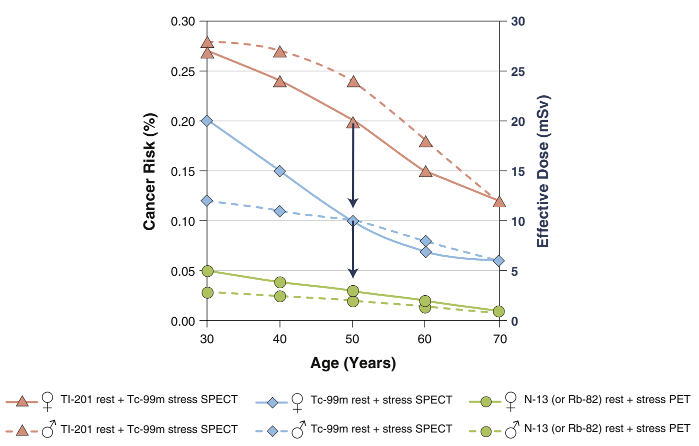
FIGURE 1 Cancer Risk in Men and Women



Cancer risk in men (♂) and women (♀) as a function of age for different myocardial perfusion imaging tracers and protocols. Using Tc-99m instead of Tl-201 SPECT decreases the radiation effective dose **(arrows)** and cancer risk by a factor of 2. Further reduction by a factor of 2 to 3 is achieved by using current PET tracers.

for evaluating the imaging protocols and technical factors contributing to radiation dose (and dose reduction) around the world.

The MPI protocols and technical factors contributing to the recommended 'best practices' were evaluated by the authors to determine their effects on radiation dose in women versus men. In particular, they found that women were ~50% more likely to benefit from stress-only imaging (avoiding the rest scan following a normal stress-first study) and 40% to 50% less likely to receive the higher dose Tl-201 stress or dual-isotope tracer studies. However, camera-based dose reduction technologies were used 25% less frequently in women. Indeed, when these factors were included in the statistical analysis model, the small sex effect was no longer significant, confirming the value of these best practices for dose reduction in women. The greater use of camera-based technologies in men, suggests that additional dose reduction may still be possible in women with further exploitation of these methods (attenuation correction, supine plus prone imaging, advanced hardware [PET, solid-state SPECT], and advanced iterative reconstruction software). It is important to note that attenuation correction was not recorded at the patient level, but rather considered as a laboratory-dependent dose-reduction factor likely to facilitate stress-first or stress-only imaging. It is well recognized that attenuation correction (AC) should be performed when a dose reduction strategy of stress-first perfusion imaging is used, but this was not mandated in the present cross-sectional study; therefore the reported stress-only dose reductions may not translate exactly to those labs using AC-stress-first SPECT imaging protocols. Weight-based doses were also not evaluated at the patient level as a dose-reduction technique but rather at the laboratory level based on a significant correlation between injected activity and weight. The specific implementations and consistency of weight-based dosages were not evaluated but would be important in recommending an effective method for widespread clinical application.

The authors did not report the proportion of women compared to men with radiation doses below 9 mSv, according to the 2014 target recommended by the American Society for Nuclear Cardiology (ASNC) in 2010 (4). Their original paper reported that only approximately 40% of patients had achieved this target dose worldwide in 2013, with the highest adoption rate in Europe (60%) and the lowest in North America (30%) (5). This suggests that we can learn much from our European colleagues, educators, and regulators about implementing these existing and proven dose reduction strategies further.

WHERE DO WE GO FROM HERE?

The x-ray CT imaging community, including health care providers and equipment manufacturers, have been very active in promoting the development and use of lower-dose scanners and protocols. The Joint Commission on Diagnostic Imaging Requirements recently published guidelines for diagnostic imaging facilities that now require radiation dose index values (e.g., dose length product [DLP] or computed tomography dose index [CTDI]) to be recorded for every patient and compared to current clinical standards (e.g., dose reference level [DRL] values) to help promote dose reduction in CT (5). In support of this effort, the American College of Radiology (ACR) has implemented the Dose Index Registry (DIR) that allows facilities to compare their CT dose indices to regional and national values (6).

The Joint Commission and ASNC should be encouraged to expand these positive efforts of the CT imaging community into the nuclear cardiology domain and require that patient-specific records of injected activity be maintained at all imaging centers and then collected and analyzed centrally to monitor and promote continuous quality improvement in dose reduction by publishing laboratory-specific results. In the current era of patient-centered imaging, patients should be provided with easy (e.g., online) access to this essential health information (7). The same consensus conference paper recommended a target level of <3 mSv for cardiac imaging procedures, a value similar to the annual natural background which may be considered "very low dose" and not requiring an extended risk-benefit discussion with patients. As illustrated in **Figure 1**, great progress has been made in nuclear cardiology by recommending against the widespread use of Tl-201 SPECT in favor of Tc-99m perfusion tracers, with a much lower average radiation dose today of ~10 mSv than 20 to 25 mSv received historically, using Tl-201. Still, this is far from the target of <3 mSv, which is currently achieved only when using PET imaging technology with tracers such as N-13-ammonia and Rb-82. ASNC has recognized the increased value of PET in nuclear cardiology, due to several technical advantages leading to improved accuracy, higher certainty of diagnosis, ability to quantify myocardial blood flow and flow reserve, as well as lower radiation dosimetry compared to SPECT (8). The use of quantitative flow reserve to identify microvascular dysfunction may be especially relevant in patients with heart failure with preserved ejection fraction, a disease with increasing prevalence that is also more common in women (9).

Positron emission tomography (PET) imaging remains substantially more expensive than SPECT and is much less available than the large installed base of SPECT scanners worldwide. The use of cardiac PET is increasing, but other methods are still needed to help continue the trend in dose reduction. We and others have shown that consistent use of advanced iterative SPECT reconstruction algorithms can be used to implement half-time (or half-dose) MPI without loss of accuracy, potentially resulting in a mean radiation dose of ~5 mSv across the entire patient population by using existing SPECT technology (10). The recent introduction of high-sensitivity solid-state SPECT cameras should help to reduce doses further; the higher equipment cost can be partially offset by the use of lower tracer activity. Further development and deployment of these advanced software and hardware solutions should be actively promoted by the nuclear cardiology community, in addition to current imaging protocol recommendations (e.g., stress-first, avoiding Tl-201) to eventually reduce the average radiation dose for MPI below 3 mSv.

The ImageGuide registry (11) is well positioned to help facilitate this culture of dose reduction in nuclear cardiology. The registry was launched by ASNC in 2015 to help physicians comply with the Centers for Medicare and Medicaid Services Physician Quality Reporting System requirements in the United States but does not yet report or publish dose index information such as patient injected activity (11). Professional societies such as ASNC, ACR, and the Society of Nuclear Medicine and Molecular Imaging (SNMMI) are also encouraged to set procedure dose reference levels and patient dose reduction targets for stress MPI (e.g., <5 mSv by 2020 and <3 mSv by 2025) as requirements for laboratory accreditation, typically required for reimbursement by health care insurers. With these policies and practices in place, we will be well-positioned to reduce MPI doses down to <3 mSv within the next few years, and promote the appropriate first-line use of this proven diagnostic technology for the diagnosis and management of CAD and other cardiovascular diseases.

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