It's about time we think about lowering radiation dose in obese patients too

Daniel A Kim, MD,[a] Mary Beth Farrell, MS,[b] and Scott D. Jerome, DO[c]

[a] University of Maryland School of Medicine, Baltimore, MD
[b] Intersocietal Accreditation Commission, Ellicott City, MD
[c] Division of Cardiovascular Medicine, University of Maryland School of Medicine, Baltimore, MD

Received Aug 1, 2016; accepted Aug 2, 2016
doi:10.1007/s12350-016-0636-7

See related article, pp. 1912–1921

Medical technology has advanced at a rapid pace, particularly, the diagnostic imaging tools relied upon daily to care for patients. Myocardial perfusion imaging (MPI) uses advanced technology and radiopharmaceuticals to detect, assess, and risk-stratify ischemic heart disease.[1,2] The level of radiation exposure from these scans is often higher than other diagnostic imaging procedures.[3] Patients and health care providers are increasingly more aware of and concerned about the potential health risks associated with radiation exposure.[4] It is, therefore, prudent that the radiation dose from diagnostic imaging scans be kept as low as possible while maximizing image quality. Therein lies the problem.

If we were to construct the ideal radiation reduction strategy, it would be adaptable to patients of all ages, body habitus, ambulatory status, and admission state. Protocols should be flexible for both patients and laboratories while hopefully improving workflow. Expensive hardware and software would not be required, and there should be associated cost savings. All of this must be accomplished while concomitantly producing high-quality images that can be confidently used to make the correct diagnosis.

To address concerns related to radiation, the American Society of Nuclear Cardiology (ASNC) published several recommendations for reducing radiation dose.[5-7] Suggested approaches include utilization of appropriate use criteria, stress-only imaging, limited use of a dual isotope protocol, and PET imaging, where appropriate. Other approaches rely on recent improvements in camera hardware and software such as high-sensitivity cadmium zinc telluride (CZT) solid-state detectors and iterative reconstruction resolution recovery algorithms, which can allow injection of less radiotracer and/or decrease image acquisition time.[8,9] Along with specific techniques for lowering radiation dose, the many recommendations emphasize patient-centered imaging that tailors the imaging protocol specifically to each patient.[10-12]

ASNC specifically advocated reducing radiation exposure such that >50% of a facility's MPI patients receive a total effective dose $\leq$9 mSv.[5] A recent study published by Jerome et al. reviewed 5216 MPI studies performed at 1074 Intersocietal Accreditation Commission accredited facilities in 2012 and 2013.[13] They found most facilities were not meeting this radiation dose goal. They reported the average effective dose was 14.9 ± 5.8 mSv, far above the $\leq$9 mSv goal. Only 1.4% of all laboratories administered $\leq$9 mSv in >50% of cases. Additionally, they found that only 0.4% of studies performed were stress-only, and 7.5% of facilities continued to use the dual isotope protocol. These findings suggest that laboratories still encounter difficulties in routinely lowering radiation dose effectively.

One particular struggle in reducing radiation exposure is obtaining quality images in obese patients at a lower radiation dose. Considering there are over 300 million obese people in the United States and with the number growing, better options to imaging obese patients are promptly needed.[14] Increased body mass results in photon attenuation which decreases the signal-to-noise ratio and increases scatter. The outcome is image noise, artifacts, and nondiagnostic results.[15,16]

Reprint requests: Mary Beth Farrell, MS, Intersocietal Accreditation Commission, Ellicott City, MD; *farrell@intersocietal.org*
J Nucl Cardiol 2017;24:1922–5.
1071-3581/$34.00

The obvious solution is to either increase image acquisition time or increase radiopharmaceutical dose. Both options are not without problems.

Longer acquisition time can lead to increased count density but at the cost of patient comfort. In practice, most patients cannot lie still for more than 20–25 minutes without moving and creating associated motion artifacts. No known measures defining adequate count density exist to help labs determine appropriate time per stop or count density as camera sensitivity and acquisition parameters vary widely.

Likewise, there are no clear guidelines for weight-based dosing in obese patients. Most published recommendations only suggest dosing schemes for lighter-weight patients[5] or dosing using advanced technology instead of conventional SPECT cameras.[17] This issue is so multifaceted that the authors of the 2015 European Association of Nuclear Medicine Guidelines for MPI state that ''it is not possible to make precise recommendations regarding injected activities as hard evidence documenting superior results with certain activities is not available.''[18] The most recent ASNC SPECT Imaging Guidelines are also noncommittal with regard to dosing strategies for obese patients.[19] The guidelines suggest, ''as a strategy to be considered,'' a two-day protocol for patients weighing more than 250 lbs. using 18 to 30 mCi of a Tc99m tracer administered each day. A one-day protocol can also be followed using 10 mCi of Tc99m for patients with a BMI 30 to 35 kg/m^2 or 12 mCi for patients with a BMI >35 kg/m^2 for the first dose and three times the amount used for the second dose. The recommendations also suggest the substitution of PET in place of SPECT imaging for overweight patients as an option. Clearly, there is no consensus on the best approach.

In the current issue of Journal of Nuclear Cardiology, Oddstig et al. tackled the question of reducing radiation dose by evaluating a linear weight-adjusted low-dose protocol for obese patients. Based on their prior study of a low-dose protocol for nonobese patients using 2.5 MBq/kg body weight, they projected this concept for patients who were obese in an attempt to expand the 2.5 MBq/kg to all types of patients.[20] In this prospective study, patients weighing less than 110 kg received 2.5 MBq/kg of 99Tc-tetrofosmin, while for patients weighing 110 to 120 kg and >120 kg, a fixed dose of 430 and 570 MBq, respectively, were used. Images were obtained using a conventional gamma camera with resolution recovery software or a newer CZT cameras, with about half of the subjects imaged in each of the two groups.

A subgroup consisting of sixteen patients with body weights over 110 kg were resampled into a reduced acquisition time based on a mathematical calculation that corresponded to an administered activity of 2.5 MBq/kg. Those that received a reduced imaging time were found to have total counts in the left ventricle that were similar to counts from the nonobese patients who received the same dose. Two blinded observers measured perceived quality and found the quality between the fixed dose and shorter imaging time to be identical. Given these findings, Oddstig et al. concluded that the traditional higher administered activity and prolonged acquisition time for obese patients were not necessary to obtain an adequate myocardial perfusion study in terms of image quality and ischemia quantification.

This innovative dosing scheme is to be commended, but it is not without limitations. First, the results are a theoretical representation of a proof of concept. In the methods, the investigators did not acquire actual images from lower administered radiotracer doses. Count rates were simulated using the acquired count rate; then, a new acquisition time was calculated to correspond to the number of counts that would have been acquired if the administered activity was 2.5 MBq/kg.

The authors acknowledge that the study only examined four patients with a weight of >120 kg on the CZT camera due to positioning challenges. The overall number of obese patients was still small at 33 patients, and those patients had a wide range of BMIs (31 to 58 kg/m^2).

Thirdly, the investigators imaged patients using a GE Discovery 530 CZT camera and GE Ventri conventional camera with resolution recovery reconstruction. Both cameras models are relatively new on the market, utilizing state-of-the-art technology. In 2013, Bateman et al. reported an average camera age of 7.7 ± 4.8 years.[21] A recent query of the Intersocietal Accreditation Commission database shows that the average camera age of facilities applying for accreditation in 2015 was 11.5 ± 5.1 years. Therefore, in order for the results of this study to apply to a majority of facilities, the results would need to be validated on a wide variety of camera types which are in use by most laboratories.

The proposed dosing scheme also may be limited in terms of practicality. Administering an exact dose of radiotracer may be problematic. Calibration of smaller doses may limit flexibility and negatively affect the ability to administer doses to patients who arrive late for their study. In addition, adhesion of both Tc99m radiopharmaceuticals to the syringe can be problematic. A recent study suggested that 20.1% ± 8.0% of the sestamibi dose can remain in the syringe.[22] Dispensing the hypothesized lower amount proposed by Oddstig et al. could result in actual administered doses less than intended and risk compromising image quality. This could be compounded because most facilities in the United States utilize delivered unit doses. Finally, Jerome et al. found that most labs routinely use 10 and 30 mCi Tc99m MPI doses for all patients.[13] The new dosing scheme would require labs to obtain height and weight and then calculate the exact dose to be ordered. This would create a small, albeit noticeable amount of additional work for technologists and potential loss of flexibility. All of these practical limitations are surmountable but would need to be considered by a laboratory prior to implementation.

The intention of this study was to achieve a reduction in radiation dose given to the obese patient. With the hypothesized approach of administering a lower dose, which the authors have shown works in ''normal'' weight patients as well as obese patients, there is an unintended benefit of using less Tc99m overall—even worldwide. In the recent past, we suffered Tc99m shortages, and another shortage may gloom our future.[23] If the author's strategy proves to be effective and adopted widely, further study of the amount of Tc99m usage throughout the world needs to be looked at as this may have a major impact on the supply/demand and future generator production.

In summary, before the hypothesized, 2.5 MBq/kg administration schedule can be added to the arsenal of radiation reduction techniques, further dedicated research is needed to confirm the practicality of this approach, the maintenance of image quality and accuracy. Studies need to be performed actually administering the proposed individual weight-based dose and overcoming the challenges cited above. The investigators are to be congratulated for ''thinking outside of the box'' and proposing a novel method to lower radiation dose, especially in obese patients where there is a performance gap. In their study, they were mindful of the effect of lower doses on image quality, reinforcing that image quality must never be jeopardized at the expense of lowering dose. Their proposed dosing strategy follows the principles of patient-centered imaging and is another step toward the goal of personalized medicine. The results of this study appear to be promising in reducing radiation dose for obese patients, and research on additional strategies to lower and standardize radiation doses in obese patients is encouraged.

References

1. Klocke FJ, Baird MG, Lorell BH, et al. ACC/AHA/ASNC guidelines for the clinical use of cardiac radionuclide imaging–executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (ACC/AHA/ASNC Committee to Revise the 1995 Guidelines for the Clinical Use of Cardiac Radionuclide Imaging). Circulation 2003;108:1404–18.
2. Holly TA, Abbott BG, Al-Mallah M, et al. Single photon-emission computed tomography. J Nucl Cardiol 2010;17:941–73.
3. Chen J, Einstein AJ, Fazel R, et al. Cumulative exposure to ionizing radiation from diagnostic and therapeutic cardiac imaging procedures: a population-based analysis. J Am Coll Cardiol 2010;56:702–11.
4. Fazel R, Shaw LJ. Radiation exposure from radionuclide myocardial perfusion imaging: concerns and solutions. J Nucl Cardiol 2011;18:562–5.
5. Cerqueira MD, Allman KC, Ficaro EP, et al. Recommendations for reducing radiation exposure in myocardial perfusion imaging. J Nucl Cardiol 2010;17:709–18.
6. Dorbala S, Blankstein R, Skali H, et al. Approaches to reducing radiation dose from radionuclide myocardial perfusion imaging. J Nucl Med 2015;56:592–9.
7. Fazel R, Gerber TC, Balter S, et al. Approaches to enhancing radiation safety in cardiovascular imaging: a scientific statement from the American Heart Association. Circulation 2014;130:1730–48.
8. Pagnanelli R, Borges-Neto S. Technical aspects of resolution recovery reconstruction. J Nucl Cardiol 2016;23:149–52.
9. Einstein AJ, Blankstein R, Andrews H, et al. Comparison of image quality, myocardial perfusion, and left ventricular function between standard imaging and single-injection ultra-low-dose imaging using a high-efficiency SPECT camera: the MILLI-SIEVERT study. J Nucl Med 2014;55:1430–7.
10. Einstein AJ, Berman DS, Min JK, et al. Patient-centered imaging: shared decision making for cardiac imaging procedures with exposure to ionizing radiation. J Am Coll Cardiol 2014;63:1480–9.
11. Walsh MN, Bove AA, Cross RR, et al. ACCF 2012 health policy statement on patient-centered care in cardiovascular medicine: a report of the American College of Cardiology Foundation Clinical Quality Committee. J Am Coll Cardiol 2012;59:2125–43.
12. Depuey EG, Mahmarian JJ, Miller TD, et al. Patient-centered imaging. J Nucl Cardiol 2012;19:185–215.
13. Jerome SD, Tilkemeier PL, Farrell MB, Shaw LJ. Nationwide laboratory adherence to myocardial perfusion imaging radiation dose reduction practices: a report from the intersocietal accreditation commission data repository. JACC Cardiovasc Imaging 2015;8:1170–6.
14. Duvall WL, Croft LB, Corriel JS, et al. SPECT myocardial perfusion imaging in morbidly obese patients: image quality, hemodynamic response to pharmacologic stress, and diagnostic and prognostic value. J Nucl Cardiol 2006;13:202–9.
15. Wackers FJ. Cardiac single-photon emission computed tomography myocardial perfusion imaging: finally up to speed? J Am Coll Cardiol 2010;55:1975–8.
16. Burrell S, MacDonald A. Artifacts and pitfalls in myocardial perfusion imaging. J Nucl Med Technol 2006;34:193–211.
17. Marcassa C, Zoccarato O, Calza P, Campini R. Temporal evolution of administered activity in cardiac gated SPECT and patients' effective dose: analysis of an historical series. Eur J Nucl Med Mol Imaging 2013;40:325–30.
18. Verberne HJ, Acampa W, Anagnostopoulos C, et al. EANM procedural guidelines for radionuclide myocardial perfusion imaging with SPECT and SPECT/CT: 2015 revision. Eur J Nucl Med Mol Imaging 2015;42:1929–40.
19. Henzlova MJ, Duvall WL, Einstein AJ, Travin MI, Verberne HJ. ASNC imaging guidelines for SPECT nuclear cardiology procedures: Stress, protocols, and tracers. J Nucl Cardiol 2016;23:606–39.
20. Oddstig J, Hedeer F, Jogi J, Carlsson M, Hindorf C, Engblom H. Reduced administered activity, reduced acquisition time, and

preserved image quality for the new CZT camera. J Nucl Cardiol 2013;20:38–44.
21. Patil H, Abdallah M, Bateman T. Correlates between camera age, patient volume, and laboratory accreditation: A snapshot of equipment utilization in the practice of nuclear cardiology in the US. J Nucl Med 2013;54:516.
22. Swanson TN, Troung DT, Paulsen A, Hruska CB, O'Connor MK. Adsorption of 99mTc-sestamibi onto plastic syringes: evaluation of factors affecting the degree of adsorption and their impact on clinical studies. J Nucl Med Technol 2013;41:247–52.
23. Thomas GS, Maddahi J. The technetium shortage. J Nucl Cardiol 2010;17:993–8.