Optimizing radionuclide protocols: Dotting our I's and crossing our T's

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Received May 2, 2018; accepted May 2, 2018
doi:10.1007/s12350-018-1297-5

See related article, pp. 1869–1874

The last decade has seen rapid growth in diagnostic imaging volumes and high radiation dose incurred by many cardiovascular imaging tests. This has resulted in heightened scrutiny about ionizing radiation exposure from cardiac imaging. Per-capita annual radiation exposure from medical imaging has increased sixfold from 1980 to 2006.[1] Radionuclide myocardial perfusion imaging (MPI) studies have been implicated as having the second highest radiation exposure amongst all diagnostic imaging studies and account for nearly one-quarter of the medical exposure to the US population.[1–3] In response to these concerns, the American Society of Nuclear Cardiology (ASNC) published a position statement recommending MPI imaging adhere to the ALARA (''as low as reasonably achievable'') principle.[4] Subsequently, in 2012, recommendations were made to pursue patient-centered imaging, including administration of weight-based radioisotope dosage to reduce radiation exposure.[5] Imagers experience a constant struggle to strike a balance between reducing effective radiation dose to patients and maintaining adequate count statistics for diagnostic image quality, one often at the expense of the other, particularly in obese patients. The advent of scanner hardware innovations coupled with improvements in image reconstruction and radiotracer development have resulted in significant improvements in image quality in addition to dose reduction with MPI imaging.[5]

Increased availability of positron emission tomography (PET) scanners and generator-produced perfusion tracers such as rubidium-82 (^{82}Rb) have also resulted in more widespread clinical utilization of PET imaging for assessment of myocardial ischemia. PET imaging has high accuracy for detection of coronary disease and offers incremental prognostic value to clinical variables.[5] Compared to single positron emission computed tomography (SPECT) imaging, PET imaging offers inbuilt attenuation correction, higher spatial resolution, and the ability to quantify myocardial blood flow, despite significantly lower radiation doses. Given these advantages, PET MPI imaging is particularly favorable for women, obese, and younger patients.[5] Innovations in PET technology have allowed for ongoing improvements in image quality and reduction in radiation exposure. Developments in PET hardware include use of time of flight imaging in 3D mode; new detector material such as lutetium-based crystals (LSO and LYSO) with excellent stopping power at higher energy resolution; addition of CT for more accurate and faster attenuation correction; more compact silicone photomultipliers with improved photon amplification and higher spatial resolution; and faster computing hardware.[6] Advancements in PET software reconstruction algorithms have also resulted in significantly improved image quality, and subsequently lower radiotracer administration. Iterative reconstruction algorithms for attenuation correction, motion correction, scatter rejection, and dead-time assessment are gaining popularity. Furthermore, continuous image acquisition techniques are also feasible and allow for even lower radiotracer doses.[4]

In the study titled ''Saline-push improves ^{82}Rb PET image quality,'' Ms. Renaud and colleagues evaluated the additive value of 25-30 mL of saline flush following the ^{82}Rb injection in patients undergoing rest-stress PET

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J Nucl Cardiol 2019;26:1875–7.
1071-3581/$34.00

MPI.[7] The authors report that despite the same eluted ^{82}Rb activity from the generator, the saline-push resulted in a twofold higher activity delivered to the heart, and increased radioisotope retention in the left ventricular myocardium. Furthermore, there was a 25% improvement in the signal-to-noise and contrast-to-noise ratios, ultimately resulting in improved image quality. The saline-push helps flush the infuser tubing, patient intravenous lines, and in vivo venous system between injection site and right atrium of the heart, resulting in accelerated tracer transit to the heart.

^{82}Rb has a very short half-life of 76 seconds and hence requires high initial count rate in the region of interest. A delay in the arrival of ^{82}Rb to the heart (for instance due to varicose veins in the chest or venous thoracic outlet syndrome) results in significant decay of ^{82}Rb before reaching the heart, with resultant reduced count density in the heart, and ultimately impaired image quality.[8] A saline-push technique makes intuitive sense, particularly in patients with low cardiac outputs and delayed venous transits, as highlighted by the Renaud et al.[7]

The variability in adherence and residual activity in an injection system can result in unpredictable delivery of a radiotracer dose to the patient, at times leading to inadequate image count density. This may necessitate a separate radiotracer injection and repeat imaging, thereby exposing the patient to unwarranted radiation exposure. Alternatively, systematically higher prescribed radiotracer doses will result in excess dosage in some patients than diagnostically necessary. Presently, wide variability exists in radiotracer retention in the heart with MPI studies (20-30% for ^{82}Rb and 30-60% for ^{13}N-ammonia).[9] Ensuring more consistency in residual activity has been associated with a 20% reduction in dispensed radiotracer doses, with lower test–retest variance, more reproducible image quality, and higher diagnostic confidence.[10]

The results of the present study are consistent with our existing knowledge from other imaging modalities. A saline flush technique is routinely used for computed tomography and magnetic resonance angiography and helps reduce contrast medium doses by 16-29%.[11] Similar to other modalities, improved positron count statistic in the heart on PET imaging following the saline-push might conceivably allow for reduction in injected dose. Reduced radiotracer administration without increasing scan time will also result in significant cost savings over time and improved throughput of the laboratory.

Knowledge of the exact dose injected in a patient and consistency in residual dose wasted in the delivery process is important to ensure adequate dose injection. Most laboratories only measure the pre-injection calibrated activity and use this as a surrogate for the effective dose injected in the patient. In reality, radiotracers may adhere to the syringe and can falsely overestimate the exposure to radiation.[12] A poor correlation exists between the dispensed dose and injected dose of a radiotracer.[10] Extensive variability (4-32%) in the degree of adhesion of the Technetium-99m sestamibi radiotracer to the syringe is present,[12] in turn translating to variability in the effective dose injected. Ideally, both the pre- and the post-injection radiotracer activity should be monitored. Similar studies are warranted to determine ^{82}Rb or ^{13}N-ammonia adhere to the syringe, intravenous line or infuser tubing.

Quality control efforts need to be mindful of reproducible tracer elution, type of syringe, composition and length of tubing, volume and rate of saline solution for flushing, and residence time of the radiotracer in the tubing and syringe. Although the concept of saline flush appears simple, intuitive, cheap, and effective, it is not explicitly included in the PET or SPECT practice guidelines or uniformly implemented by all nuclear medicine laboratories across the country.[4,5] The authors should be applauded for highlighting a fundamental component of imaging that we may have taken for granted and looked past in day-to-day practice.[7] Purchase of expensive hardware and software is often needed to improve image quality and reduce radiation exposure. However, this is not a substitute for meticulous attention to detail during tracer infusion, image acquisition and analysis, which at times may be right under our nose, and be too obvious. At times the answer involves dotting our I's and crossing our T's.

Disclosure

The author has no conflict of interest to disclose.

References

1. Mettler FA Jr, Bhargavan M, Faulkner K, Gilley DB, Gray JE, Ibbott GS, Lipoti JA, Mahesh M, McCrohan JL, Stabin MG, Thomadsen BR, Yoshizumi TT. Radiologic and nuclear medicine studies in the United States and worldwide: Frequency, radiation dose, and comparison with other radiation sources—1950–2007. Radiology 2009;253:520-31.
2. Einstein AJ. Effects of radiation exposure from cardiac imaging: How good are the data? J Am Coll Cardiol 2012;59:553-65.
3. National Council on Radiation Protection and Measurements. Ionizing radiation exposure of the population of the United States. National Council on Radiation Protection report no. 160. Bethesda, MD: National Council on Radiation Protection and Measurements, 2009.
4. Cerqueira MD, Allman KC, Ficaro EP, Hansen CL, Nichols KJ, Thompson RC, Van Decker WA, Yakovlevitch M. Recommendations for reducing radiation exposure in myocardial perfusion imaging. J Nucl Cardiol 2010;17:709-18.

5. Depuey EG, Mahmarian JJ, Miller TD, Einstein AJ, Hansen CL, Holly TA, Miller EJ, Polk DM, Samuel Wann L. Patient-centered imaging. J Nucl Cardiol 2012;19:185-215.
6. Dilsizian V, Bacharach SL, Beanlands RS, Bergmann SR, Delbeke D, Dorbala S, Gropler RJ, Knuuti J, Schelbert HR, Travin MI. ASNC imaging guidelines/SNMMI procedure standard for positron emission tomography (PET) nuclear cardiology procedures. J Nucl Cardiol 2016;23:1187-226.
7. Renaud JM, Wu KY, Gardner K, Aung M, Beanlands RSB, deKemp RA. Saline-push improves rubidium-82 PET image quality. J Nucl Cardiol 2018. https://doi.org/10.1007/s12350-018-1261-4.
8. Byrne C, Enevoldsen LH, Kjaer A, Hasbak P. Impaired cardiac PET image quality due to delayed (82)Rubidium dose delivery to the heart. J Nucl Cardiol 2016;23:1173-5.
9. Klein R, Ocneanu A, Renaud JM, Ziadi MC, Beanlands RS, deKemp RA. Consistent tracer administration profile improves test-retest repeatability of myocardial blood flow quantification with (82)Rb dynamic PET imaging. J Nucl Cardiol 2016. https://doi.org/10.1007/s12350-016-0698-6.
10. 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.
11. Schindera ST, Nelson RC, Howle L, Nichols E, DeLong DM, Merkle EM. Effect of varying injection rates of a saline chaser on aortic enhancement in CT angiography: Phantom study. Eur Radiol 2008;18:1683-9.
12. Taillefer R. The clinical importance of accurate measurement of injected doses for radionuclide myocardial perfusion imaging. J Nucl Cardiol 2016;23:265-7.