# Dose Reduction in Planar Nuclear Medicine Imaging

**Beth Harkness, MS** *Henry Ford Hospital, Detroit, MI*

In nuclear medicine, the imaging procedure is a combination of radiopharmaceutical selection, injected dosage of radioactivity, collimator selection and imaging time.[1] The goal is to optimize each of the parameters to obtain an image quality that allows the nuclear medicine physician to answer the clinical question. The difficulty is that these parameters are not independent. Changing one parameter will affect the others. In this section, we will address each of these parameters with an eye toward the interdependence and dose reduction. Finally, we will discuss image restoration in planar nuclear medicine.

> Changing one parameter in a nuclear medicine procedure will affect all others. It is critical to understand all of the changes that occur when modifying a single parameter.

## Radiopharmaceutical Selection

There are a variety of radionuclides used in nuclear medicine. The radionuclide used most commonly in nuclear medicine is 99mTc. It is readily available using the 99Mo/99mTc generator, has a monoenergetic gamma emission at 140 keV, has a short half-life of 6 hours, and is easily tagged to chemical forms that allow imaging of many physiologic processes. Other radionuclides such as 131I and 123I, 67Ga, and 201Tl are also used but with much less frequency. They have longer half-lives and higher energy gamma emissions, or in the case of 201Tl, also emit Auger electrons and therefore lead to an increase in the radiation dose even for smaller injected dosages.

In addition, because 99mTc is used so frequently, most nuclear medicine cameras are designed for the imaging of this radionuclide. Thus, the thickness of the NaI(Tl) is commonly 9.5 mm. This results in an intrinsic efficiency of about 92%. As the energy of the photons increase, the linear attenuation coefficient decreases and thus so does the detection efficiency. The selection of radionuclides that have energy close to 140 keV will result in better quality images for less radiation dose. An example would be the use of 123I (160 keV) rather than 131I (364 keV) for the post-surgical evaluation of patients with thyroid cancer.

Finally, some 99mTc radiopharmaceuticals used for the same purpose have different uptake and clearance characteristics that would make one better than the other in terms of radiation dose. For instance, the renal imaging agent 99mTc-MAG3 has higher uptake and more rapid clearance than 99mTc-DTPA which is also used for renal imaging. For the same injected dosage, the 99mTc-MAG3 would be the preferred radiopharmaceutical.

Encouraging patients to drink liquids and void frequently will also help to reduce the radiation dose for radiopharmaceuticals cleared by the kidneys.

## Injected Radioactivity

The amount of radioactivity injected into the patient is directly proportional to the radiation dose delivered. The greater the dosage injected, the higher the radiation dose to the patient. So it is important to consider the clinical question that is being asked and inject an amount of radioactivity that is sufficient to answer the question. For some procedures, one could reduce the injected radioactivity and image longer without a change in image quality. This may be true for static imaging procedures such as a whole-body bone scan, but for other procedures, reducing the injected radioactivity is not as simple. Some dynamic imaging procedures are severely compromised by a reduction in injected radioactivity. Dynamic imaging procedures that have a short time per frame need to have enough counts in each image to visualize the process of interest and not compromise the quantitative results by the analysis of overly noisy data. An example of this would be the 2-phase renal scan. The first phase, used to evaluate perfusion of the kidneys, is usually acquired at 1 second/image. The second phase use to evaluate the renal function is acquired at 30 seconds/image. If one were interested in the perfusion to the kidneys, a higher injected radioactivity would be needed to obtain reasonable quality images than if one were only interested in the renal function. If renal function were the question, a smaller quantity of injected radioactivity could be considered to reduce the radiation dose to the patient.

When assigning a quantity of radioactivity to be injected, the clinical question at hand must be considered. The smallest amount of radioactivity that will provide images that will answer that question should be used.

## Collimator Selection and Imaging Time

The choice of collimators in nuclear medicine is a tradeoff between sensitivity and resolution. Collimators with better resolution typically will have smaller holes and because of this will have lower sensitivity. The converse is true for collimators that are higher in sensitivity; they will have larger holes and thus poorer resolution. In addition, thicker collimators will maintain their resolution as the distance from the collimator increases than will a thinner collimator.[2] The goal is to match the collimator to the imaging task. In general, dynamic images do not require high resolution and can be acquired using a low-energy general purpose (LEGP) or a high sensitivity collimator. Some static images such as lung ventilation and perfusion scans are also lower resolution and could also be acquired using a LEGP collimator. The use of the lower resolution collimator would allow for a shorter imaging time or a reduction in the injected dosage. In general, high resolution studies, such as bone scans, are best done with a higher resolution collimator such as the low-energy high-resolution (LEHR). One would have to image longer if less radioactivity were injected to reduce the absorbed dose.

Finally, the fabrication of collimators varies depending on the manufacturer. One should have a good understanding of the collimators you are using. One manufacturer's low energy all-purpose (LEAP) collimator may have a very similar resolution at 10 cm to another manufacturer's LEHR collimator at the same distance. If the sensitivity of the LEAP were better than the LEHR, it may be the better choice for studies such as the bone scan.

## Image Restoration

Image restoration in nuclear medicine has been of interest for many years. Early attempts were to reduce the noise and improve resolution by the use of deconvolution filters such as the Metz or Weiner filters. Although these filters have been available for many years, they have not been routinely used to improve image quality and allow for the reduction of the injected dosage.[3]

More recently, all camera manufacturers and some software companies have developed software to improve the quality of the nuclear medicine images by implementing algorithms that make use of information about the imaging systems or vary the amount of processing depending on the image content. These approaches can lead to improved image quality with fewer counts. The goal was to allow for faster imaging and increased throughput. These same software programs can also be used, however, to reduce the injected dosage while keeping the imaging time at what was used without the image restoration software. The use of these software packages may provide for as much as a 50% reduction in radiation dose to the patient.

## Summary

Each procedure in nuclear medicine should be reviewed with the goal of reducing patient dose. The lowest injected dosage should be used that will answer the clinical question.  The physical characteristics of the imaging system such as detector efficiency, collimator resolution and sensitivity, and software for resolution recovery should be considered when defining nuclear medicine procedures with the goal of reducing radiation dose to the patient.

## References


1. Chandra R: Nuclear medicine physics: the basics, 7th ed. Philadelphia, Williams & Wilkins, 2011. (http://www.lww.com/webapp/wcs/stores/servlet/product_Nuclear-Medicine-Physics:-The-Basics_11851_-1_9012053_Prod-9781451109412)
2. Cherry SR, Sorenson JA, Phelps ME: Physics in Nuclear Medicine, 4th ed. Philadelphia, Elsevier, 2012, Ch14,Section C.

3. Hannequin P, Mas J: Statistical and heuristic noise extraction (SHINE): a new method for processing Poisson noise in scintigraphic images. Phys Med Biol, 2002, 47:4329-4344.
4. Wesolowski CA, Yahil A, Puetter RC, Babyn PS, Gilday DL, Khan MZ. Improved lesion detection from spatially adaptive, minimally complex, Pixon reconstruction of planar scintigraphic images. Comput Med Imaging Grap, 2005, 29(1): 65 – 81. (http://www.ncbi.nlm.nih.gov/pubmed/15710542)
5. Hsiao E, Cao X, Zurakowsi D, Zukotynski K, Drubach L, Grant F, Yahil A, Vijay H, Davis RT, Fahey FH, Treves ST. Reduction in Radiation Dose in MAG3 Renography by Enhanced Planar Processing. Radiology, 2011, 261:907-915. (http://radiology.rsna.org/content/261/3/907.full.pdf+html)

 