# Collimator integrity

Frank P. DiFilippo, PhD, Sue H. Abreu, MD, and Haresh Majmundar, CNMT, RT(N)

## OVERVIEW

Collimators constitute a critical component of the imaging system and have a direct effect on image quality. Therefore ensuring collimator integrity is vital for quality assurance in nuclear cardiology. Routine checks should be performed on all collimators in clinical use (Table 1). Extrinsic flood images provide an assessment of collimator uniformity and should be acquired at regular intervals. Technologists must be conscious of unintended damage to the collimators and other related issues that might cause artifacts in nuclear cardiology images, keeping in mind that damage could occur off-hours by nontechnologists.

## CAMERA UNIFORMITY: CALIBRATION

The gamma camera sensitivity must be sufficiently uniform across the field of view to avoid nonuniformity artifacts in images. There are 2 components to gamma camera uniformity, arising from the detector itself and from the collimator. *Intrinsic uniformity* refers to the spatial-dependent sensitivity of the camera without a collimator. *Extrinsic uniformity* refers to the spatial-dependent sensitivity of the camera with a specific collimator mounted in place.

Gamma cameras are calibrated to ensure a high degree of uniformity. Calibration is based on a high-count acquisition of flood-field data. Manufacturers' recommendations vary, although a typical acquisition is in the range of 100 million counts for a camera with a large field of view. Correction tables are derived from the high-count flood image and applied to data in subsequent clinical acquisitions. Calibrations of camera uniformity are performed on a routine basis (typically monthly) to correct for changes in camera sensitivity over time.

Gamma cameras differ in their uniformity calibration procedures, and the manufacturer's guidelines must be followed for each specific model. For some gamma cameras, uniformity calibration is performed only extrinsically, accounting for both the detector's and collimator's nonuniformities in a single correction table. For these systems, a separate high-count extrinsic flood must be acquired for each collimator in clinical use, at each routine calibration interval. Here, we designate this type of gamma camera as *extrinsically calibrated*.

Other gamma cameras are designed such that separate correction tables are generated for the detector and for the collimator. A high-count intrinsic flood is acquired first, to produce a correction table for detector nonuniformities. Next, a high-count extrinsic flood is acquired. The ratio of the extrinsic and intrinsic flood data reflects the collimator nonuniformity, which enables a correction table for that collimator to be generated. For subsequent clinical acquisitions, both correction tables are used to account for both the detector's and collimator's nonuniformities. The collimator's correction table is expected to be highly stable because the collimator is a mechanically rigid structure, whereas the detector's correction table is expected to drift over time because the detector electronics are much less stable in comparison. Thus, at routine calibration intervals, only a high-count intrinsic flood image is acquired to generate a new detector correction table. Under the assumption that the collimator correction table does not change over these routine intervals, there is no need to acquire a new high-count extrinsic flood image. Here, we designate this type of gamma camera as *intrinsically calibrated*.

On some gamma cameras, the uniformity may exhibit a significant dependence on the emission energy of the radionuclide being imaged. This dependence is typically greater for older analog gamma cameras compared with newer cameras with digital event positioning. Therefore one should follow the manufacturer's recommended calibration procedures, considering which radio-

Prepared by the American Society of Nuclear Cardiology (ASNC) Quality Assurance Subcommittee for Laboratory Quality.

Reviewed by members of the ASNC Quality Assurance Committee: Edward P. Ficaro, PhD, Chair; Olakunle O. Akinboboye, MBBS, MPH, MBA; Elias H. Botvinick, MD; Ji Chen, PhD; Keith B. Churchwell, MD; C. David Cooke, MSEE; Roger D. Des Prez, MD; Guido Germano, PhD; Richard A. Goldstein, MD, MBA; Christopher L. Hansen, MD; Robert C. Hendel, MD; Milena J. Henzlova, MD; Brad J. Kemp, PhD; Benjamin D. McCallister, MD; Vahini V. Naidoo, MD; Patty Reames, CNMT, RT(R), NCT; Raymond R. Russell III, MD, PhD; Albert J. Sinusas, MD; Massimiliano Szulc, PhD; Peter L. Tilkemeier, MD; Yvonne J. Weaver, MD; and David G. Wolinsky, MD.

Approved by the American Society of Nuclear Cardiology Board of Directors, September 7, 2006.

Reprint requests: American Society of Nuclear Cardiology, 4550 Montgomery Ave, Suite 780 North, Bethesda, MD 20814; *admin@asnc.org*.

J Nucl Cardiol 2006;13:889-91.
1071-3581/$32.00

doi:10.1016/j.nuclcard.2006.10.004

**Table 1.** Summary of suggested procedures

| | |
|---|---|
| Daily QA | Visual inspection for collimator damage; extrinsic or intrinsic low-count (3-5 million counts) flood image (extrinsic is preferred, requires Co-57 sheet source or Tc-99m planar phantom) |
| Monthly calibration (or PMR) | Detector calibration (intrinsic or extrinsic PMR) |
| Quarterly collimator QA | Extrinsic high-count (30 million counts) flood image (if daily QA and monthly calibration are done intrinsically) |
| Annual calibration and QA | Extrinsic flood calibration (100 million counts or PMR); SPECT uniformity phantom (optional) |

*QA*, Quality assurance; *PMR*, per manufacturer's recommendation.

nuclides will be imaged clinically (technetium 99m, thallium 201, iodine 123, and so on). For some gamma cameras, the manufacturer recommends a single set of intrinsic and extrinsic flood images for calibration, whereas for other gamma cameras, specific intrinsic or extrinsic flood images (or both) via different radionuclide sources may be needed.

## CAMERA UNIFORMITY: QUALITY ASSURANCE

On a daily basis, flood images are acquired and inspected to ensure that substantial changes to camera uniformity have not occurred. For example, such changes may be caused by a malfunctioning photomultiplier tube, a malfunctioning electronic circuit, or a significant environmental change such as a power surge or temperature change. It is not practical to acquire high-count flood images on a daily basis. Instead, lower-count flood images are acquired, typically 3 to 5 million counts, which are sufficient for detecting significant changes in camera uniformity.

Like the procedures for calibration of camera uniformity, daily quality assurance may be done either intrinsically or extrinsically. For intrinsic quality assurance of camera uniformity, the collimators are removed, and a point source of Tc-99m is used as the radionuclide source. The point source must be sufficiently far away from the detectors to flood the entire detector surface with a reasonable degree of uniformity. Most often, the source is placed at a distance of at least 5 times the detector field of view, although some gamma cameras are designed to correct for curvature in the count profile, allowing the source to be positioned closer to the detector.

For extrinsic quality assurance of camera uniformity, the collimators are not removed, and an extended planar flood source is required to illuminate the entire surface of the detector. The flood source may be prepared by filling a planar phantom with radionuclide solution, most often Tc-99m. Care must be taken to avoid air bubbles and impurities such as biologic growth to ensure a uniform distribution. More conveniently, a long-lived sealed planar cobalt 57 source may be used instead of a fillable phantom. The gamma ray emission energy of Co-57 (122 keV) is similar to that of Tc-99m (140 keV) and provides a suitable substitute. A disadvantage of Co-57 sealed sources is that they must be replaced regularly (typically annually) because of decay losses.

If using a Co-57 sheet source, one should be aware that there may be noticeable contamination from higher-energy gamma rays arising from other isotopes, namely Co-56 and Co-58. The higher-energy rays more easily penetrate the collimator and often interact deeper in the crystal, as compared with the 122-keV gamma rays from Co-57. As a result, one may see nonuniformities in a photomultiplier tube pattern as a result of the depth-dependent detector response. To minimize the effect of the higher-energy contaminants, it is suggested that the sheet source be positioned farther away from the collimator (30-cm distance). In addition, because Co-56 and Co-58 have shorter half-lives than Co-57, using an aged sheet source will help minimize this effect.

## COLLIMATOR DAMAGE AND CAMERA UNIFORMITY

The collimator covers the front surface of the gamma camera and is vulnerable to impact. Damage to the collimator may occur if an external object collides with the collimator surface, or vice versa. Collimator damage may occur knowingly or unknowingly to the technologist (eg, after hours by the cleaning staff). Collimators are made of lead, which is a soft metal that may be deformed or dented relatively easily. In addition, most collimators are constructed from lead foil sheets bonded together and may be sensitive to mechanical or thermal stresses.

A damaged collimator will exhibit a change in the local sensitivity, because the acceptance angle in the damaged area is modified, and uniformity-related artifacts may result. (For examples, see O'Connor in the "Suggested Reading" section.) A dented portion of the collimator often produces a region of reduced sensitivity, because the dent may partially block some collimator channels. Alternatively, a cracked portion of the collimator (eg, where lead foil sheets have separated) often produces a region of increased sensitivity resulting from leakage. It is therefore essential to monitor the status of the collimators on a routine basis to detect whether damage has occurred, whether the uniformity correction tables need to be regenerated, and whether the collimator is still suitable for imaging.

An important distinction between intrinsic and extrinsic flood images is in regard to collimator involvement. An intrinsic flood image evaluates the uniformity of the detector only, whereas an extrinsic flood image evaluates the uniformity of the entire gamma camera (combination of the detector and the collimator). The intrinsic measurements do not reveal the status of the collimator and may leave doubt as to the suitability for use, unless other tests are performed. Therefore, depending on whether the gamma camera is intrinsically calibrated or extrinsically calibrated or whether daily quality assurance is intrinsic or extrinsic, the guidelines for ensuring collimator integrity will differ.

## MECHANICAL INTEGRITY GUIDELINES

On a daily basis, technologists should inspect collimators for visual signs of surface damage, such as marks or indentations that would arise from an object impacting the collimator. Patient safety mechanisms (touch pads/contact sensors) should be tested routinely for proper operation. During use, technologists should take care to avoid mechanical damage to the collimators from collisions with other equipment.

When changing collimators, the latching mechanism should be observed to ensure that the collimators are properly mounted. Proper mounting is essential for safety reasons and for preserving collimator alignment. Mechanical alignment issues would be evident in center-of-rotation calibrations, and thus it is recommended that the center-of-rotation values be observed for consistency over time.

## CAMERA UNIFORMITY GUIDELINES

Acquiring an extrinsic flood image allows collimator uniformity to be evaluated, whereas an intrinsic flood image does not provide this information. The extrinsic flood image should be inspected in combination with the intrinsic flood image to distinguish collimator-related nonuniformity from detector-related nonuniformity. In addition, inspecting extrinsic flood images acquired with the uniformity correction tables disabled provides further information as to the integrity of the collimator, because the correction tables may mask accumulated minor damage before the most recent calibration.

Extrinsic flood acquisitions require a planar radionuclide source (sealed Co-57 sheet source or fillable Tc-99m phantom). The entire field of view of the gamma camera must be illuminated for complete inspection of the collimator. Daily lower-count extrinsic flood images (3-5 million counts) are valuable for detecting significant collimator damage. Periodic high-count extrinsic flood images (at least 30 million counts, preferably 100 million counts) are recommended for more thorough assessment of collimator integrity.

High-count extrinsic flood images should be acquired and inspected whenever collimator damage is suspected. However, in addition to known hard collisions between the gamma camera and other equipment, the possibility exists that other collisions may occur unknown to the technologist. Because the face of the collimator is typically covered with a safety touch pad sensor, some damage may not be visibly obvious. Therefore routine assessment of extrinsic uniformity is needed for collimator quality assurance. For laboratories acquiring daily intrinsic flood images for camera quality assurance, it is recommended that high-count extrinsic flood images be acquired and inspected at least quarterly. For laboratories acquiring daily extrinsic flood images, it is recommended that high-count extrinsic flood images also be acquired and inspected at least annually to detect more subtle damage to the collimator.

In addition to the periodic high-count extrinsic flood images, an optional supplemental test of collimator uniformity is inspection of high-count single photon emission computed tomography (SPECT) images of a uniform phantom. Using a phantom at least 20 cm in diameter and acquiring 30 million counts are recommended. Camera nonuniformities may result in ring-like artifacts in the reconstructed SPECT images. Because the source of the artifact may be from detector or collimator nonuniformity, these images should be interpreted in conjunction with intrinsic and extrinsic flood images.

The reader should refer to the operator's manual of the SPECT scanner for the manufacturer's recommendation for calibration and quality assurance procedures for that specific scanner model.

## Suggested Reading

1. DePuey EG, Nichols K, Bacharach SL, et al. ASNC imaging guidelines for nuclear cardiology procedures; June 2006—instrumentation quality assurance and performance. Available at http://www.asnc.org/section_73.cfm Accessed Aug 3, 2006.
2. Hines H, Kayayan R, Colsher J, et al. Recommendations for implementing SPECT instrumentation quality control. Eur J Nucl Med 1999;26:527-32.
3. NU 1-2001: Performance measurements of scintillation cameras. Rosslyn (VA): National Electrical Manufacturers Association; 2001.
4. O'Connor MK. Instrument- and computer-related problems and artifacts in nuclear medicine. Semin Nucl Med 1996;26:256-77.