J of Nuclear Medicine Technology, first published online April 24, 2019 as doi:10.2967/jnmt.118.222489

Increasing awareness of a quality control problem in aging gamma cameras

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Abstract

Quality control (QC) in a nuclear medicine department plays an important role in providing quality care for patients. Closely monitoring the uniformity values on extrinsic QC can give insight into problems outside typical equipment issues. This facility noticed increasing uniformity values along with a photopenic image artifact. The detector required photo-coupling gel replacement a full rebuild by service engineers. This process took time for rebuild and time for the gel to set. Another adjustment of the voltage to the photomultiplier tubes (PMT) was required due to photocathode excitation in every cathode in every PMT in that detector. After the detector was rebuilt, the voltage was re-tuned with the field service engineers' knowledge that the PMTs would need to be re-tuned due to this excitation. Communication and understanding of equipment problems in aging gamma cameras can lead to proper equipment use and better quality in nuclear medicine departments.

Introduction

Imaging professionals strive for the best quality of care. One way to provide quality care is to produce excellent images. Image quality can be verified through quality control (QC) and quality assurance. Quality assurance usually includes departmental requirements that technologists need to be certified and participate in continuing education to maintain that certification. In addition, equipment must work properly and function within the guidelines provided by the Nuclear Regulatory Commission. Many imaging departments choose to have either Intersocietal Accreditation Commission (IAC) or American College of Radiology approval. In numerous states, reimbursement directives that require accreditation of the facility have been instituted by Medicare carriers as well as private, third-party insurers. *(1)*

A published IAC study showed that dated equipment predicts poor laboratory quality and delay in accreditation in echocardiology and nuclear accreditation status. "During the study period (2012 to 2014), there was a statistically significant trend towards an increasing lack of quality metrics with increasing quartiles of equipment age" *(2).* This study showed that the interaction between equipment age and the number of missing quality metrics was a significant predictor of lack of accreditation *(2).* The IAC are dedicated to ensuring quality patient care and "improving health care through accreditation®" *(3).* Since its creation, the IAC Nuclear/Positron Emission

Tomography (PET) accreditation program has offered a pathway for those utilizing Nuclear/PET to document their quality and comply with insurers' payment policies that mandate accreditation *(1).* Achieving accreditation assures patients that a department provides high quality and safety; it also aids a facility to meet governmental and third-party payer criteria *(4*).

As imaging equipment ages, many institutions may choose to make repairs rather than buying new. This process can increase the likelihood of parts needing replacement or repair. Closely monitoring the integral uniformity values and daily extrinsic images on QC are vital to patient care. This manuscript examines how closely monitoring the QC helped find a major problem in a detector and brings attention to a lesser known equipment problem.

During routine daily QC on gamma cameras, technologists may habitually look for issues that arise from the crystal, PMT, electronics, and the collimator. However, it is not always routine to test for other issues outside of these commonplace issues. Some service engineers and physicists only work on routine issues and may not know the steps to prevent further scanner downtime when these lesser encountered problems occur. "A photopenic circular artifact that resulted in a gamma camera head rebuild: A technologist case study" *(5)* was presented at the Society of Nuclear Medicine and Molecular Imaging annual meeting in 2016 and has sparked follow up discussion. The authors of this manuscript want technologists to be aware of this issue and the experiences encountered.

Problem

During daily extrinsic QC, it was discovered that detector two of a Philips Forte Anger style gamma camera had an integral uniformity field of view (FOV) value that was slowly increasing (Fig 1D) *(5).* Most of the rising values were not significant enough to raise alarm during QC as results were within the manufacturer recommendation of less than 5% deviation range. The manufacturer recommends that both intrinsic and extrinsic uniformity floods would be 15,000,000 counts at 20,000 to 50,000 counts per second for Epic detectors on the Forte (M. Schmidt, e-mail communication, January 4, 2019). This recommendation was followed by the department and this manuscript's figures include the total counts for each image. Once the 5% deviation range was reached, the scanner was taken out of service. Since the daily uniformity values had been increasing the past several days, the technologists kept watch on the QC and patient images to ensure no problems were present. This Forte (Fig 1E) had routine maintenance performed since its installation in 2003. Upon in depth QC image review, there was a photopenic circular image artifact noticed on the day the scanner was taken out of service (Fig 1A and 1B) which resulted in a call to the field service engineers.

Field service engineers performed intrinsic QC uniformity with the mask removed (Fig 1C) and discovered detector two would require a camera detector rebuild. A rebuild is disassembling the detector, cleaning the all the coupling gel from each of the PMTs and the crystal/light pipe assembly, then reapplying new coupling gel to the tubes and reinstalling them. A rebuild is necessary when the gel gets old or too hot and air bubbles get between the tube and light pipe or when tubes fail (M. Schmidt, e-mail communication, February 22, 2018) *(5).* As part of this rebuild, the service engineers tuned the PMTs. because of the cathode excitation; the service engineers predicted that a second or third tune might be necessary. Cathode excitation can

occur when the tube is exposed to light and the tube may need several hours or days in darkness (See Fig 4D for the PMT manual explanation). Tuning historically was the original uniformity correction technique applied to gamma cameras and it involved adjusting the high voltage to individual PMTs to produce equal count rates across the FOV *(6).* Manual tuning is performed infrequently in modern gamma cameras because of the large number of PMTs *(6).*

The importance of the photo-coupling gel in an Anger camera can be under-appreciated by technologists. “Optical coupling gel (usually some kind of silicon grease) reduces the loss of scintillation photons by preventing reflection at the scintillation crystal/light pipe and light pipe/photocathode interfaces. If the coupling gel degrades, the number of scintillation photons reaching the PMT is greatly diminished” *(6).* In this case, the QC had discovered part of the problem quantitatively (with increasing uniformity values) and qualitatively (with non-uniform images) and we could notice the issue on the rising integral uniformity values. Since the coupling gel needed replacement, the photons reaching the PMT were reduced and the QC images were affected.

Results

The service engineers took this scanner out of use to replace the defective coupling gel. Detector two was functional again two days later *(5).* The extrinsic QC imaging (Fig 2A) was satisfactory again, but a new artifact was introduced four days later (Fig 2C). The cause of this artifact was cathode excitation which required a tuning session *(5).* This artifact looked visually like the first artifact, so an untrained eye might perform another time-consuming rebuild with new gel when only tuning of the detector was required. The uniformity values were increasing again (Fig 2B) and it was operating outside the acceptable range. Service was once again called to assess the problem which resulted in another 1.5 days of service work *(5).* After this additional work of tuning the PMTs, service stated that another tune might be necessary in several days’ time if the extrinsic QC increased. After four weeks the tubes had time to stabilize and the gel had time to set; it was determined a third tune was unnecessary (Fig 3C and Fig 3B solid arrow). After the second tune, an extrinsic flood showed uniform images (Fig 3A). When the extrinsic QC passed, an intrinsic flood was acquired to prove that a third tune was unnecessary (Fig 3C) (no extrinsic image included on this day). By this time, the values had normalized, and the image artifact was not seen.

Discussion

The importance of thoroughly monitoring QC cannot be overstated. After the uniformity values were noted to exceed the manufacturer’s maximum recommended integral uniformity values, service was notified. The service engineers that found the problem worked quickly and efficiently. Upon further investigation by service for this case, the engineers noted that the factory assembles the detectors in darkroom conditions to improve the time taken to stabilize. An excerpt from the PMT manual (Fig 4D) noted to avoid light when working with the cathode substrate (photo-coupling gel) *(7)*. Avoiding light in an imaging room can be difficult in a room with windows (Fig 4A, 4B, 4C). The excitation issue may have caused the lost tuning after the initial detector rebuild, which caused the second artifact and required re-tuning. Since this is an 4gamma camera, the tuning session took four hours for the camera to adjust the voltage signal

on the PMTs. Older equipment as compared to newer systems can possess older hardware which degrades with time and some of those electronic parts have been replaced. It is difficult for the authors to determine the exact cause of the slowdown of this gamma camera that had been in use for approximately 13 years.

This department had three other gamma cameras to utilize while this Forte was out of service. Upon retrospective review on the patient studies performed the few days prior to the initial service call, the technologists and physicians did not believe the images were affected. So, ultimately this facility did not have any negative impact on patient care due to the detector rebuild.

This issue may be of greater importance as Anger gamma cameras continue to be utilized. A recently published case report using a gamma camera from a different manufacturer describes an artifact that required further investigation *(8).* This case noted an imaging artifact on an Infinia Hawkeye SPECT/CT system (GE Healthcare) that was found to be gradual leakage of optical coupling grease *(8).* For this case report, fresh optical coupling grease was applied, and the artifact did not appear on later images *(8).*

The coupling gel can degrade and cause imaging artifacts which impact image quality. It is important to communicate with service professionals when a problem like this occurs, so the department can properly prepare for maintenance on the equipment. If specific conditions cannot be accommodated, several more down days may be required to repair issues. The authors of this article believe the service engineers were able to repair this issue as quickly as possible; these are seasoned engineers that have fixed numerous departmental issues. The technologists were not fully aware that specific conditions (darkroom) were needed during the rebuild and that room was still utilized for non-imaging purposes during the maintenance.

It is also important for departments seeking or maintaining accreditation to understand that equipment may degrade with time. If a department becomes accredited once, the gamma cameras utilized are not guaranteed to continue operating at the same quality in perpetuity. Gamma camera QC procedures catch problems when quantitative measurements occur outside of standard acceptable ranges. Technologists reviewing the QC can visually assess these images daily. Some issues like the one discussed in this manuscript with the photo-coupling gel and the leakage of coupling gel from the previously published article *(8),* can happen over time and may degrade the image quality prior to becoming a quantitative issue.

Conclusion

When determining the quality of the image acquisition on a gamma camera, aging equipment may lead to unexpected QC concerns. During a detector rebuild on a gamma camera, it may be important to work in specific lighting conditions. Performing the recoupling without ambient light and giving ample time for the gel to set is more advantageous for fewer scanner down days. This scanner ended up being out of service for a total of four days. After the rebuild of this detector, the integral and differential values on daily QC must be closely monitored *(5).* If these steps are not taken, the gel may not have time to set or the electronic voltage may drift, and

problems may occur again. The scanner may require more service work and down time as another tune might be necessary *(5).*

The goal of this manuscript is to educate technologists that there are a variety of different problems that can occur in aging Anger style gamma cameras. This specific problem ended up being bad coupling gel and PMT tuning complications. These problems can occur, and it is important to communicate with everyone involved in this process to resolve these issues in the most efficient way possible. Quality of patient care is imperative, and every individual involved in the maintenance, QC, and quality assessment plays a part.

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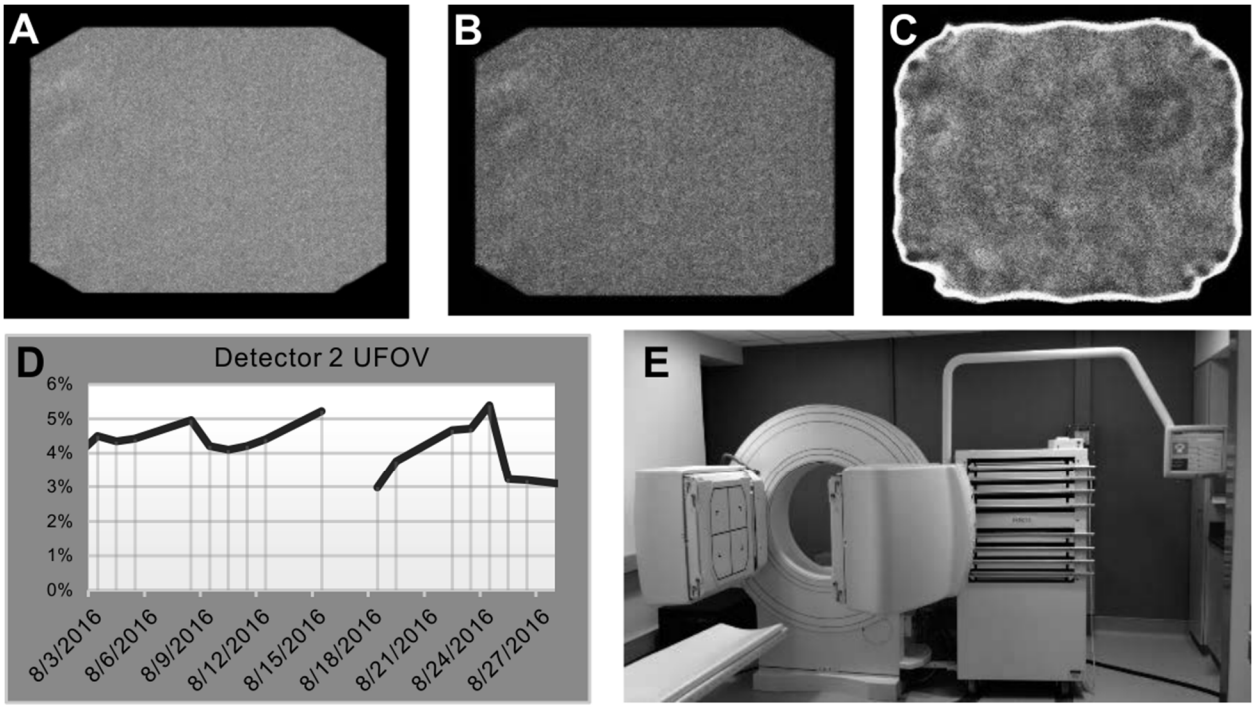


Figure 1: (A) Extrinsic Quality Control Uniformity, Detector 2 (D2), 08/15/2016, 15000K counts, Grayscale. (B) Extrinsic QC Uniformity, D2, 08/15/2016, 15000K counts, Thermal intensity increased to 91% (printed in grayscale). (C) Intrinsic QCU with mask removed, D2, 08/17/2016, 11706K counts, Thermal intensity at 12% (printed in grayscale). (D) Line graph of the daily integral Uniformity measurements of the useful FOV. (E) Image of the Philips Forte from VA Saint Louis Healthcare System John Cochran Division, St. Louis, MO. *(3)*

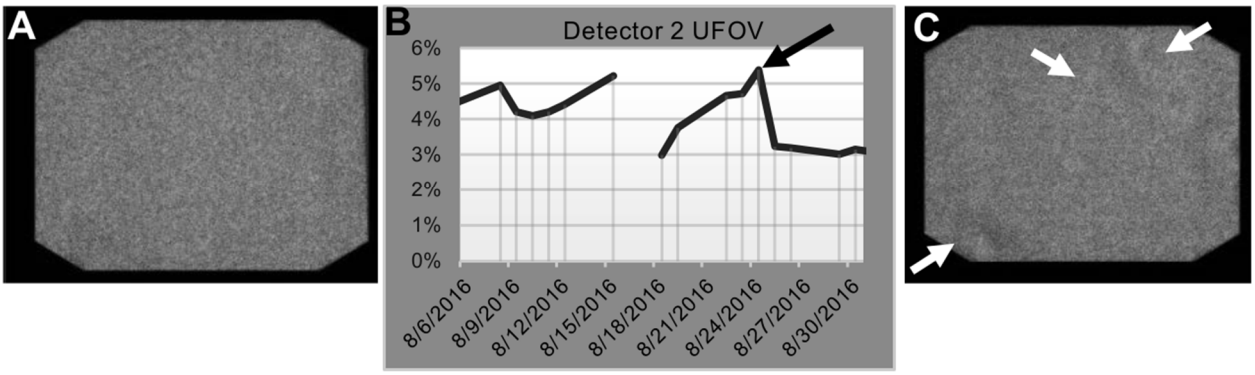


Figure 2: (A) Extrinsic QC Uniformity, D2, 08/18/2016, 15000K counts, Thermal intensity at 91% (printed in grayscale). After detector rebuild. (B) Line graph of QC with arrow pointing to 08/24/2016 which was after the first rebuild which showed QC problems again. (C) Extrinsic QCU, D2, 08/24/2016, 15000K counts, Thermal intensity at 91% (printed in grayscale). Extensive modeling across the FOV due to PMT excitation; tune was done to remove the modeling. *(3)* Arrows indicate some mottling areas.

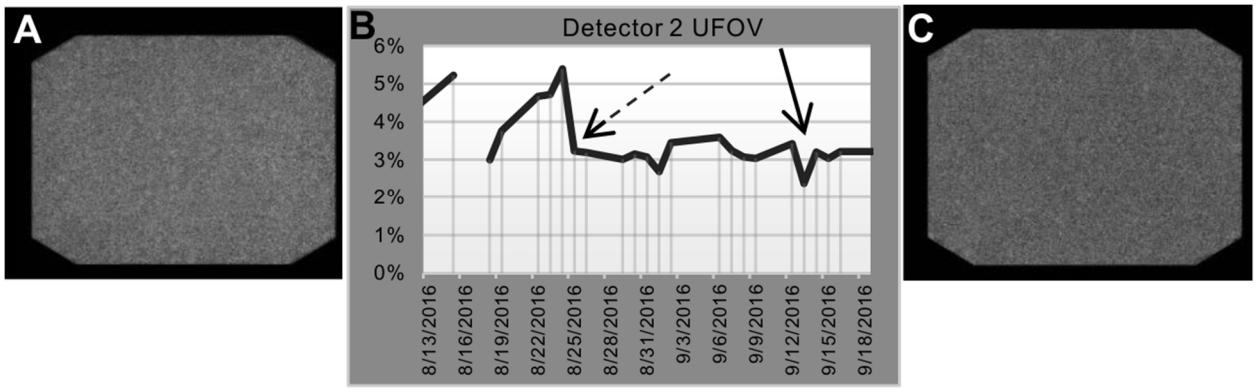
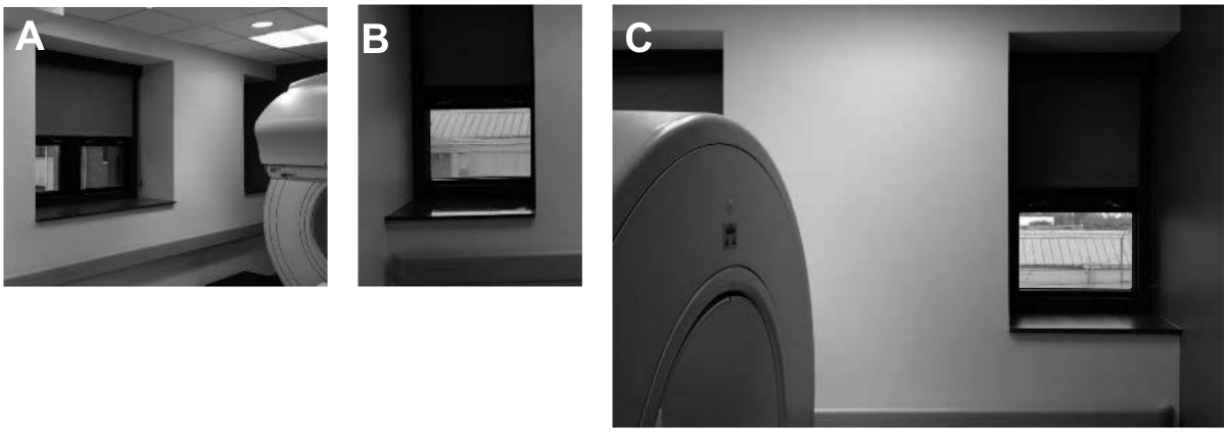


Figure 3: (A) Extrinsic QC Uniformity, D2, 08/25/2016, 15000K counts, Thermal intensity at 91% (printed in grayscale). After the second tune. (B) Line graph of QC with dashed arrow pointing to the extrinsic UFOV from 08/25/2016. The solid arrow is pointing to the extrinsic QCU from 09/14/2016 which is when D2 might have needed another tune. Another tune was not needed per our QC results. (C) Intrinsic QC Uniformity, D2, 09/14/2016, 15000K counts, Thermal intensity at 91 %. An extrinsic QC image was not captured on this day. *(3)*



D

Cathode excitation

When a tube is exposed to even very low levels of ambient light, especially just before the tube is put into operation, the dark current in operation can initially be several orders of magnitude larger than that when the tube has stabilized several hours or even days in darkness.

The pulse height spectrum is similar to that for single photoelectrons. This phenomenon is very dependent on the cathode substrate. In normal use, take simple precautions to limit exposure. In all cases, avoid fluorescent light and daylight.

Figure 4: (A) Image of windows and ceiling with fluorescent light in the Philips Forte gamma camera room. (B) Additional window (C) Third window. *(3)* (D) Excerpt from the Photonis Photomultiplier Tube (PMT) manual. *(5)*