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# The Need for Increased Awareness About Potential Quality Control Problems in Aging $\gamma$ -Cameras

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

**Key Words:** quality assurance; cathode; excitation; gamma camera; photomultiplier tube; quality

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**I**maging 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 be certified and participate in continuing education to maintain that certification. In addition, equipment must work properly and must 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 and by private, third-party insurers (1).

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A published IAC study showed that dated equipment predicts poor laboratory quality and delay in echocardiology and nuclear accreditation. “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 is dedicated to ensuring quality patient care and “Improving health care through accreditation®” (3). Since its creation, the IAC nuclear/PET accreditation program has offered a pathway for those using 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 helps a facility meet governmental and third-party payer criteria (4).

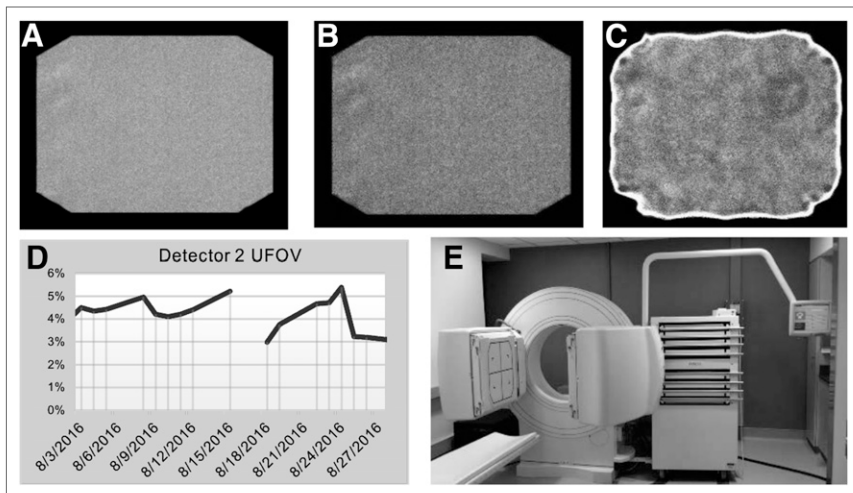
As imaging equipment ages, many institutions may choose to make repairs rather than buy new equipment. The repair process can increase the likelihood that parts will need replacement. Closely monitoring the integral uniformity values and daily extrinsic images on QC is vital to patient care.

During routine daily QC on  $\gamma$ -cameras, technologists may habitually look for issues that arise from the crystal, photomultiplier tube (PMT), electronics, and collimator. However, it is not always routine to test for issues outside these commonplace ones. Some service engineers and physicists work on only routine issues and may not know the steps to prevent further scanner downtime when these less common problems occur. “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. We want technologists to be aware of this issue and the experiences encountered.

This article describes how close monitoring of the QC helped uncover a major problem in a detector and brings attention to a lesser known equipment problem.

## MATERIALS AND METHODS

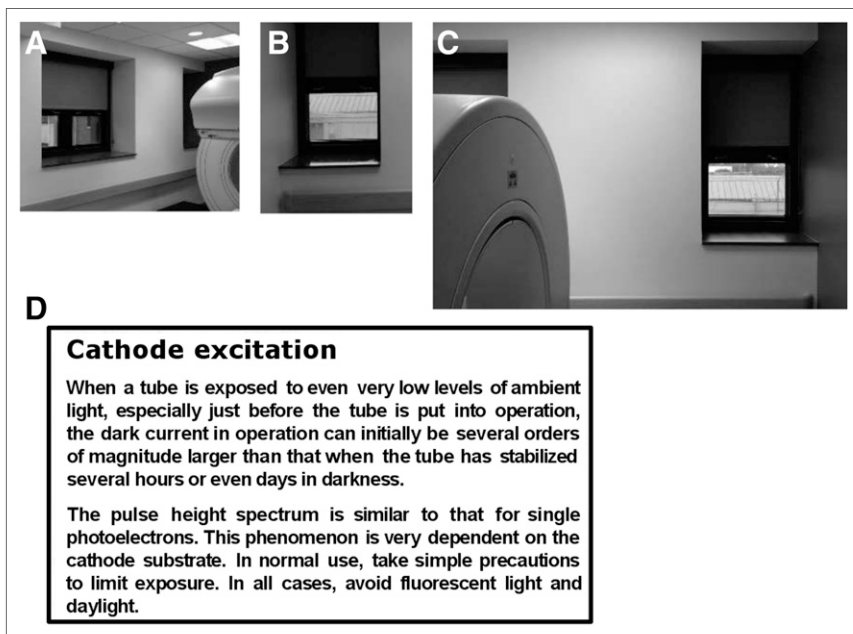
During daily extrinsic QC, it was discovered that detector 2 of a Philips Forte Anger-style  $\gamma$ -camera had an integral uniformity



**FIGURE 1.** (A) Extrinsic QC uniformity image from detector 2 on August 15, 2016 (15 million counts, gray scale). (B) Extrinsic QC uniformity image from detector 2 on August 15, 2016 (15 million counts, thermal intensity increased to 91% [printed in gray scale]). (C) Intrinsic QC uniformity image from detector 2 on August 17, 2016, with mask removed (11.706 million counts, thermal intensity at 12% [printed in gray scale]). (D) Line graph of daily integral uniformity measurements of useful field of view (UFOV). (E) Image of Forte  $\gamma$ -camera at VA Saint Louis Healthcare System, John Cochran Division, St. Louis, MO (5).

field-of-view value that was slowly increasing (Fig. 1D) (5). Most of the rising values were not significant enough to raise alarm during QC, as the results were within the manufacturer recommendation of less than a 5% deviation. The manufacturer recommends that both intrinsic and extrinsic uniformity floods be 15 million counts at 20,000–50,000 counts per second for Epic detectors on the Forte (Mark Schmidt, written communication, January 4, 2019). This recommendation was followed by the department, and the figures in

written communication, February 22, 2018) (5). As part of the rebuild, the service engineers tuned the PMTs. Because of the cathode excitation, the service engineers predicted that a second or third tuning might be necessary. Cathode excitation can occur when the tube is exposed to light, and the tube may need to remain in darkness for several hours or days (Fig. 2D). Historically, tuning was the original uniformity correction technique applied to  $\gamma$ -cameras and involved adjusting the high voltage to individual PMTs to produce equal count rates across the field of view (6). Manual tuning is performed infrequently in modern  $\gamma$ -cameras because of the large number of PMTs (6).



**FIGURE 2.** (A) Photograph of windows and ceiling with fluorescent light in Forte  $\gamma$ -camera room. (B) Photograph of second window. (C) Photograph of third window (5). (D) Excerpt from Photonis PMT manual (7).

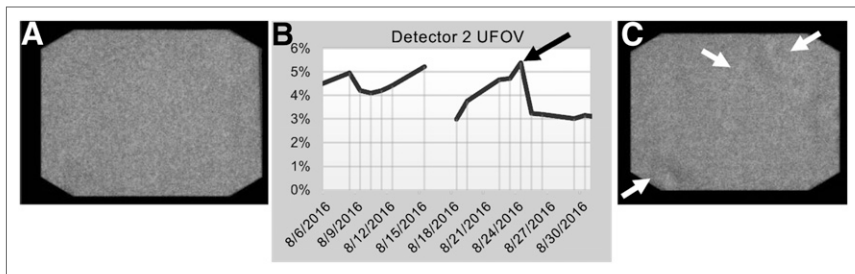
this article include the total counts for each image. Once the 5% deviation range was reached, the scanner was taken out of service. Because the daily uniformity values had been increasing over the previous several days, the technologists kept watch on the QC and patient images to ensure no problems were present. The Forte (Fig. 1E) had undergone routine maintenance since its installation in 2003. On in-depth QC image review, there was a photopenic circular image artifact noticed on the day the scanner was taken out of service (Figs. 1A and 1B), which resulted in a call to the field service engineers.

The field service engineers performed intrinsic QC uniformity with the mask removed (Fig. 1C) and found that detector 2 would require a rebuild. A rebuild involves disassembly of the detector, cleaning of all coupling gel from each PMT and from the crystal/light-pipe assembly, and then application of new coupling gel to the tubes followed by their reinstallation. A rebuild is necessary when the gel gets old or too hot and air bubbles form between the tube and light pipe or when the tubes fail (Mark Schmidt, written communication, February 22, 2018) (5). As part of the rebuild, the service engineers tuned the PMTs. Because of the cathode excitation, the service engineers predicted that a second or third tuning might be necessary. Cathode excitation can occur when the tube is exposed to light, and the tube may need to remain in darkness for several hours or days (Fig. 2D). Historically, tuning was the original uniformity correction technique applied to  $\gamma$ -cameras and involved adjusting the high voltage to individual PMTs to produce equal count rates across the field of view (6). Manual tuning is performed infrequently in modern  $\gamma$ -cameras because of the large number of PMTs (6).

The importance of the photocoupling gel in an Anger camera can be underappreciated by technologists. “Optical coupling grease (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 nonuniform images), and we could detect the issue in view of the rising integral uniformity values. Because 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 service to replace the defective



**FIGURE 3.** (A) Extrinsic QC uniformity image from detector 2 on August 18, 2016 (15 million counts, thermal intensity at 91% [printed in gray scale]), after detector rebuild. (B) Line graph showing QC problems again; arrow points to August 24, 2016, which was after first rebuild. (C) Extrinsic QC uniformity image from detector 2 on August 24, 2016 (15 million counts, thermal intensity at 91% [printed in gray scale]). Extensive modeling (arrows) across field of view is due to PMT excitation; tuning was done to remove modeling (5). UFOV = useful field of view.

coupling gel. Detector 2 was functional again 2 d later (5). The extrinsic QC imaging (Fig. 3A) was satisfactory again, but a new artifact was introduced 4 d later (Fig. 3C). The cause of this artifact was cathode excitation, which required a tuning session (5). Because the new artifact looked like the first artifact, a person with an untrained eye might have performed another time-consuming rebuild with new gel, when only tuning of the detector was required. The uniformity values were increasing again (Fig. 3B), and the scanner was operating outside the acceptable range. Servicing was once again requested to assess the problem, resulting in another 1.5 d of service work (5). After this additional work of tuning the PMTs, the service engineers stated that another tuning might be necessary in several days if the extrinsic QC increased. The tubes were given time to stabilize, and the gel was given time to set; after 4 wk, it was determined that a third tuning was unnecessary (Figs. 4C and 4B). After the second tuning, an extrinsic flood test showed uniform images (Fig. 4A). When the extrinsic QC passed the test, an intrinsic flood image was acquired to prove that a third tuning was unnecessary (Fig. 4C) (no extrinsic image was included

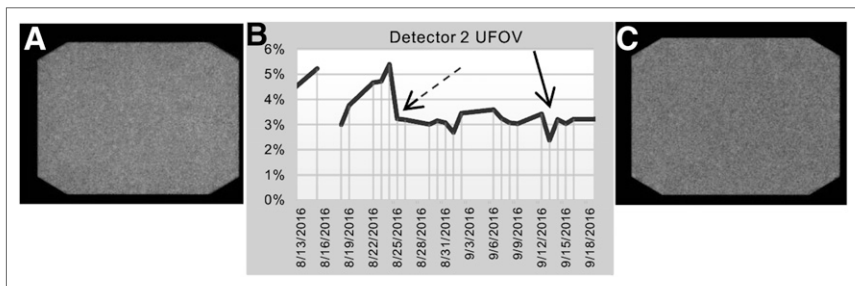
2D) noted that light should be avoided when one is working with the cathode substrate (photocoupling gel) (7). Avoiding light in an imaging room can be difficult if the room has windows (Figs. 2A–2C). The excitation issue may have caused the loss of tuning after the initial detector rebuild, which caused the second artifact and the required retuning. Because this was an older  $\gamma$ -camera, a tuning session of 4 h was required to adjust the voltage signal on the PMTs. Older equipment has older hardware. Hardware degrades over time, and some of the electronic parts in this  $\gamma$ -camera had been replaced. It was difficult for us to determine the exact cause of the slowdown of this  $\gamma$ -camera, which had been in use for approximately 13 y.

This department had 3 other  $\gamma$ -cameras to use while the Forte was out of service. Upon retrospective review of patient studies performed on the last few days before the initial service call, the technologists and physicians did not believe the images had been affected. So, ultimately, the detector rebuild at this facility did not have any negative impact on patient care.

This issue may become of greater importance as Anger  $\gamma$ -cameras continue to be used. A recent case report using a

$\gamma$ -camera from a different manufacturer (an Infinia Hawkeye SPECT/CT system; GE Healthcare) described an imaging artifact that required further investigation (8). The artifact in that case was found to be caused by gradual leakage of optical coupling grease. Fresh grease was applied, and the artifact did not appear on later images.

Coupling gel can degrade and cause imaging artifacts that affect image quality. It is important to communicate with service professionals when such problems occur, so the department can learn how to properly prepare for servicing of the equipment. If specific conditions such as a darkened room cannot be accommodated, the camera may need to



**FIGURE 4.** (A) Extrinsic QC uniformity image from detector 2 on August 25, 2016 (15 million counts, thermal intensity at 91% [printed in gray scale]), after second tuning. (B) Line graph showing extrinsic useful field of view on August 25, 2016 (dashed arrow), and extrinsic QC uniformity on September 14, 2016 (solid arrow), which is when detector 2 might have needed another tuning. Another tuning was not needed per the QC results. (C) Intrinsic QC uniformity image from detector 2 on September 14, 2016 (15 million counts, thermal intensity at 91%). Extrinsic QC image was not captured on that day (5). UFOV = useful field of view.

be out of service for several more days. We believe our service engineers were able to repair the issue as quickly as possible; they are seasoned engineers who have fixed numerous departmental issues. The technologists were not fully aware that specific conditions (a darkened room) were needed during the rebuild, and the room was still used for nonimaging purposes during the maintenance.

It is also important for departments seeking or maintaining accreditation to understand that equipment may degrade over time. Once a department becomes accredited, its  $\gamma$ -cameras are not guaranteed to continue operating at the same quality in perpetuity.  $\gamma$ -camera QC procedures catch problems when quantitative measurements fall outside standard acceptable ranges. Technologists reviewing the QC can visually assess these images daily. Some issues, such as the one with the photocoupling gel discussed in this article, and the one involving leakage of coupling gel discussed in the previous article (8), can happen over time and may degrade image quality before becoming quantitative.

## CONCLUSION

When determining the quality of an image acquisition on a  $\gamma$ -camera, one must keep in mind that aging equipment may lead to unexpected QC concerns. During a detector rebuild on a  $\gamma$ -camera, the service engineers may need to work in specific lighting conditions such as a darkened room. Performing a recoupling without ambient light may be advantageous in that the scanner will be out of service a shorter time (our scanner was out of service 4 d). After a detector rebuild, the integral and differential values must be closely monitored on daily QC (5), because if the gel has not had enough time to set or the electronic voltage drifts, the problem may reoccur and another tuning requiring more downtime be needed (5).

The goal of this article is to educate technologists that there are a variety of different problems that can occur in aging Anger-style  $\gamma$ -cameras. The specific problem described here ended up being due to bad coupling gel and PMT tuning complications. Such problems can occur, and it is important to communicate with everyone involved in the resolution process to ensure it is completed as efficiently as possible. High-quality patient care is an imperative goal in which every individual involved in the maintenance, QC, and quality assessment of imaging equipment plays a role.

## DISCLOSURE

No potential conflict of interest relevant to this article was reported.

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