A Method to Assess Collimator Integrity

Don Beyea and Debbie Boudreau

Nuclear Medicine Department, Saint John Regional Hospital, Saint John, New Brunswick, Canada

Objective: In this paper we evaluate a new method for assessing the structural integrity of parallel-hole collimators.
Methods: Images of various collimators were acquired using a dual-energy, x-ray bone densitometry unit.
Results: X-ray images of collimators acquired by this method were of high quality and revealed delaminations, hole misalignments, denting and other damage or structural collimator deformities.
Conclusion: The bone densitometry unit x-ray beam is parallel, while the beam from a conventional x-ray unit is divergent. X-ray imaging of collimators with a parallel-beam bone densitometry unit is a convenient, inexpensive and technically superior means of assessing collimator integrity.
Key Words: collimator assessment; acceptance testing

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The currently accepted method, for both manufacturers and users, to assess collimator uniformity, is to obtain a high-count flood image (*1*). SPECT imaging places rigorous demands on camera system performance, and minor collimator defects and damage such as hole misalignments, subtly gouged septa or foil delaminations (separation of the lead foil that forms the hexagonal channels) will introduce reconstruction artifacts (*1*). Such subtle damage may not be demonstrated on high-count floods and certainly the cause of the resulting artifact will not be obvious (*2*).

Hole angulation errors degrade tomographic resolution and can be evaluated by the use of a distant radioactive point source (*3*). With this method, point sources are placed at progressively increased distances from the camera/collimator. A tilt in the collimator channel (as opposed to being perfectly perpendicular) will produce an increasing shift in the point source image with increasing distances. This is an excellent technique to perform, as correction floods performed at the collimator surface will be different from those at a distance if collimator channels are tilted. However, this method is technically demanding and time-consuming to perform.

For correspondence and reprints contact: Don Beyea, Nuclear Medicine, Saint John Regional Hospital, PO Box 2100, Saint John, New Brunswick E2L 4L2 Canada.

At our institution, we have always performed high-count floods upon receipt of new collimators, and routinely thereafter. Collimators are also x-rayed upon arrival and subsequently once each year. Because the beam from a conventional x-ray machine is divergent, it is not possible to place enough distance between the collimator and the x-ray tube to obtain a parallel image of the entire collimator face. Therefore, only a parallel image of a very small area in the central portion of the beam is obtained.

High-count floods do not demonstrate the physical structure of the lead septa and cannot be used to measure the size and alignment of the holes. The purchaser usually assumes that the collimator meets the vendor's specifications and that it is structurally intact. Kappes et al. reported that autoradiography of collimators is a "simple and inexpensive high resolution method for assessing collimator integrity" (*4*). They recommended using refillable flood jackets. We attempted an alternate method of autoradiography with a 6.5-mCi ^{57}Co disc. However, to obtain an image that was dark enough to evaluate, even with an intensifying screen on the x-ray cassette, we had to leave the film exposed to the source for 64 hr. Leaving the film overnight was not long enough to obtain a discernible image. The image obtained from the 64-hr weekend exposure was acceptable, but not nearly as clear and sharp as the densitometry images. This was probably due to the fact that the radiations emanating from the flood were coming from all directions, causing some septal penetration, whereas the x-ray beam from the densitometry unit is parallel. The length of time required to obtain an autoradiograph image was inconvenient. Access to an x-ray bone densitometry unit provides a convenient, easy to perform and technically high-quality method for assessing collimators.

MATERIALS AND METHODS

A bone densitometry unit (Lunar Corporation, Madison, WI) was used to obtain the images. The collimator was placed on the scan table, over the x-ray tube. An x-ray cassette, with intensifying screen, was placed on top of the collimator (Fig. 1). The automatic width function was turned off and the manual width was set to maximum (576 mm). For this collimator (480 mm wide and circular) the length was set for the same distance as the width.

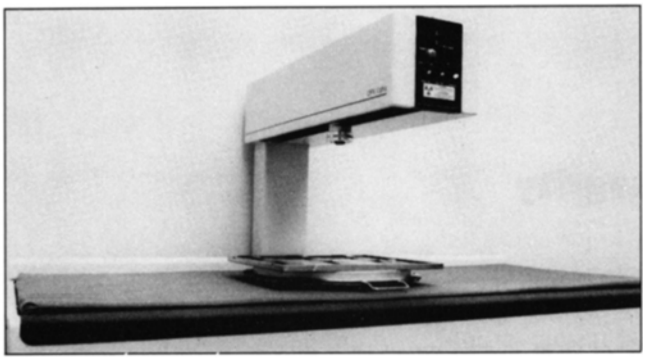

FIGURE 1. X-ray densitometry unit with collimator and x-ray cassette setup.

A scan mode of 750 slow was chosen; 750 refers to the magnitude of the x-ray tube beam current (measured in micro-amperes) which determines the number of electrons that strike the target. This, in turn, determines the number of x-rays that are produced. This bone densitometry unit allows a choice of amperages between 750 μA and 3000 μA, and scan speeds of screening, fast, medium and slow. The unit does not allow a choice of 3000 μA slow, in order to preserve the life of the tube. The cooling system in the machine cannot handle more than 12 min of acquisition at 3000 μA and must shut down to cool off. Therefore, the scanning mode of 750 slow was chosen, as a slow scanning speed was preferable. The unit automatically sets a voltage of 76 kV(p) for all scan modes. The time required to complete the scan was 90 min.

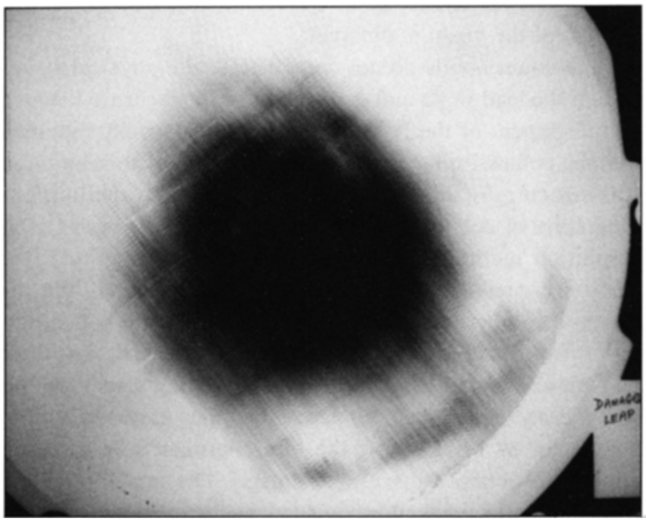

FIGURE 2. Conventional x-ray image of damaged collimator.

RESULTS

Figure 2 shows a conventional x-ray image of a damaged low-energy all purpose (LEAP) collimator. Although gouged septa are visible, only a portion of the collimator face can be analyzed. Most of the holes are not visualized as hexagonal channels (because the x-ray beam is divergent) and the intensity of the image varies from being too black to too white. Figure 3A shows a bone densitometry image of this same damaged collimator. Figures 3B and C show detailed enlargements of sections of the image shown in Figure 3A. Figure 4A shows the structurally intact LEAP collimator, while Figure 4B is a detailed enlargement.

The advantage of the parallel x-ray beam is evidenced by the visualization of more of the hexagonal channels, except for those damaged channels where gouging occurred and the lead foil was folded over. The images are so clear that even measurement of the holes and the septa is possible. When the bone densitometry image of the damaged collimator is compared to an actual photograph of the collimator (Fig. 5), the large gouges seen on the surface of the collimator correlate with defective areas seen on the densitometry image, along with many other scrapes and indentations not observed on the outside covering of this collimator.

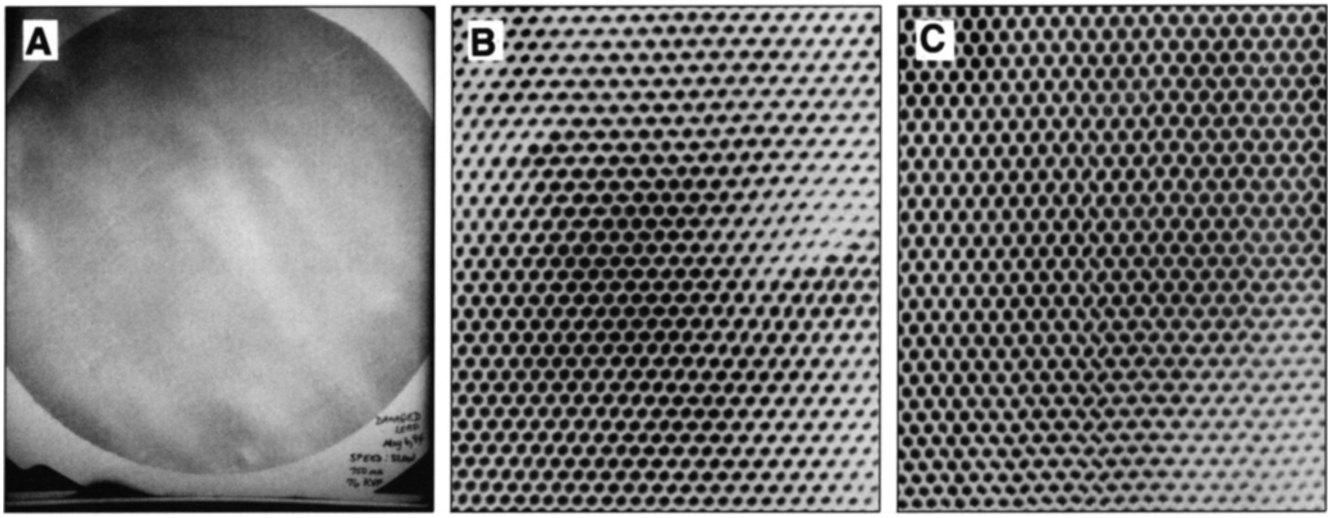

FIGURE 3. (A) X-ray densitometry image of damaged collimator. (B, C) Detailed enlargements of two sections of the damaged collimator.

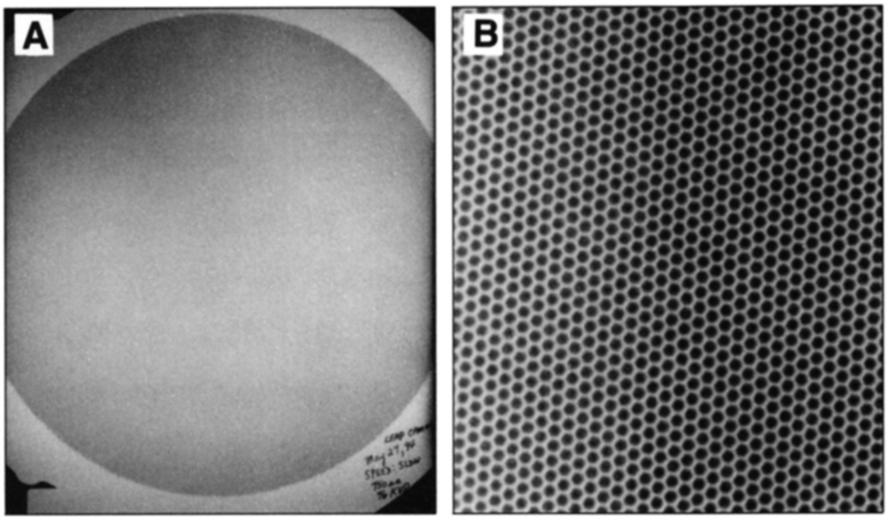

FIGURE 4. (A) X-ray densitometry image of intact collimator. (B) Detailed enlargement of a section of the intact collimator.

DISCUSSION

The bone densitometry radiograph can clearly reveal any structural abnormalities inherent in damaged or defective collimators. How do these collimator defects affect nuclear medicine images? Quantification of the uniformity of these images would be difficult and therefore this method, at present, could not be used as a substitute for NEMA (National Electrical Manufacturers Association) (*5*) uniformity measurements. This method may be too rigorous, in that some structural abnormalities demonstrated by the technique may or may not have any consequences for clinical imaging. This is yet to be ascertained. However, bone density radiography could certainly be used as an acceptance test for new collimators. Clearly, the undamaged LEAP had no structural defects whatsoever, and if such a collimator can be produced, it would be unwise for anyone to accept a less perfect product. Also, if routine uniformity measurements on an existing collimator were to become unacceptable, the bone density radiograph would unquestionably demonstrate whether or not this unsatisfactory result was the consequence of collimator damage.

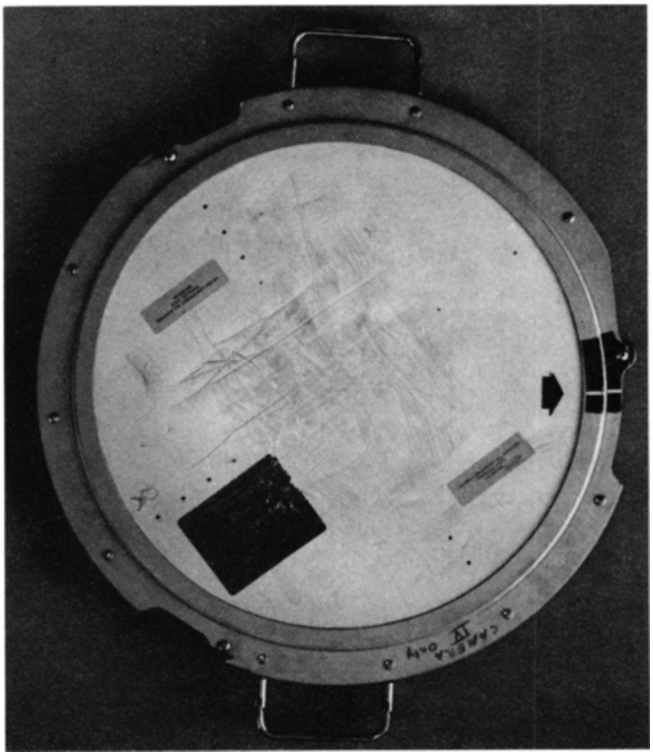

FIGURE 5. Photograph of damaged collimator.

CONCLUSION

Collimator damage or defects of construction may not be apparent on high-count flood images. For institutions with access to an x-ray bone densitometry unit, imaging collimators by this method provides high-quality structural images. These images are very simple to obtain and cost virtually nothing except approximately 1.5 hr of technical time. This offers not only an excellent acceptance test but also can be conveniently performed on a regular schedule.

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