OPTIMIZING THE WINDOW OF AN ANGER CAMERA FOR ^{99m}Tc

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With an Anger camera, as with any imaging device, picture quality depends partly on the detail that can be distinguished in the scan image. If scattered radiation contributes to this image, fine detail may be obscured. Ideally we would like to set the baseline of the pulse-height analyzer to include only primary radiation, but when we use lower energy radionuclides such as ^{99m}Tc (140 keV), this becomes increasingly difficult. The energy of the scattered radiation is quite similar to that of the primary radiation. When conventional pulse-height analysis is used to reduce detection of scatter, enough primary radiation is also excluded to cause a decrease in relative sensitivity with corresponding adverse effect on image quality.

Previous studies (*1–3*) have been made on the effects of reducing detection of scattered radiation by pulse-height analysis for various radionuclides. The purpose of this investigation is to examine some of the effects of scatter inclusion on images made in the clinical scanning situation with the Anger camera with the object of determining the "best" window setting for ^{99m}Tc.

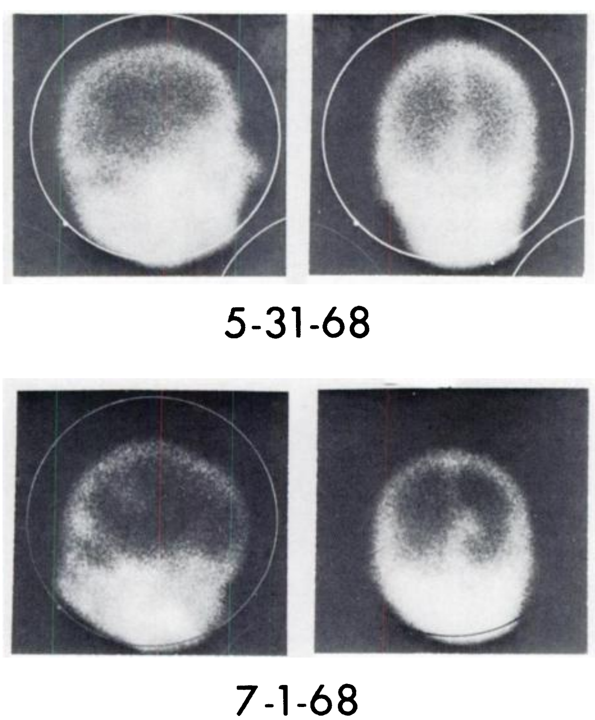

FIG. 1. Two of series of brain scans made with Anger camera on patient with solitary metastasis to right occipital lobe. Both studies were completed 45 min after intravenous administration of 15 mCi of TcO_4^- and pretreatment with $KClO_4$. They each contained 500,000 counts and were made at equivalent dot intensities. PHA setting for first study was 126–154 keV; PHA setting for second study was 133–168 keV.

We did this work because we saw wide variations in the appearance of the scan images that could not be explained by differences in patient anatomy or disease in the organ being imaged. An example of this phenomenon is seen in Fig. 1 which shows two of a series of brain scans of a patient with carcinoma of the lung who developed a solitary metastasis to the occipital lobe. The pictures were made 5 weeks apart and, with one exception, with similar imaging techniques. The appearance of the two studies is quite different; in the second scan it is much easier to separate normal brain from the structures surrounding it. The lesion is seen more clearly not only because it has grown in the interval between the two scans but also because its margins are sharper. The technique used to make these scans varied because gamma energies from 126 to 154 keV* were included in the first examination, but the lower discriminator level was raised for the second study to detect only those energies from 133 to 168 keV†. We thought that the scattered radiation had degraded the initial scans and went about investigating this possibility.

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* Conventional 20% window centered on the photopeak.

† To obtain this window on an Anger camera, adjust the window setting to 10% and graph the counting rate response to a small ^{99m}Tc source (in air) over the full range of "isotope peak" settings. From the graph, find the two "isotope peak" settings at which the counting rate response is one half maximum and adjust the "isotope peak" dial to the setting midway between these two points. This centers a 10% window on the photopeak. Then, with no other adjustment, increase the window width to 25%. The window limits are now 133 and 168 keV.

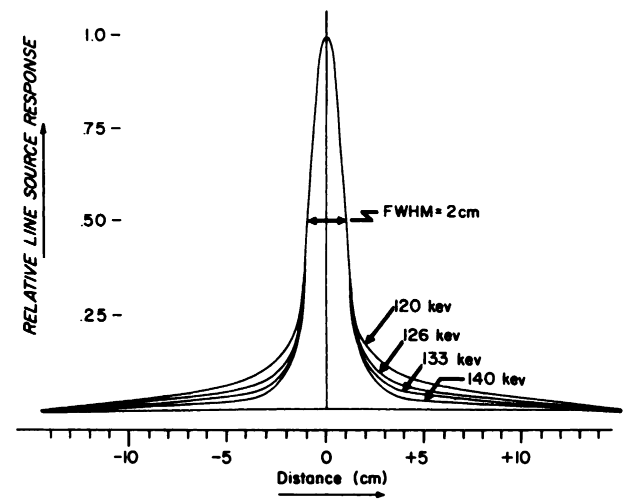

FIG. 2. Line-spread functions on Anger camera at each of baseline settings with 4 in. of front- and backscatter.

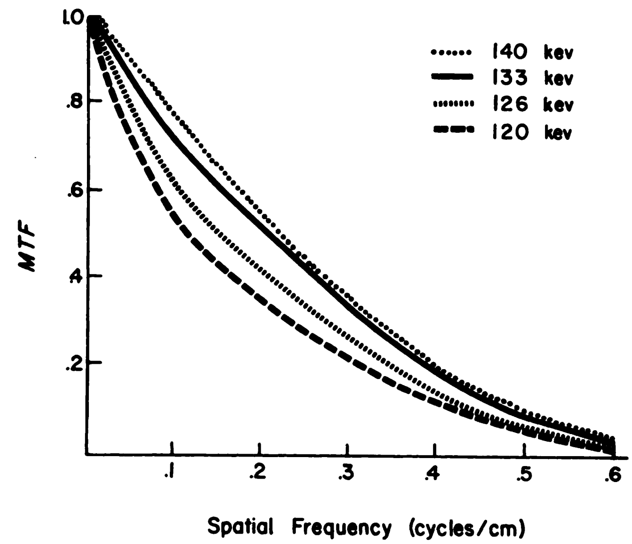

FIG. 3. Modulation transfer functions made at each of baseline settings with 4 in. of front- and backscatter.

METHOD

We evaluated this clinical phenomenon in two ways:

1. Figure of merit studies. These provided objective statistical criteria based on probability of detection.
2. Observer testing. This provided subjective criteria based on an observer's preference for one picture as compared with another.

These studies were performed with four different baseline settings—120, 126, 133, and 140 keV—chosen to include gradually decreasing amounts of scatter.

Figure of merit [Q(υ)] studies. Line-spread functions [LSF(x)] were measured at the four baseline settings 4 in. from the face of the camera with a 4,000-hole collimator and with 4 in. of front-scatter and 4 in. of backscatter*. The relative sensitivity (ψ_{rel}) was also measured at these four baseline settings. Figure of merit (*4–8*) was calculated for each of the baseline settings using the relationship

$$Q(\upsilon) \propto \psi_{rel}\,[MTF(\upsilon)]^2,$$

in which MTF is the modulation transfer function computed from the LSF(x).

Observer testing. Fifteen observers were given a series of scans to rate according to preference. The series consisted of four scans of the same object at the four different baseline settings. All scans in a given series were made with identical study times. Each observer was asked to evaluate three series:

1. Phantom study. A liver phantom containing a simulated low-contrast (0.15) deep-seated defect 2 cm in diameter.
2. Brain scan of a patient with a large frontal lesion.
3. Liver scan of a patient with multiple intrahepatic metastases.

RESULTS

The line-spread function at each of the four baseline settings is shown in Fig. 2. The full width at half maximum (FWHM) is the same for each setting, but the "tails" of the curve are gradually reduced as the baseline is raised. The MTF(υ) computed from these line-spread functions are shown in Fig. 3. The MTF steadily improves for all frequencies as the baseline

* These measurements were obtained on a Pho/Gamma II scintillation camera, 1,600-channel analyzer system at the Argonne Cancer Research Hospital, University of Chicago, Chicago, Ill. The system response was normalized to correct for any crystal nonuniformity.

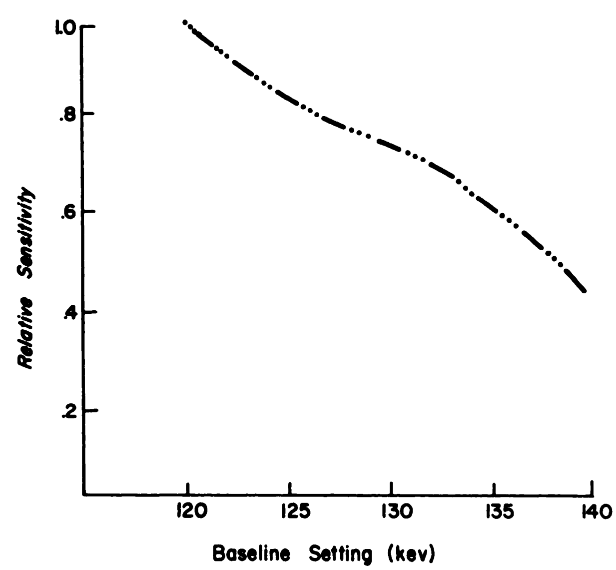

FIG. 4. Relative sensitivity as function of baseline setting.

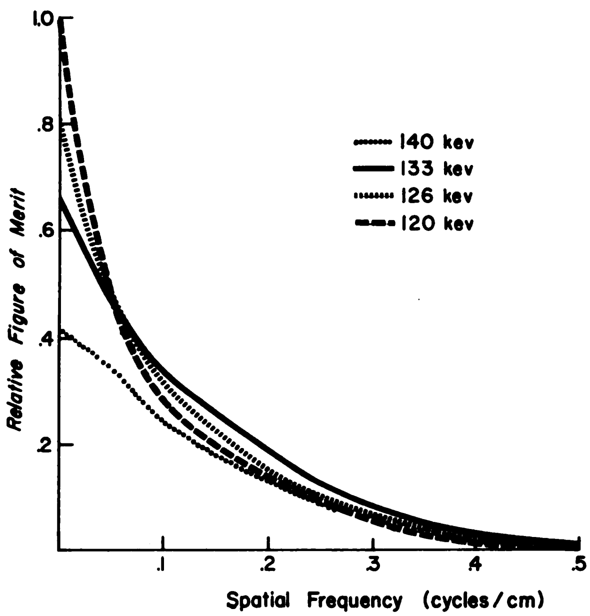

FIG. 5. Relative figure of merit for each baseline setting with 4 in. of front and back scatter.

TABLE 1. RESULTS OF OBSERVER TESTING*

	Phantom	Brain	Liver	Total No.	Total %
Number of observations rated first at:					
120-keV baseline	—	1	—	1	2
126-keV baseline	1	—	1	2	5
133-keV baseline	13	14	14	41	91
140-keV baseline	1	—	—	1	2
Number of observations rated second at:					
120-keV baseline	2	8	4	14	31
126-keV baseline	6	3	7	16	35
133-keV baseline	2	—	1	3	7
140-keV baseline	5	4	3	12	27

* The 133-keV baseline setting was rated first 91% of the time. The observers did not clearly prefer any other baseline setting second.

is raised, but the improvement is less from 133 to 140 keV. As expected, when the baseline is raised, the relative sensitivity is reduced (Fig. 4). Here, however, there is a disproportionate loss when the setting is changed from 133 to 140 keV.

When figure of merit is calculated from these data, system detectability, as defined by these criteria, is best for the 133-keV baseline setting in the spatial frequency range above 0.1 cycles/cm (Fig. 5). The spatial frequency range from 0.1 to 0.35 cycles/cm is probably most significant in scanning since these frequencies correspond to the fundamental wave lengths of objects of approximately 1.5–5.0 cm in diam (*9*).

The results of the observer testing are tabulated in Table 1. The 15 observers, physicians with varying experience in scan interpretation, preferred scan images made at the 133-keV baseline 91% of the time, a clear preference we would not have predicted on the basis of figure-of-merit studies alone.

DISCUSSION

Reinforced by these results, our policy for the past 2 years has been to use the asymmetric 133–168-keV window for all ^{99m}Tc imaging with the scintillation camera. We recognize that the asymmetric window imposes an additional constraint on the system that may increase electronic instability (*1*) and nonuniformity of screen response. Each day before the clinical work is begun, screen uniformity is checked visually with a flood field screen response which should be uniform. A decrease or increase response in the screen center is corrected by adjusting the fine gain of photomultiplier tube 10. We have rarely had to make this adjustment.

SUMMARY

Figure of merit studies and multiple observer testing show that for imaging thick organs on the Anger camera using ^{99m}Tc a window from 133 to 168 keV is preferable to the conventional 126 to 154 keV (20% centered) window.

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