Bone Imaging with Energy-Weighted Acquisition

Muralidhara G. Rao

Nuclear Medicine Service, Dwight D. Eisenhower Medical Center, Leavenworth, Kansas

Scattered radiation is the principal cause of image degradation in nuclear imaging. Several strategies have been tried to reduce the contribution of scattered radiation in nuclear imaging including energy-weighted acquisition (EWA). EWA reduces the effect of scattered radiation by assigning a positive value for primary photon and a negative value for scattered radiation. The effect of EWA for lesion detection on bone scans was compared with a standard acquisition protocol, referred to as normal weighted acquisition (NWA), in 97 patients by simultaneously acquiring bone scan images using both protocols. EWA identified 436 lesions (mean 4.49) and NWA 415 lesions (mean 4.28). There was no statistical difference in the number of lesions identified nor in the intensity of uptake in these lesions when assessed qualitatively. Therefore, it is concluded that EWA does not enhance lesion detection on ^{99m}Tc bone scans.

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Energy-weighted acquisition (EWA) reduces the contribution of scattered radiation, the principal cause of image degradation for nuclear imaging. The energy window used for routine imaging is centered about the photopeak. Gamma energies outside the photopeaks are rejected because they are thought to represent primarily scattered radiation. In EWA, the gamma rays outside the photopeaks are not rejected but are given a value based on the probability of whether the given event truly represents primary photon or scattered radiation (*1*). For example, a gamma ray in the primary photopeak will be given a positive value and a gamma ray in the compton scatter will be given a negative value.

For a 20% ^{99m}Tc window centered around the 140 keV peak, 30% of the accepted events may represent scattered radiation. For lower energy ^{201}Tl, this fraction is higher. Off peak acquisition can reduce scatter by centering the window to reject lower energies in the photopeak. However, this method has the disadvantage of reducing count rate.

Previous studies reported improvement in contrast with EWA. This improvement is more pronounced for isotopes with multiple photopeaks (*2*). Since ^{99m}Tc is the most commonly used radiopharmaceutical in nuclear medicine, this study was undertaken to compare bone scan images obtained with EWA and normal-weighted acquisition (NWA).

MATERIALS AND METHODS

Ninety-seven consecutive patients who were referred for a bone scan for a variety of indications are included in this review. Each patient was injected with 740 MBq of ^{99m}Tc-hydroxymethylene diphosphonate and images were obtained 3 hr later on a Siemens camera equipped with a weighted acquisition module (Siemens Medical Systems, Inc., Hoffman Estates, IL). A low-energy, all-purpose collimator was used to acquire 750,000 count spot images. Acquisition of images on EWA mode results in simultaneous acquisition of NWA images. These images are stored on the Siemens computer. Separate WAM and NWA hard copies were generated on a multiformat camera, after adjusting upper and lower thresholds for each image. Forty-nine patients had images of the torso, 29 had images of the extremities, 18 had images of the torso and extremities and 1 had images of the head.

The bone scans were interpreted by the author in a blinded fashion without clinical history, EWA or NWA status. The number of lesions on each patient study was noted. Uptake intensity was graded on a scale of 1 to 3, with 1 representing subtle uptake and 3 representing marked increased in uptake.

RESULTS

EWA bone scans identified 436 lesions (mean 4.49) and NWA identified 415 lesions (mean 4.28). The Wilcoxon signed rank test was utilized to test the null hypothesis that the medians of the populations from which the two sets of data for the variable number of lesions are assumed to be coming were equal. This null hypothesis could not be rejected, i.e., these data supported the conclusion that the two medians were not significantly different from each other (Table 1). The numerical value for the sign test was 79.5 ($p = 0.3320$). The score for intensity uptake in the bone scan lesions was 834 (mean 8.60) for EWA and 848 (mean 8.74) for NWA images. By using the same test, there was no significant statistical difference. The numerical value for the sign test in this case was 134.5 ($p = 0.2554$).

DISCUSSION

Several strategies have been used in nuclear imaging to reject scattered radiation since it reduces contrast and

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For correspondence or reprints contact: Muralidhara G. Rao, MD, Nuclear Medicine Service (115), Dwight D. Eisenhower Medical Center, Leavenworth, Kansas 66048.

TABLE 1
Descriptive Statistics for Number of Lesions and Intensity of Uptake Using EWA and NWA

	$\bar{x}$	$\tilde{x}$	Max	Min	Q_1	Q_2	s.d.	s.e.
Number of lesions								
EWA method	4.49	2	77	0	1	4	10.15	1.03
NWA method	4.28	2	66	0	0	4	9.70	0.99
Uptake intensity								
EWA method	8.60	3	172	0	1	8	21.03	2.14
NWA method	8.74	3	171	0	0	8	23.61	2.40

$\bar{x}$ = mean; $\tilde{x}$ = median; max = maximum value; min = minimum value; Q_1 = lower quartile; Q_2 = upper quartile; s.d. = standard deviation; s.e. = standard error for both methods. The sample size was n = 97 for both methods.

therefore lesion detection. The most frequent method is to use a narrow window over the photopeak to reduce scattered radiation. Depending on the patient's physical size, the radioisotope and the organ being imaged, a significant portion of the photopeak is composed of scattered radiation. In addition, a significant number of primary photons that fall outside the photopeak are rejected, thereby reducing overall counts in the image. Asymmetric window over the photopeak will also reduce scattered radiation but exacerbates the problem by rejecting primary photons that fall outside the windows. In EWA, none of the photons are rejected. Every photon is assigned a positive or negative value based on the energy value. The net effect is to reduce the contribution of scattered radiation and increase image contrast.

A recent review article on clinical radionuclide bone imaging recommended EWA as a means of improving image contrast (*3*). This study was undertaken to determine if EWA results in increased lesion detection on bone scans. The results suggest that there is no difference in the number of lesions detected or in the intensity of uptake on EWA and NWA acquisitions.

Previous studies using EWA showed that improvement in contrast was greater for ^{67}Ga and ^{201}Tl than with ^{99m}Tc (*4*). This may be due to single photopeak of technetium as compared with more than one photopeak for thallium and gallium. Technetium-99m was chosen for this review because it is the most frequently used radiopharmaceutical. There are several explanations why addition of EWA did not result in increased lesion detection in this study:

1. Bone scans performed on a modern nuclear camera with a 20-mCi dose injection have sufficient lesion contrast so that the addition of EWA does not make any difference.
2. In order to prevent interpreter bias, these images were acquired on a computer and later photographed on a multiformat camera to optimize contrast for each set of images using upper and lower threshholds (Figs. 1 and 2). This maneuver, in most studies, will increase image contrast by reducing background and increasing lesion intensity.
3. There are few scatter photons in ^{99m}Tc in comparison to an isotope with multiple photo peaks or lower energy gamma rays.

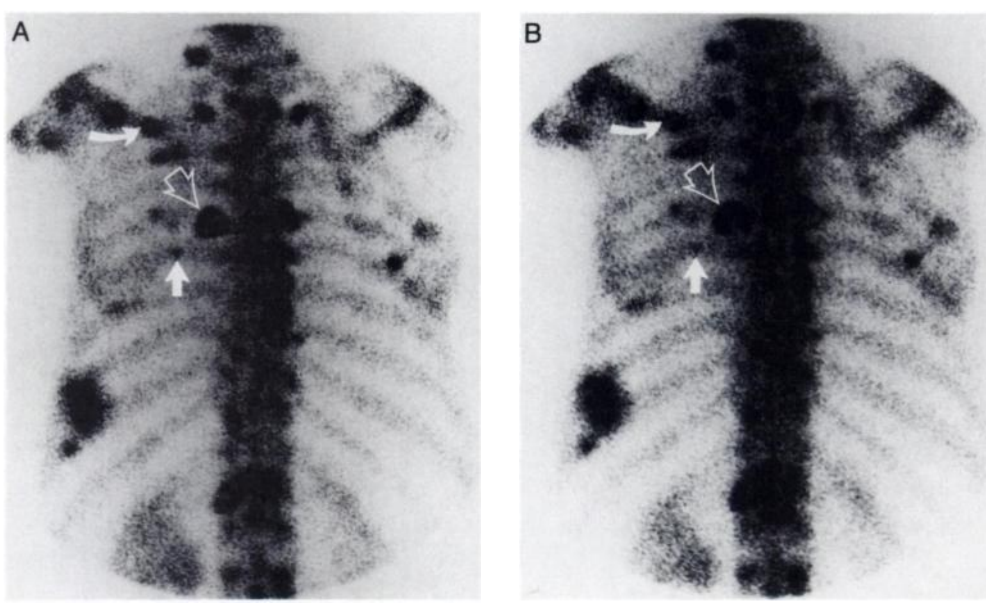

FIGURE 1. Posterior view of the rib cage with WAM (A) and NWA (B) shows multiple metastases. The WAM image has less background and blotchy uptake in the normal bone. Lesions are graded 1 (subtle uptake, straight arrow), 2 (good uptake, curved arrow) or 3 (marked increase in uptake, open arrow), depending on intensity of uptake.

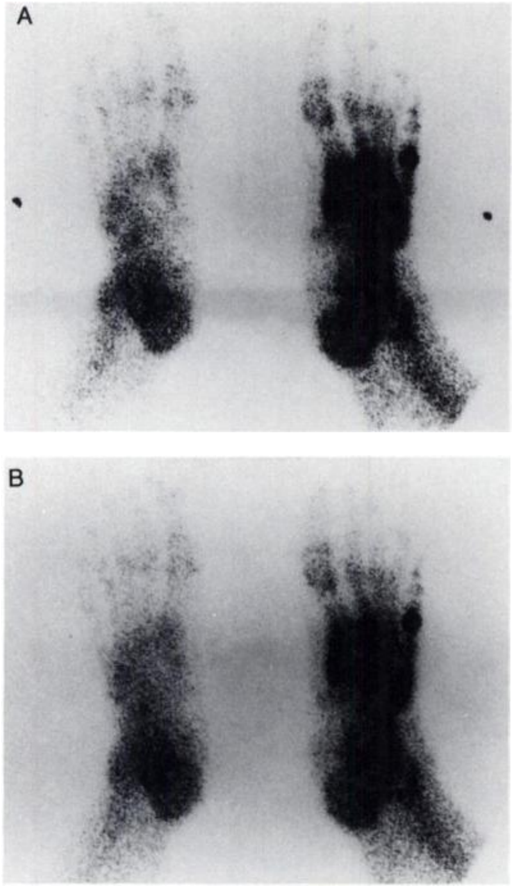

FIGURE 2. Bone scan of the feet with WAM (A) and NWA (B) shows equal resolution of small bony structures in the feet. The number of lesions and uptake intensity are similar in the left foot in the WAM and NWA images.

In conclusion, EWA does not increase lesion detection in ^{99m}Tc bone scans in planar imaging. Contrast may be increased on bone scans by acquiring the study on the computer and adjusting upper and lower thresholds to optimize the image. Additional studies are needed to show whether images acquired on WAM result in increased disease detection and not just more visually pleasing images.

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