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Efforts to Improve the Images from ^{67}Ga Whole-Body Scintigraphy

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Abstract

The acquisition method for planar ^{67}Ga imaging has hardly changed for 30 years. In this study, in order to improve image quality and diagnostic accuracy, we take steps to optimize the acquisition method, and to choose a scatter correction. First, we acquired individual images from the 93 keV, 185 keV, and 300 keV photopeak; then the images were added together and compared to the individual images. Second, we compared results from a low-medium-energy (LME) collimator with those from a conventional medium-energy (ME) collimator. Also, we examined whether to combine the data from all three of the usual window locations (set about 93 keV, 185 keV, and 300 keV) or to use the data from only two. Third, we compared results from a conventional photopeak ± 10% window with those from a photopeak ± 9 keV window. Fourth, for scatter correction we compared results using the triple energy window (TEW) method with those using the multi-photopeak dual window (MDW) method. The phantoms studied were cold rods in a uniform background, and hot spheres within a cylinder containing uniformly radioactive water. The clinical study involved 22 patients with lung lesions. By the comparison by the contrast ratio in cold rods phantom, 15.6% is improved in LME (2 peaks) than ME (3 peaks), and 3.2% is improved in photopeak ± 9 keV than photopeak ± 10%, 10.2% is improved in TEW than MDW. However, the TEW scatter correction method recognized unstable to the contrast ratio in a clinical study. In addition, a body outline might disappear.

Keywords

^{67}Ga Imaging, LME Collimator, MDW Scatter Correction

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1. Introduction

^{67}Ga-citrate is used for the diagnosis of malignant tumors. It is a still an effective nuclide in hospitals that do not own a PET imager [1]. But the acquisition method for ^{67}Ga imaging has hardly changed for 30 years. A medium energy collimator is used for the acquisition of three photopeak windows (center energy at 93, 185, and 300 keV). The resultant ^{67}Ga images are not very sharp, and there are few reports about image processing to improve the resolution [2].

2. Materials and Methods

2.1. Base Study

First, we acquired individual images from the 93 keV, 185 keV, and 300 keV photopeak; then the images were added together and compared to the individual images.

Second, we compared the results with the LME collimator [3] with those from the conventional ME collimator. The LME collimator has characteristics that are intermediate between the low energy (LE) and the ME collimator. That is the LME collimator has lower spatial resolution and less septal penetration than the LE collimator and higher spatial resolution and more septal penetration than the ME collimator. The energy window width is conventional photopeak ± 10%.

Third, photopeak ± 9 keV was compared with conventional photopeak ± 10%. Also, using photopeak ± 9 keV, the energy width of the 93 keV photopeak and that of the 185 keV photopeak were set to be equal. On the other hand, energy width for the conventional photopeak ± 10%, 93 keV is 9 keV about 93 keV, and 18 keV about 185 keV.

Fourth, about the scatter correction, before correction were compared with the MDW method and TEW method [4]. The MDW method we employed is analogous to the ^{123}I-dual window (IDW) method [5]. The scattered radiation estimate wind is set in the upper part of the photoepeak by the same wind width (photopeak ± 9 keV or 10%). The Compton scattered radiation by the acquisition energy peak of the upper photopeak is removed. This approach may be effective for all multi-photopeak nuclides.

A dual detector system (E-CAM, Toshiba Medical Systems, Tochigi, Japan) was used for the research. For the first phantom study, we used a hot planar phantom containing seven cold rods (ILS Type, Kyoto Kagaku Co., Ltd., Kyoto, Japan). The thickness was 15 mm. The diameters of the cold rods were 6, 8, 10, 15, 20, 25, 30, 40 mm. For the second phantom study, we used a cylindrical phantom with three hot spheres arranged at equal intervals (NEMA IEC Body Phantom Set™, Data Spectrum Co., Hillsborough, USA). The diameters were 20, 25, and 30 mm. The activity injected into the parts of the phantom was calculated to make the background concentration to be in the proportion of 1.0 to 5.0 compared to the tumor concentration. Static images of the phantom study scanned at 60 counts/pixel, using a 256 × 256 matrix. This proportion is similar to that in a clinical study.

2.2. Clinical Study

For the clinical studies, whole body images were acquired within 48 hours after the intravenous injection of 111MBq ^{67}Ga-citrate. In the whole body scan, both anterior and posterior images were acquired at a speed of 15 cm/min, using a 256 × 1024 matrix. In 22 patients' (15 men and 7 women; mean age ± SD, 62.5 ± 14.1 years old) the whole body images before and after scatter correction were compared by using the visual evaluation of three nuclear medicine physicians.

3. Statistical

The detectability of the signal in different images is compared with a profile curve. Profile curves (arrows shown in each scheme) were used for the evaluation of the cold rods. They are shown after normalizing the maximum of each static image to 100%. The contrast ratio compared in 25 mm or more that a partial volume effect was hard to influence. The contrast ratio assigned pixel values to the cold rods counts of 25 mm (min) and to the maximum counts (max), and calculated the contrast ratio (P-CR) by the following formula; P-CR = (max − min)/(max + min). The sphere measured 25 mm in diameter.

In the clinical study, the investigators assigned ROIs to ascertain the thigh counts per pixel (T) and the lung lesion counts per pixel (L). Here, we calculated the contrast ratio (C-CR) by the following formula; C-CR =

[(L − T)/(L + T)] × 100 (%). Values are described as mean ± standard deviation (SD). Data was analyzed with JMP 9.0 software (SAS Institute Japan, Inc. Japan). One-way repeated-measures ANOVA with the least-square differences post hoc test was used for comparison of the three whole body image. Probability values < 0.05 were considered statistically significant.

4. Results

As for P-CR of the cold rods, LME (2 peaks) was the best at 55.4% (**Figure 1** and **Figure 3(a)**), compared to 39.8% for ME (3 peaks), and 42.1% for ME (2 peaks). Next, with respect to the P-CR dependence on width of the LME2 peak, photopeak ± 9 keV was slightly better at 58.5% compared to 55.4% for photopeak ± 10% (**Figure 2** upper and **Figure 3(b)**). And, P-CR after scattered correction was better with the TEW method at 80.1%, compared to 69.9% with the MDW method (**Figure 2** upper and **Figure 3(c)**). With the sphere, after TEW was the better at 100.0%, after MDW was 75.4%, and before SC was 65.2 (**Figure 2** lower and **Figure 3(d)**). Further, P-CR was the tendency that was similar about other signals. We did not add 300 keV image of LME because could not recognize the signal. TEW subtracted counts from too much in hot spheres, backgrounds became 0 counts.

The clinical study is 65 years old man by sarcoidosis (**Figure 4**); the abnormal accumulations are located in the lungs or its associated lymph nodes. When the mean C-CR (%) was calculated, that with the TEW correction was 53.2%, that with the MDW correction was 48.6%, and that without a correction was 40.5%. All three difference were statistically significant. We judged that the MDW method gave a satisfactory, improved clinical image. The TEW scatter correction method seemed prone to yield inaccurate contrast ratios and could sometimes remove the body outline. Such a removal was deemed undesirable.

5. Discussion

The evaluation of the ^{67}Ga whole body image is difficult, because the ^{67}Ga has little uptake in normal organs. Generally, tumor uptake is compared visually, but "truth" is not known. In our clinical study, we looked at the contrast of a lung lesion relate to the thigh.

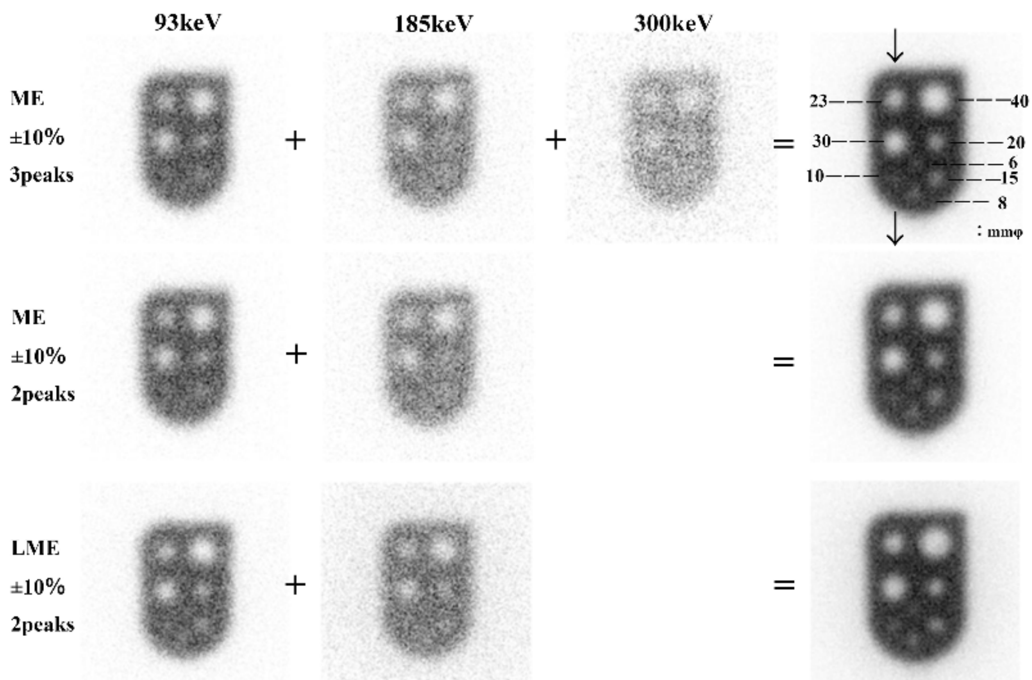

Figure 1. Cold-rods phantom results. Image are shown for each photopeak (centered at 93, 185, and 300 keV) and for the sum of the three images. Window width is always ±10%. The three different rows are distinguished by the collimator type and the number of peaks summed for the leftmost column. Note that some individual images are repeated.

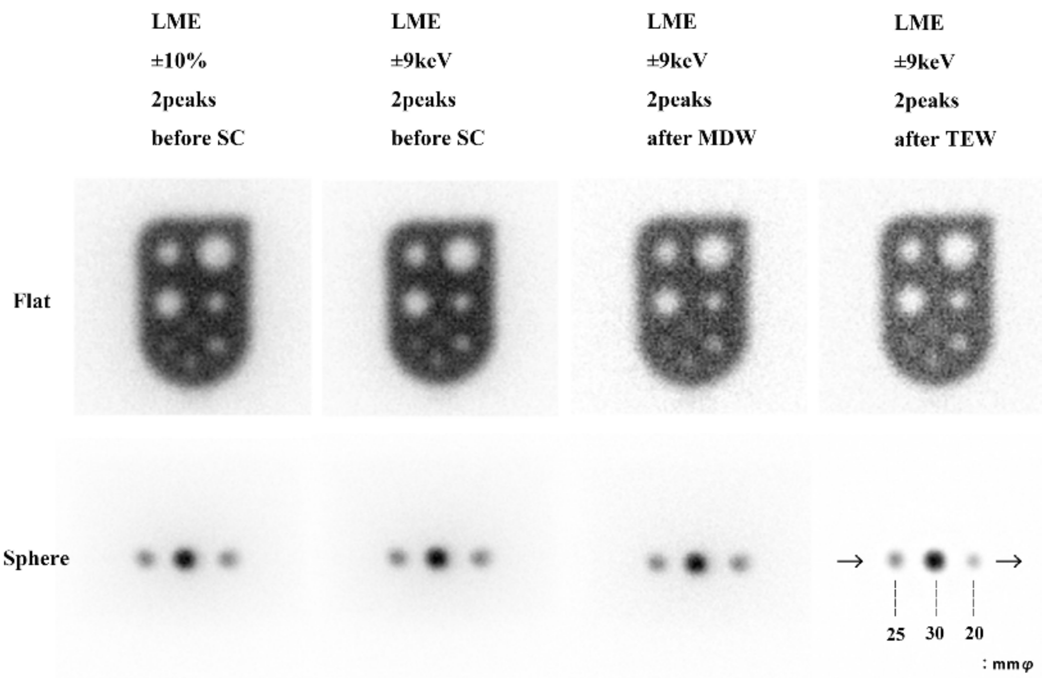

Figure 2. Phantom images for different photopeak width and before scattered correction and then for the ±9 keV width after scattered correction of two types. Upper row is for planar phantom. Lower row is for sphere phantom.

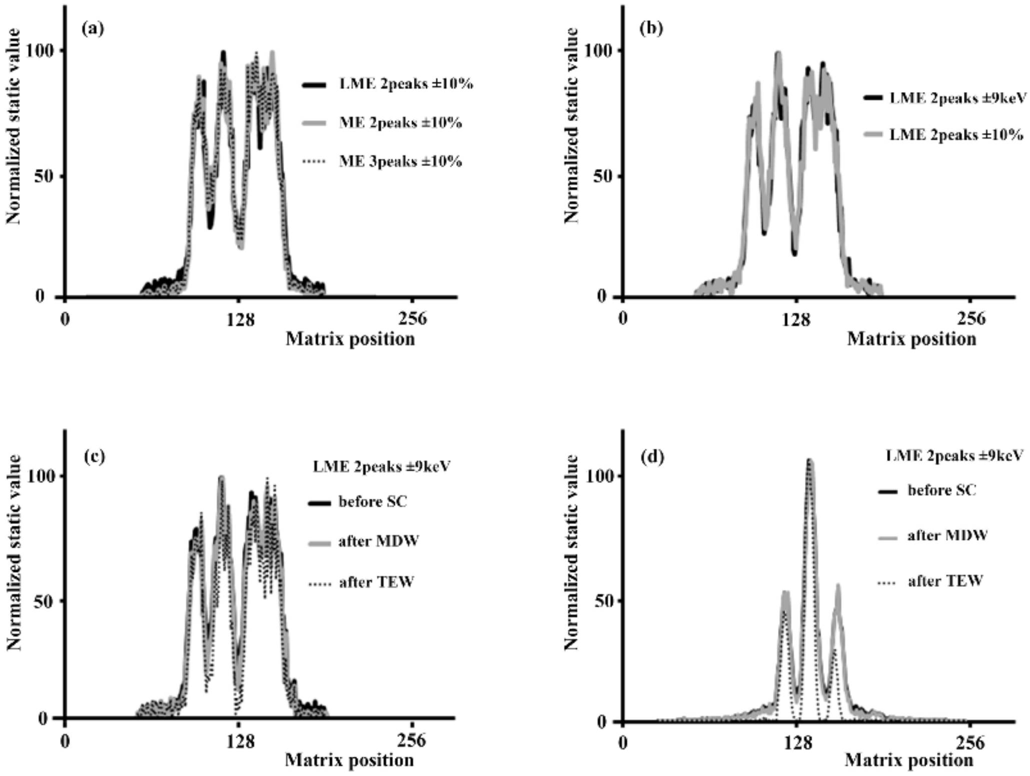

Figure 3. Profile curves. First three are for cold-rod phantom. Left upper (a) is different collimator and combination of photopeak (±10%). Right upper (b) shows results with different photopeak width. Left lower (c) shows results with each scatter correction method (LME 2 peaks ± 9 keV). Right lower (d) is shows results from the sphere phantom with each scatter correction method (LME 2 peaks ± 9 keV).

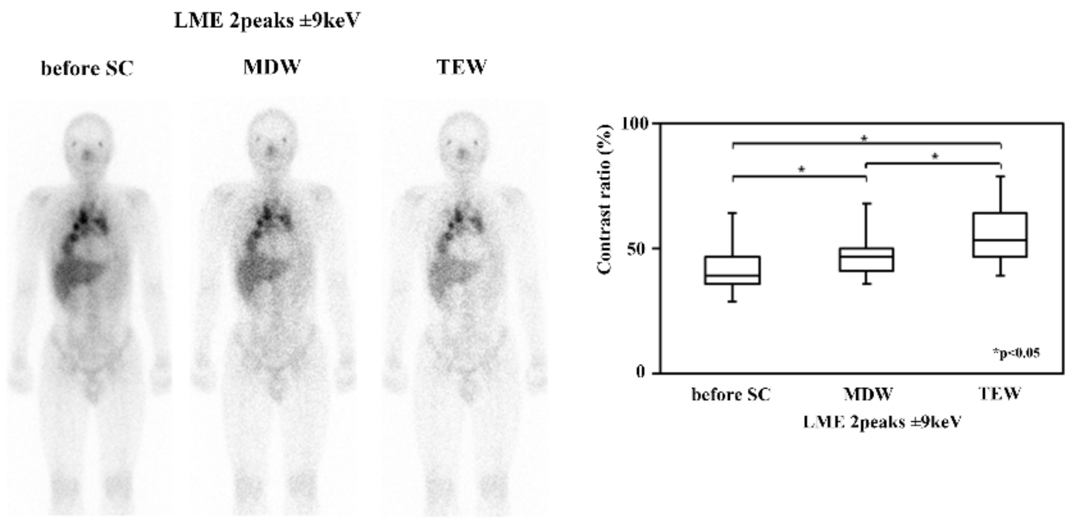

Figure 4. Patient studies. In left half is sample whole body image without scatter correction and with scatter correction by each of the two methods. In the right half we plot the contrast ratio averaged over the 22 cases without scatter correction and with scatter correction by each of the two methods.

Report on image improvement of ^{67}Ga imaging has been limited to whole body (WB) SPECT until now [2]. Such SPECT was performed using LE collimation with photopeaks at 93, 185 keV and scatter compensation by the TEW method. SPECT of Head and neck, thorax, and each SPECT was merged to get WB SPECT. After these data acquisition, three-dimentional display of the body was shown based on the Maximum Intensity Projection method. The detectability of tumor is improved, but SPECT image decreases remarkably. We reviewed acquisition condition by the basic phantom study from the beginning.

Initially, we investigated using the LME collimator for ^{67}Ga whole body scintigraphy. System resolution was improved with this collimator compared to ME collimator. And sensitivity improved by a factor of 1.3 compared to ME collimator, it was able to supply for counts decreasing by scatter correction. This is clear from a result. The image was improved exclude 300 keV image and narrowing wind width of 185 keV image. Third, scatter radiation estimate image by TEW scatter image which an image has decreased many counts by subtraction. However, the MDW method subtracted a dispersion ingredient from moderately, and an image was improved. A surface of body counts (BG) decreases by the TEW method remarkably. As for this, the oversight of small tumor is expected.

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