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A new method for crosstalk correction in simultaneous dual-isotope myocardial imaging with Tl-201 and I-123

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We have developed a new method of crosstalk correction in simultaneous dual-isotope imaging with Tl-201 and I-123 by using crosstalk ratios and a blurring filter.

Single isotope myocardial studies (10 for Tl-201 and 7 for I-123) were performed with a dual energy window acquisition mode and two low energy general-purpose collimators. Then two planar images acquired with dual energy windows for a Tl-201 line source and an I-123 line source were obtained to measure line spread functions (LSFs) and crosstalk ratios for each image.

The line source experiments showed that the LSFs for the Tl-201 imaging window from the single Tl-201 source were very similar to those for the I-123 imaging window from the single Tl-201 source, but the LSFs for the Tl-201 imaging window from the single I-123 source had broad shapes which differed from those for the I-123 imaging window from the single I-123.

To obtain accurate I-123 crosstalk images in the Tl-201 imaging window from the I-123 images in the I-123 imaging window, we designed a low-pass blurring filter. In 7 clinical I-123 MIBG studies, I-123 window images processed with this filter became very similar to the Tl-201 window image from the single I-123 source.

The method proposed in this study can accurately correct the crosstalk in dual isotope studies with Tl-201 and I-123 and is easily applicable to conventional gamma camera systems with any dual energy window acquisition mode.

Key words: crosstalk correction, dual-isotope myocardial imaging, Tl-201, I-123 MIBG

INTRODUCTION

RECENTLY, simultaneous dual-isotope imaging has been applied to heart, brain, lung, thyroid and parathyroid studies.[1–6] For myocardial imaging, studies with new I-123 labeled agents, such as I-123 meta-iodobenzyl-guanidine (MIBG) and I-123 β-methyl-p-iodophenyl-pentadecanoic acid (BMIPP), have been developed and compared with the Tl-201 perfusion study in Japan.[7] Simultaneous dual-isotope study offers many advantages: evaluation under the same physiological conditions, geometrically identical registration, reduction of the time for data acquisition, and improvement of patient throughput, but crosstalk between the two radionuclides impairs image quality and quantification. We developed a new crosstalk correction method for simultaneous Tl-201 and I-123 dual-isotope imaging; the method uses a crosstalk ratio and a blurring filter to estimate crosstalk from Tl-201 to the I-123 window and that from I-123 to the Tl-201 window, respectively.

MATERIALS AND METHODS

We used a dual-head gamma camera (GCA-7200A/DI, Toshiba, Japan) with low energy general purpose (GP) collimators and an image processor (GMS-5500DI, Toshiba, Japan).

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Crosstalk measurement in clinical studies
Clinical myocardial studies with a single isotope, Tl-201 (148 MBq) or I-123 (111 MBq), were performed to measure crosstalk ratios.

Six males and 4 females, age range 11–68 yr, with ischemic heart disease or familial amyloid polyneuropathy were examined in Tl-201 myocardial studies. Five males and 2 females, age range 11–74 yr, with the same diseases were examined in I-123 MIBG myocardial studies.

Images were acquired with a dual energy window mode: a 25% energy window centered at 71 keV for Tl-201 and a 20% energy window centered at 159 keV for I-123. Planar images were obtained in the anterior (ANT), 45° left anterior oblique (LAO45) and 70° left anterior oblique views (LAO70). Each imaging time was 5 min. SPECT acquisitions of 60 frames over 360° were performed in step and shoot mode, 30 sec per frame, with 64 × 64 image matrices, and a zoom factor of 1.5.

After two-dimensional Butterworth filtering (order of 8 and cutoff frequency of 0.25 cycles/pixel) for projection images, SPECT images were reconstructed by a filtered backprojection method with a ramp filter.

Figure 1 shows the locations of various ROIs in planar and SPECT images. In the planar images, three ROIs were set at the heart, liver and left lung regions. In SPECT images, all short axis images of the LV myocardium were summed, and four ROIs were set at the anterior, lateral, inferior and septal walls. The ratio of the Tl-201 counts in the I-123 window to the Tl-201 counts in the Tl-201 window was defined as the crosstalk ratio of Tl-201 in the I-123 window. The ratio of I-123 counts in the Tl-201 window to I-123 counts in the I-123 window was defined as the crosstalk ratio of I-123 in the Tl-201 window.

Crosstalk measurement in phantom experiment
To investigate the characteristics of the two crosstalk in clinical studies, we performed a basic phantom experiment with a Tl-201 or a I-123 line source (0.5 MBq, two line sources were 2 cm in length). The Tl-201 or I-123 line source was placed at the center of the water tank (20 × 20 × 20 cm), and planar images were obtained with the two energy windows. Imaging was performed with the line source suspended in the air or surrounded by forward scattering materials ranging in thickness from 1 cm to 9 cm and a fixed backward scattering material 10 cm thick. The distance between the source and the collimator was 12 cm (Fig. 2). One ROI with the source size and four rectangular ROIs of various sizes as shown in Fig. 3 were set around the line source images acquired with the dual energy window, and the crosstalk ratios were calculated from the counts in these ROIs. The two planar images acquired with the dual energy window for each isotope were visually compared, and the count profile curves were also compared.

Development of a method for crosstalk correction
On the basis of characteristics of the crosstalk images and crosstalk ratios elucidated in the phantom and clinical studies, a blurring filter was developed to compensate for the crosstalk from the I-123 to the Tl-201 window as described later.

RESULTS

Crosstalk measurement in clinical study
Comparisons of crosstalk ratios in clinical Tl-201 or I-123 MIBG studies are shown in Fig. 4 for planar imaging and Fig. 5 for SPECT imaging. In the Tl-201 myocardial planar imaging, the crosstalk ratio of Tl-201 in the I-123 window was almost constant, and its mean value was 0.127 in the myocardium, lung, and liver regions at various projections, but in the I-123 MIBG planar imaging, the crosstalk ratio of I-123 in the Tl-201 window changed from 0.25 to 0.65 at various projections, especially in the heart. In the SPECT imaging, the crosstalk ratio of Tl-201 in the I-123 window was about 0.12 in all the myocardial regions, but the crosstalk ratio of I-123 in the Tl-201 window varied from 0.20 to 0.42 and had a tendency to increase in the inferior and septal regions in comparison with the anterior and lateral regions.

Crosstalk measurement in the phantom experiment
a. Planar images and profile curves

In Tl-201 imaging, the Tl-201 images obtained in the I-123 window and the Tl-201 window were similar under various water thicknesses, but in I-123 imaging, the I-123 images observed in the Tl-201 window were blurred compared with the images in the I-123 window. Figure 6 shows the planar images acquired with the dual energy window and these profile curves for the Tl-201 line source (Fig. 6a) or for the I-123 line source (Fig. 6b).

b. Measurement of crosstalk ratio

The crosstalk ratios obtained from planar images for the Tl-201 or I-123 line source are shown in Fig. 7.

The crosstalk ratios of Tl-201 in the I-123 window changed from 0.11 to 0.27 for various ROI sizes as the water thickness increased. The crosstalk ratios of I-123 in the Tl-201 window showed great changes from 0.05 to 0.53 for the wider ROI sizes, whereas these ratios in the source area (ROI1) changed from 0.03 to 0.06.

Design of a blurring filter for I-123 crosstalk image in Tl-201 window
From the results represented in Fig. 6 and Fig. 7, it was found that a constant crosstalk ratio can be applied to the crosstalk correction of Tl-201 in the I-123 window, but for the crosstalk correction from I-123 to the Tl-201 window, a specific filter, which generates a blurred image with a proper crosstalk ratio, is necessary to approximate the I-123 crosstalk image in the Tl-201 window. We therefore

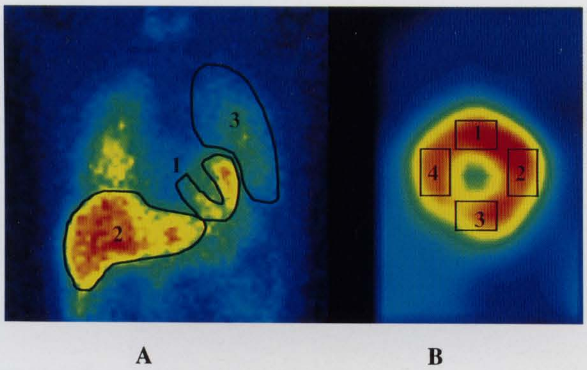


Fig. 1 ROI positions for crosstalk ratio measurement in single Tl-201 and single I-123 MIBG myocardial studies. (A) Planar images: ROI1-heart, ROI2-liver and ROI3-lung. (B) SPECT images: ROI1-anterior, ROI2-lateral, ROI3-inferior, and ROI4-septal walls

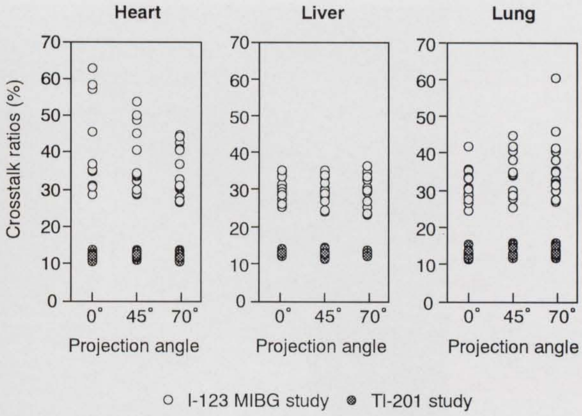


Fig. 4 Comparison of crosstalk ratios of the heart, liver and lung regions in Tl-201 and I-123 MIBG myocardial planar imaging.

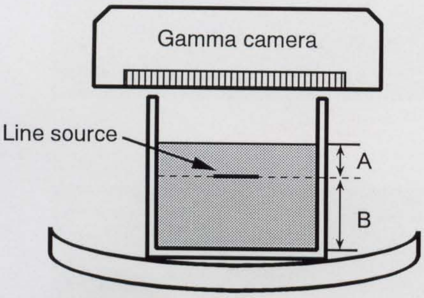


Fig. 2 Phantom experiment for Tl-201 and I-123 line sources in a water tank (20 × 20 × 20 cm). A: forward scattering materials (water, 0–9 cm) and B: backward scattering materials (water, 10 cm)

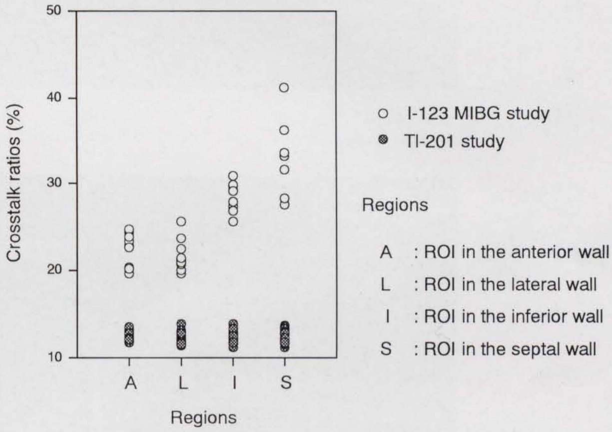


Fig. 5 Comparison of crosstalk ratios of the heart region in Tl-201 and I-123 MIBG myocardial SPECT imaging.

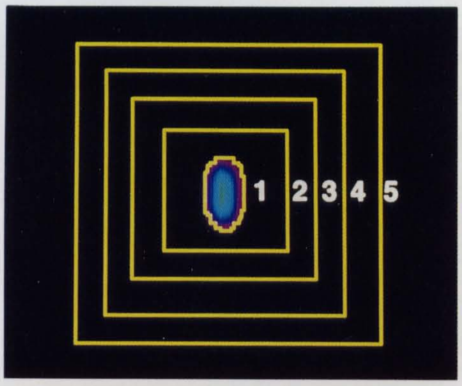
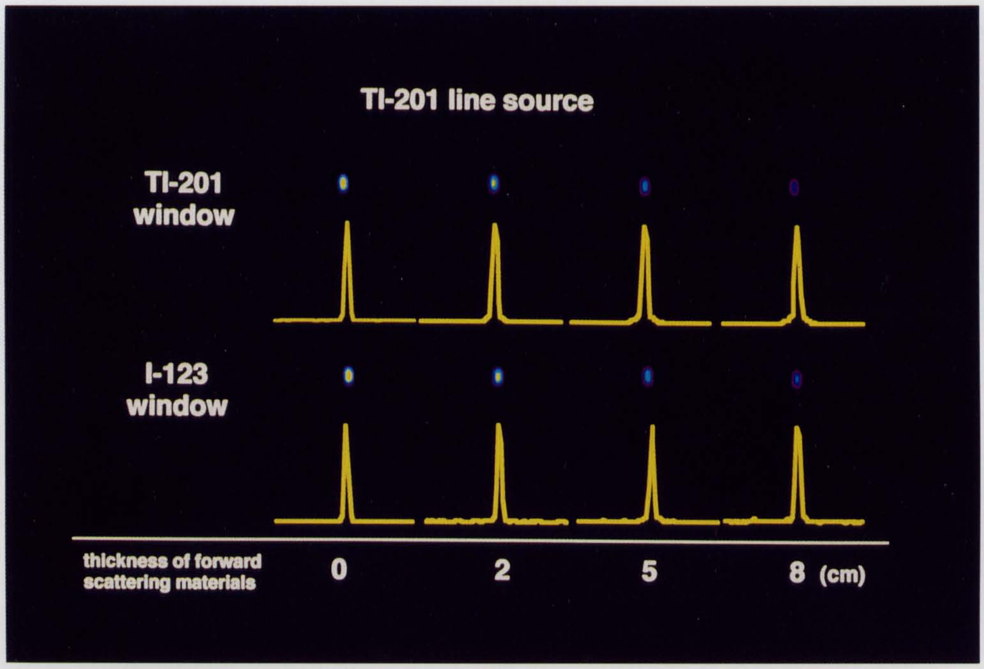


Fig. 3 ROI positions around the line source. ROI1-line source area (256 pixels), ROI2-30 × 30 pixels, ROI3-50 × 50 pixels, ROI4-70 × 70 pixels, ROI5-90 × 90 pixels

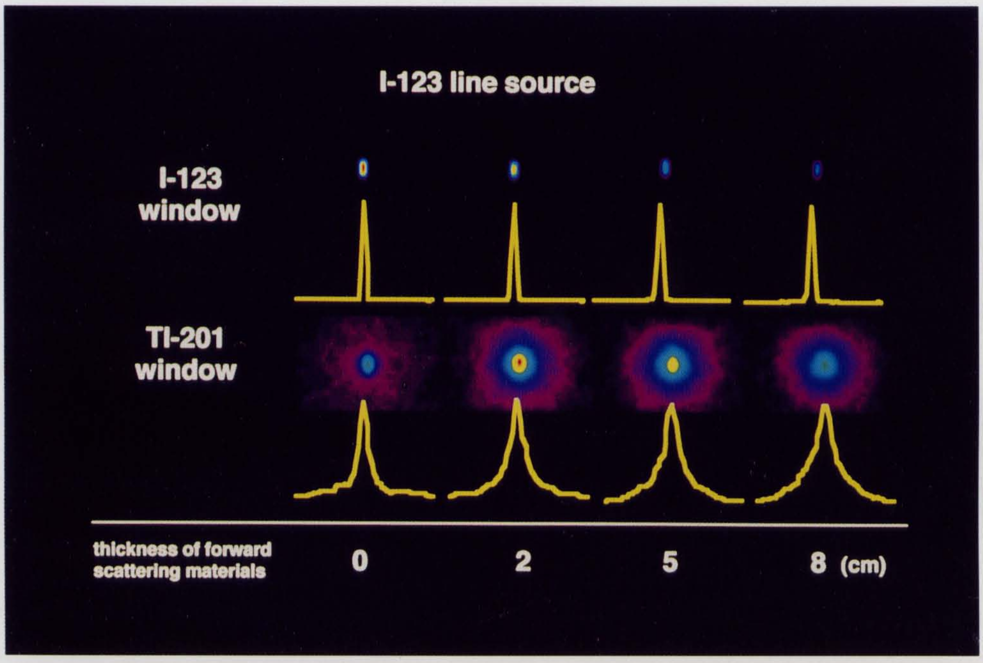
designed a blurring filter to imitate the I-123 crosstalk image in the Tl-201 window from the I-123 window image at the line source experiment with the 5 cm forward water thickness. We decided to adopt this 5 cm forward water thickness in consideration of the average myocardial depth from the thorax surface. As shown in Fig. 8, this filter was made by combining the smoothing filter and Butterworth filter. Figure 9 illustrates the planar images for the I-123 line source (Fig. 9a) and a patient in an I-123 MIBG myocardial study (Fig. 9b) obtained with the dual energy window acquisition for I-123 and Tl-201, and an estimated Tl-201 window image, which is generated from the original I-123 images in the I-123 window by using the blurring filter, and also compares the count profile curves for these three planar images. It was found that the estimated I-123 crosstalk image in the Tl-201 window was very similar to the true I-123 crosstalk image in the Tl-201 window.

We applied the blurring filter technique to I-123 MIBG clinical planar images. Figure 10 shows a correlation between the true and estimated crosstalk ratios for I-123 images in the Tl-201 window. The crosstalk ratios were well correlated with the true crosstalk ratios of I-123 in the Tl-201 window (r = 0.942).

We present a comparison of clinical SPECT images with and without crosstalk correction in Fig. 11. A patient



a



b

Fig. 6 Planar images and count profile curves for Tl-201 or I-123 line source with different forward scattering water thickness. a: Tl-201 data acquired with the dual energy window for the Tl- 201 and I-123. b: I-123 data acquired with the dual energy window for the Tl-201 and I-123.

with diabetes mellitus who was simultaneously administered Tl-201 and I-123 MIBG was imaged with the dual energy window, and data were processed by the conventional crosstalk correction method[7] and our proposed correction method. We then employed the crosstalk ratio 0.127 of Tl-201 in the I-123 window and 0.25 of I-123 in the Tl-201 window for the crosstalk correction with constant crosstalk ratios. The I-123 crosstalk to Tl-201 images, especially around the myocardium, was well corrected with the filter method in comparison with the conventional constant value method.

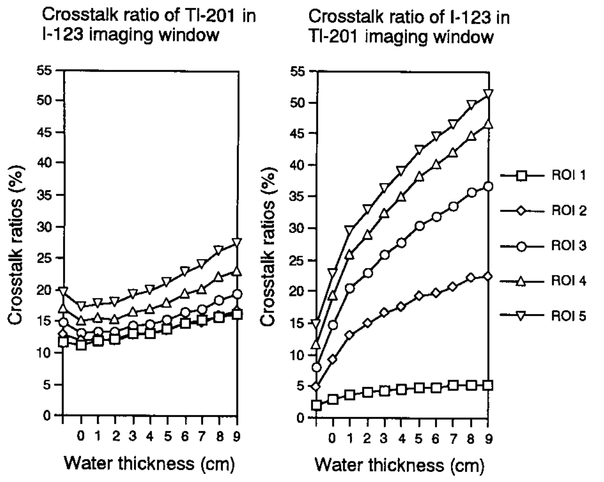


Fig. 7 Comparison of crosstalk ratios for various ROI sizes set on planar images for a Tl-201 line source or an I-123 line source.

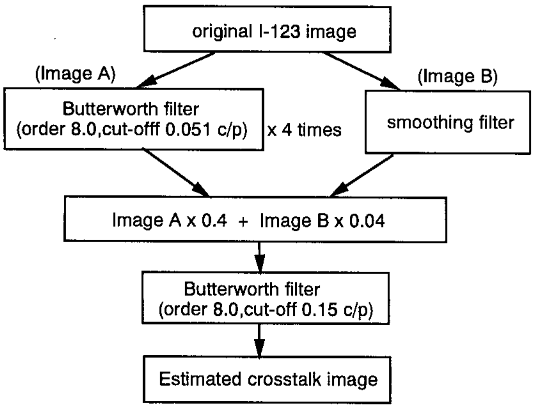


Fig. 8 Generation of estimated crosstalk image with a blurring filter which combines two different types of Butterworth filters and one conventional smoothing filter.

DISCUSSION

We reported the crosstalk contamination measured with energy spectra and images in simultaneous dual isotope imaging for Tl-201 and I-123.[8] Although the gamma camera used in the above study differed, each crosstalk image represented in the present study of Tl-201 and I-123 showed the same qualities as the images in the previous report.[8]

In Tl-201 imaging in the present study, the Tl-201 crosstalk image in the I-123 photopeak window had a similar shape to that of the Tl-201 photopeak image because the Tl-201 photopeak energy of 167 keV gamma rays is included in the I-123 photopeak energy window (159 keV-20%). From our phantom experiment with the Tl-201 line source, we found that this similarity is not affected by the thickness of the scattering materials, and the crosstalk ratio is almost constant. Therefore, for crosstalk correction of Tl-201 in the I-123 window, the application of a constant crosstalk ratio is reasonable. On the basis of our results, we employed 0.127 as the crosstalk ratio for Tl-201.

In contrast, in I-123 imaging, the I-123 energy distribution of down scatter and lead x-rays from the collimator overlap with the Tl-201 photopeak energy window (71 keV-25%) as described in our previous paper.[8] Therefore, the I-123 crosstalk image in the Tl-201 window is not similar to the I-123 photopeak image, and crosstalk ratios vary depending on the shape of the scattering materials. As the I-123 crosstalk image in the Tl-201 window is blurred due to scatter and the collimator's lead x-rays, the target source is affected by the spillover photons from other sources around it. For myocardial imaging, photons from the liver and lung become major sources of image degradation.

We have developed a method to correct I-123 crosstalk in the Tl-201 window during simultaneous Tl-201 and I-123 dual-isotope imaging. In this method, a specially designed blurring filter is used to generate the I-123 crosstalk image with poor spatial resolution from the I-123 window image, and this I-123 crosstalk image is subtracted from the Tl-201 window image. The filter was designed so as to approximate the spatial resolution of the I-123 crosstalk image in the Tl-201 window at a water thickness of 5 cm with a combination of smoothing and Butterworth filters.

Knesarek[9,10] proposed a crosstalk correction method based on the convolution technique in simultaneous Tl-201 and Tc-99m dual-isotope imaging. He designed the convolution filter by using point response functions to transform the photopeak image into the distorted crosstalk image and reported that this method improved the quality of simultaneous Tl-201 and Tc-99m SPECT imaging as compared with the simple crosstalk correction method with the crosstalk ratios.

Besides the simple crosstalk correction method using crosstalk ratios, the triple energy window (TEW) scatter correction method is used to correct crosstalk,[11] but the TEW method is only applied to special gamma camera equipment. Our crosstalk correction method is easily applicable to conventional gamma camera systems. If the measurement of point or line spread functions is performed with a certain acquisition (collimator type, center and width of energy window) for a combination of dual-isotopes, the blurring filter can be simply generated by a combination of smoothing and Butterworth filters.

The crosstalk correction method proposed in this paper improves the quality of simultaneous Tl-201 and I-123 imaging. It is practical and easily applicable to conventional gamma camera systems with the dual energy acquisition mode.

In conclusion, we propose the following crosstalk correction for simultaneous Tl-201 and I-123 dual-isotope imaging:

(1) for crosstalk correction of I-123 in the Tl-201

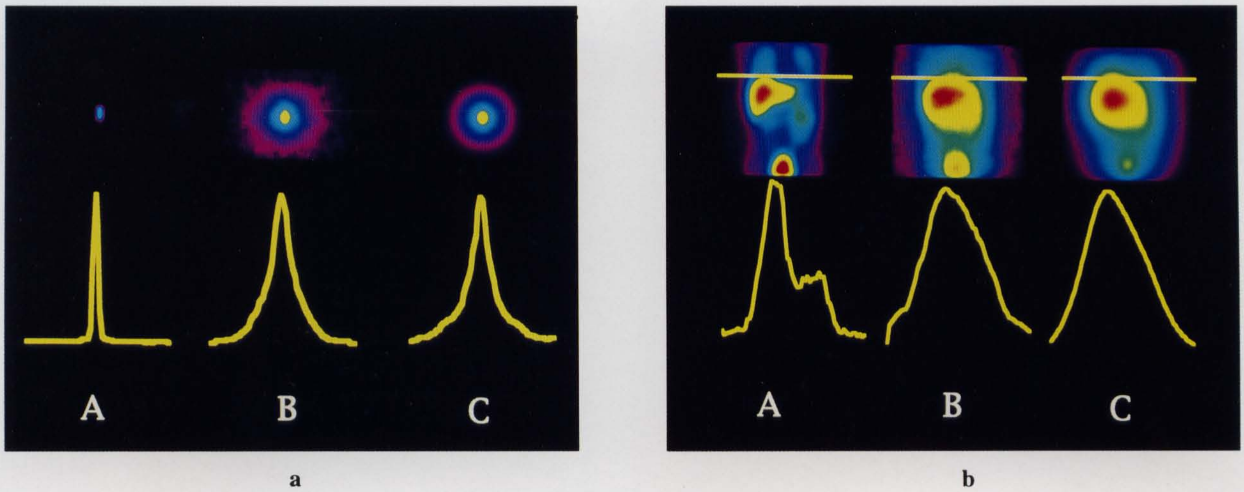


Fig. 9 Planar images and count profile curves for a I-123 line source at the 5 cm-thickness of forward scattering water (a) and a patient in I-123 MIBG myocardial study (b). A: original I-123 image from I-123 imaging window. B: true I-123 crosstalk image in Tl-201 imaging window. C: estimated I-123 crosstalk image obtained by processing an original I-123 image from the I-123 imaging window using the blurring filter.

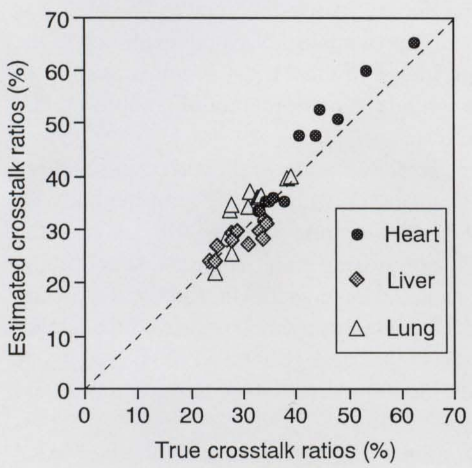


Fig. 10 Correlation between true crosstalk ratios of I-123 in a Tl-201 imaging window and estimated crosstalk ratios obtained from an I-123 photopeak image using the blurring filter. Seven patients in an I-123 MIBG study were imaged with dual energy window acquisition (Tl-201: 71 keV-25%, I-123: 159 keV-20%).

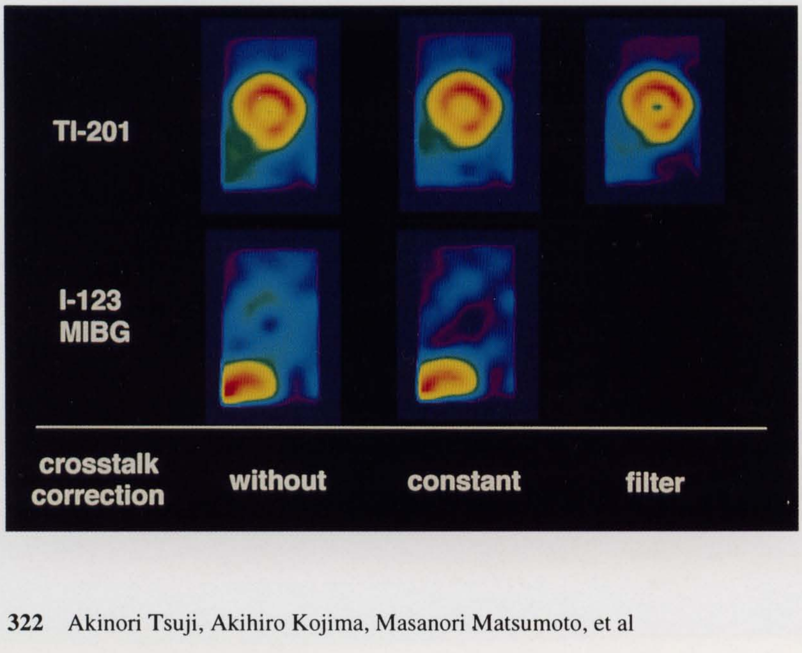


Fig. 11 Comparison of clinical SPECT images with and without crosstalk correction in simultaneous Tl-201 and Tc-99m dual-isotope imaging. The term "constant" refers to the conventional crosstalk correction method using the constant crosstalk ratio, while "filter" refers to the crosstalk correction method using the blurring filter that we proposed. The crosstalk ratio, 0.127, of Tl-201 in the I-123 window and 0.25 of I-123 in the Tl-201 window were employed for crosstalk correction using constant crosstalk ratios.

window, subtraction of the I-123 window image processed with our newly designed blurring filter from the Tl-201 window image.

(2) for crosstalk correction of Tl-201 in the I-123 window, subtraction of the Tl-201 window image multiplied by a constant crosstalk ratio from the I-123 window image.

REFERENCES

1. Zimmermann RE, Rauch B, Kapp M, Bubeck B, Neumann FJ, Seitz F, et al. Myocardial scintigraphy with iodine-123 phenylpentadecanoic acid and thallium-201 in patients with coronary artery disease: a comparative dual-isotope study. *Eur J Nucl Med* 19: 946–954, 1992.
2. Denous MD, Lowe JL, Payne JK. Dual-isotope brain SPECT imaging with technetium and iodine-123: validation by phantom studies. *J Nucl Med* 33: 2030–2035, 1992.
3. Denous MD, Payne JK, Lowe JL. Dual-isotope brain SPECT imaging with technetium and iodine-123: clinical validation using xenon-133 SPECT. *J Nucl Med* 33: 1919–1924, 1992.
4. Madsen MT, O'leary DS, Andreasen NC, Kirchner PT. Dual isotope brain SPECT imaging for monitoring cognitive activation: physical considerations. *Nucl Med Commun* 14: 391–396, 1993.
5. O'leary DS, Madsen MT, Hurtig R, Kirchner PT, Rezai K, Rogers M, et al. Dual isotope brain SPECT imaging for monitoring cognitive activation: initial studies in humans. *Nucl Med Commun* 14: 397–404, 1993.
6. Ivanovic M, Weber DA, Loncaric S, Franceschi D. Feasibility of dual radionuclide brain imaging with I-123 and Tc-99m. *Med Phys* 21: 667–674, 1994.
7. Nakajima K, Taki J, Bunko H, Shimizu M, Muramori A, Tonami N, et al. Error of uptake in dual energy acquisition with Tl-201 and I-123 labeled radiopharmaceuticals. *Eur J Nucl Med* 16: 595–599, 1990.
8. Kojima A, Tsuji A, Ohyama Y, Nabeshima M, Kira T, Nakashima R, et al. Measurement of crosstalk contamination in dual isotope imaging by means of energy spectra and images. *Radioisotopes* 43: 523–530, 1994.
9. Knesaurek K. A new dual-isotope convolution cross-talk correction method: a Tl-201/Tc-99m SPECT cardiac phantom study. *Med Phys* 21: 1577–1583, 1994.
10. Knesaurek K, Machac J. Enhanced cross-talk correction technique for simultaneous deal-isotope imaging: a Tl-201/Tc-99m myocardial perfusion SPECT dog study. *Med Phys* 24: 1914–1923, 1997.
11. Ogawa K. Simulation study of triple-energy-window scatter correction in combined Tl-201, Tc-99m SPECT. *Ann Nucl Med* 8: 277–281, 1994.