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Scatter correction by two-window method standardizes cardiac I-123 MIBG uptake in various gamma camera systems

Hideki KOBAYASHI, Mitsuru MOMOSE, Shinichi KANAYA, Chisato KONDO, Kiyoko KUSAKABE and Norio MITSUHASHI

Department of Radiology, Tokyo Women's Medical Univesity

Heart to mediastinum count ratio (H/M) has been commonly utilized as an indicator of myocardial I-123 MIBG uptake. However, normal ranges of H/M were markedly different among various gamma camera systems. The purpose of this study was to clarify whether scatter correction by two-window method standardizes H/M among various gamma camera systems. ***Methods:*** Scatter uncorrected and corrected MIBG imaging was acquired in phantom and human studies in combination with low energy high-resolution collimator (LEHR) and medium energy collimator (MEC). For scatter correction, energy window width of 159 keV ± 10% was applied to main window imaging and 193 keV ± 9.5% was applied to upper window imaging for scatter correction. ***Results:*** In phantom study, a significant difference was observed in uncorrected H/M among three gamma camera systems using LEHR or MEC (2.09 ± 0.06 vs. 2.58 ± 0.03 in GCA7200 camera, 2.00 ± 0.07 vs. 2.42 ± 0.06 in DS7 camera and 2.16 ± 0.04 vs. 2.67 ± 0.07 in Vertex plus camera). However, there was no significant difference in corrected H/M among the three gamma camera systems, either with LEHR or MEC (2.70 ± 0.07 vs. 2.69 ± 0.07 in GCA7200 camera, 2.66 ± 0.08 vs. 2.61 ± 0.05 in DS7 camera and 2.66 ± 0.05 vs. 2.61 ± 0.05 in Vertex plus camera). In human study, uncorrected H/M in DS7 camera with LEHC was significantly lower than that in GCA7200 camera with MEC (1.60 ± 0.37 vs. 1.85 ± 0.54, N = 14). In contrast, the difference was insignificant in corrected H/M (2.12 ± 0.59 vs. 2.16 ± 0.68). There was a very excellent correlation in corrected H/M between DS7 and GCA7200 cameras (r = 0.991, p < 0.001). ***Conclusion:*** This study demonstrated that scatter correction by the two-window method standardizes the H/M in MIBG scintigraphy either with LEHR or MEC. Scatter corrected H/M can be applied to measure a standardized parameter of MIBG uptake in human clinical studies using various gamma camera systems.

Key words: I-123 MIBG, scatter correction, two-window method, heart to mediastinum count ratio, collimator

INTRODUCTION

I-123 metaiodobenzylguanidine (MIBG) imaging has been widely used to predict poor prognosis in patients with heart failure.[1–5] Heart to mediastinal count ratio (H/M) has been commonly utilized as an indicator of myocardial MIBG uptake, and low H/M values generally indicate a poor prognosis in patients with heart failure.[1–5] However, it was reported that normal ranges of H/M were markedly different among various gamma camera systems.[6] Shiga et al.[7] reported that a normal range in the H/M value was 2.62 ± 0.58 using a collimator specialized for I-123, and 2.18 ± 0.43 with a low energy high resolution collimator (LEHR). If a patient undergoes MIBG scintigraphy repeatedly using different gamma camera systems, we may not be able to compare the H/M values obtained because of differences in the measured normal H/M value. A standardized method for measuring MIBG uptake in various gamma camera systems may be required in clinical practice. In this study, we evaluated the two-window

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For reprint contact: Hideki Kobayashi, M.D., Department of Radiology, Tokyo Women's Medical University, 8–1 Kawada-cho, Shinjuku-ku, Tokyo 162–8666, JAPAN.
E-mail: mkobayas@hij.twmu.ac.jp

method as a standardized method for measuring myocardial MIBG uptake in patients with heart failure.[8]

MATERIAL AND METHODS

Phantom study
A phantom study was performed using a liver-heart phantom (Kyoto Kagaku, Kyoto, Japan) as shown in Figure 1. For the phantom images, the myocardial cavity was filled with 15 MBq of I-123 diluted in 150 m*l* of solution. Liver, lung and mediastinal cavities were filled with 74 MBq of I-123 in 1,500 m*l*, 37 MBq in 1,500 m*l* and 15 MBq in 3,000 m*l*, respectively. Three gamma camera systems, DS7 camera (Sophy Medical, Buc, France), GCA7200 camera (Toshiba, Tokyo, Japan) and Vertex plus camera (ADAC, Milpitas, USA) were used. We compared the heart to mediastinal count ratios (H/M) with or without scatter correction measured using the low energy high resolution collimator (LEHR) or medium energy collimator (MEC) mounted on the three gamma camera systems.

Human study
Fourteen patients with various heart diseases were enrolled in this study [5 females and 9 males; aged 46.6 ± 10.6 years (mean ± SD)]. Four hours after the injection of 111 MBq of MIBG, an anterior planar image was acquired using a DS7 camera equipped with a LEHR. Immediately after the imaging, patients were moved to a GCA7200 camera and underwent anterior planar imaging by use of MEC.

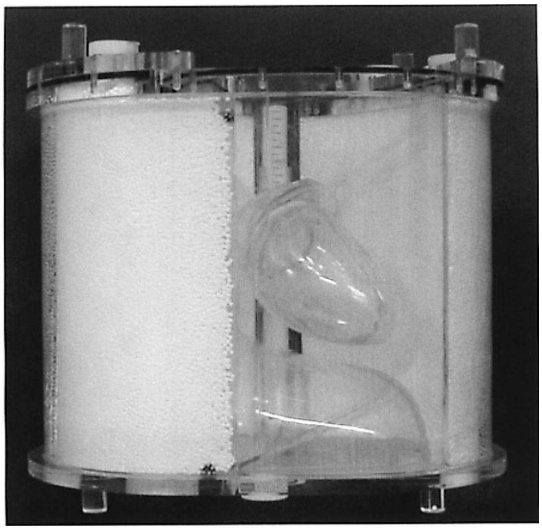

Fig. 1 Liver heart phantom for phantom imaging.

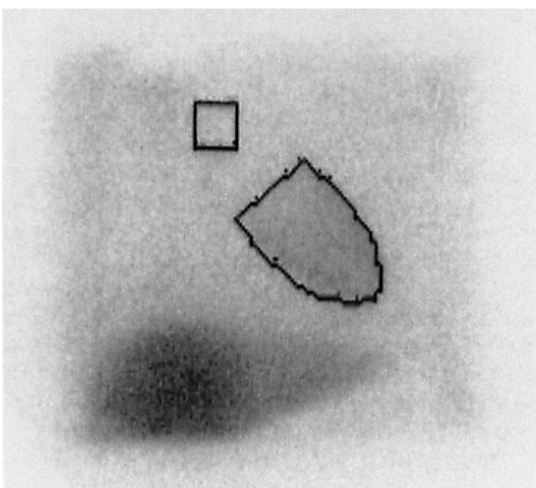

Fig. 2 ROI1 in the myocardium was drawn manually and a square ROI was used in the mediastinum region (ROI2) for calculating H/M.

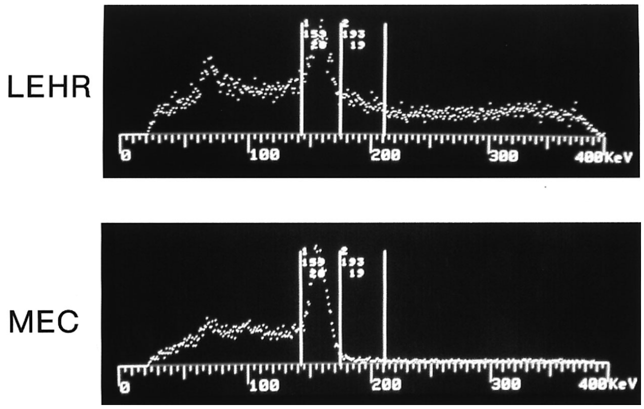

Fig. 3 Comparison of energy spectrum in phantom studies between LEHR and MEC in DS7 gamma camera.

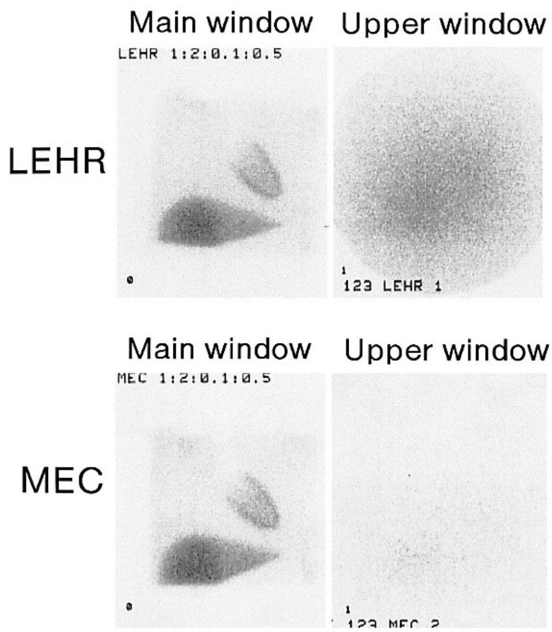

Fig. 4 Phantom images acquired with main window (159 keV ± 10%) and upper window (193 keV ± 9.5%) in DS7 gamma camera.

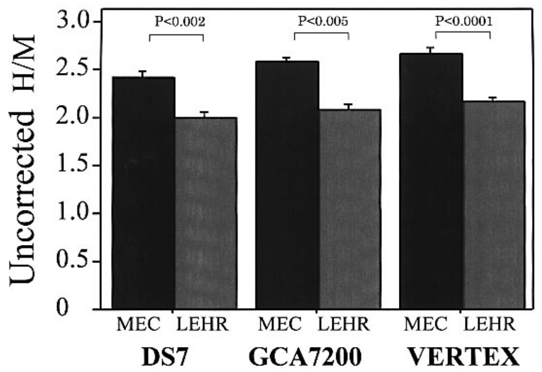

Fig. 5 Scatter uncorrected H/M among three gamma camera systems in combination with MEC and LEHR in phantom study (LEHR vs. MEC $p < 0.002$, among the three cameras $p < 0.001$, according to two way ANOVA).

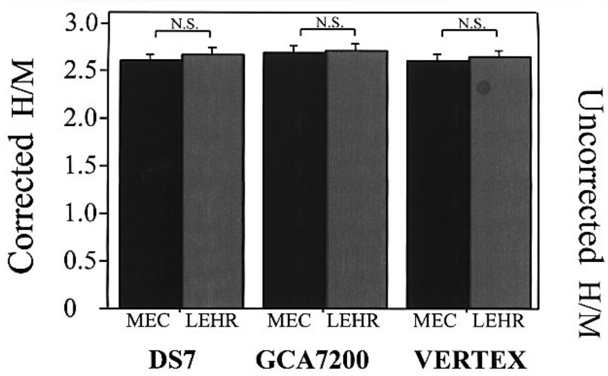

Fig. 6 Scatter corrected H/M among three gamma camera systems in combination with MEC and LEHR in phantom study.

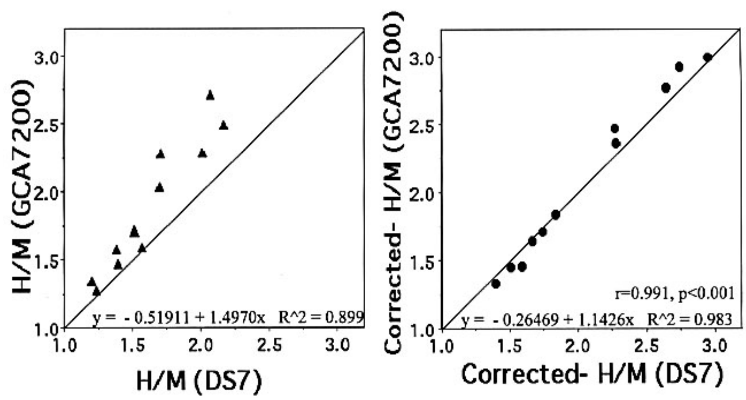

Fig. 7 Scatter uncorrected and corrected H/M between DS7 camera with LEHR and GCA7200 camera with MEC in human study.

Image acquisition and scatter correction

For scatter correction, we used the two-window method of scatter correction according to Motomura et al.[8] An energy window width of 159 keV ± 10% was applied to 159 keV main window imaging of I-123. Another window of 193 keV ± 9.5% was used for upper window imaging, in which the scatter fraction from the 529 keV component was estimated. Images were acquired with 256 × 256 matrix for 240 seconds in the phantom study and for 300 seconds in the human study. In the phantom study, three images were acquired for each combination of camera and collimator.

For the scatter correction, counts in the upper window imaging were corrected by use of the following formula:

$$Cscat529(x,y) = Cupper \times 31.8/36.6$$

where Cupper is the counts at a pixel located at the (z,y) coordinate in the imaging matrix. In this formula, 31.8 is the window width of the main window and 36.6 is the window width of the upper window. Cscat529(x,y) is the counts generated by estimated down scatter from the 529 keV component. Scatter corrected counts were calculated by use of the formula:

$$Ccorr(x,y) = Cmain(x,y) - Cscat529(x,y)$$

where Cmain is the counts of the pixel in the 159 keV main window imaging. Ccorr(x,y) is the scatter corrected data.

Table 1 H/M with or without scatter correction in human study

	DS7 with LEHR	GCA7200 with MEC	
Uncorrected H/M	1.60 ± 0.37	1.85 ± 0.54	$p < 0.05$
Corrected H/M	2.12 ± 0.59	2.16 ± 0.68	N.S.

mean ± standard deviation, H/M: heart to mediastinum count ratio

Data analysis

H/M values in scatter corrected and uncorrected images were calculated as follows.[7] The first region of interest (ROI) was drawn manually in the myocardium (ROI1), and the second ROI was drawn in the mediastinal region

$$H/M = \frac{H \times A2}{B \times A1}$$

(ROI2) (Fig. 2). H/M in the scatter corrected and uncorrected images was calculated by use of the formula: where H is the myocardial counts at ROI1, B is the mediastinal counts at ROI2, and A1 and A2 are the number of pixels within the ROI1 and ROI2.

Statistical analysis

Data are presented as the mean ± SD. The two way ANOVA was used to compare the scatter corrected and uncorrected H/M among three gamma cameras in combination with MEC or LEHR in the phantom study. A simple linear regression analysis was used to compare the H/M with and without scatter correction in the human studies.

RESULTS

Phantom study

Figure 3 shows energy spectrums in the phantom studies using a LEHR and MEC in the DS7 gamma camera. Scattered photons from the 529 keV component were apparently observed in the energy spectrum curve obtained with LEHR. In contrast, only a small number of scattered photons were observed in the energy spectrum curve obtained with MEC.

Figure 4 shows the phantom images acquired with the main and upper windows for I-123 with the DS7 gamma camera. The upper window image acquired with LEHR showed relatively homogeneous accumulation, whereas the upper window image acquired with MEC showed markedly reduced lower accumulations than LEHR.

Figure 5 shows uncorrected H/M in the phantom study, with a significant difference observed in the uncorrected H/M among the three gamma camera systems in combination with LEHR or MEC according to two way ANOVA statistics. The difference was also significant between the LEHR and MEC in each gamma camera system. However, there was no significant difference in corrected H/M among the three gamma camera systems either with LEHR or MEC, as shown in Figure 6. These results indicated that scatter correction by the two-window method reduces the difference in H/M among the three gamma camera systems in the phantom study.

Human study

Table 1 shows the comparisons between LEHR with the DS7 camera and MEC with the GCA7200 camera in measuring corrected and uncorrected H/M in the human study. Uncorrected H/M in LEHR with the DS7 camera was significantly lower than that in MEC with the GCA7200 camera. However, the difference was not significant in scatter corrected H/M. An excellent correlation was found between the DS7 and GCA 7200 cameras in measuring scatter corrected H/M ($r = 0.991$, $p < 0.001$), as shown in Figure 7.

DISCUSSION

The normal range of H/M in MIBG varied significantly among many institutions,[6,7] and this variability is unfavorable in multicenter trials or meta-analyses of MIBG scintigraphy for the establishment of prognosis in patients with heart failure. In this study, we evaluated the two-window method for standardizing H/M among the various gamma camera systems in combination with LEHR or MEC.

Scatter-corrected H/M

In the phantom study, there was no significant difference in scatter-corrected H/M among the three gamma camera systems irrespective of the collimators used, whereas the differences became significant in uncorrected H/M. In the human study, there was an excellent correlation between the DS7 camera with LEHR and the GCA7200 camera with MEC in measuring scatter corrected H/M, but this was not the case when measuring uncorrected H/M. The present results strongly suggested that H/M corrected by the two-window method is predominantly effective for standardizing parameters of MIBG uptake in different gamma camera systems.[8]

Iodine-123 gamma photon radiation included a 529 keV component in 1.39% of the total number of photons.[9] The number of scattered photons from the 529 keV component was strongly dependent upon the physical characteristics of the collimator.[10] In the human study with LEHR, estimated scatter fraction measured in the upper window was 53.6 ± 4% of the total count in the mediastinal region and 37.1 ± 6% of the total count in the myocardial region. On the other hand, with MEC, scatter fraction decreased to 15.7 ± 1% of the total count in the mediastinal region and 10.2 ± 1% of the total count in the myocardial region. The count in the mediastinal region was highly influenced by photon scattering and increased mediastinal counts yielded lower H/M using LEHR compared with MEC. If the scattered photons from the 529 keV component are effectively corrected by the two-window method, scatter corrected H/M data from different gamma camera systems might be identical in the same patient.

Scattered correction method

Several scatter correction methods have been previously reported,[11–16] and the triple energy window scatter correction method (TEW) is one of the commercially available methods.[14,15] However, the TEW method has limited availability in various gamma camera systems, because TEW requires special hardware and software. On the other hand, the two-window method has no such limitations and can be applied to all gamma camera systems using a conventional two-window acquisition technique. In the present study, the two-window scatter correction method effectively corrected the scattered photons from the 529 keV component both in phantom and human studies for determining H/M in I-123 MIBG scintigraphy.

Clinical significance

Standardization of H/M in I-123 MIBG scintigraphy has a certain advantage in examining patients with heart failure, since the H/M data without scatter correction cannot be used to compare data acquired in two different gamma camera systems for the same patient. When an old gamma camera system is replaced by a new one, follow-up H/M data should be carefully evaluated because of the differences in the normal H/M value depending upon the different physical characteristics of the collimators.

Since calculation of the H/M value is easy and standardized in the two-window scatter correction method, comparison of H/M between different gamma camera systems can be performed simply and reliably. In the future, multicenter studies of MIBG will be possible using scatter corrected H/M in patients with heart failure.

Study limitation

In the human study, we compared the scatter corrected and uncorrected H/M between two camera and collimator systems. Myocardial uptake of MIBG gradually decreased after the injection and only two images could be acquired for comparing MIBG uptake in the same patient. To determine whether or not scatter corrected H/M shows the same H/M value among many gamma camera systems, additional human studies are required using various gamma camera systems. In summary, this study demonstrated that scatter correction by the two-window method standardizes the H/M in MIBG scintigraphy either with LEHR or MEC. Scatter corrected H/M can be applied to measure a standardized parameter of MIBG uptake in human clinical studies using various gamma camera systems.

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