Experimental Study on the Collimator for Increasing the Resolution of *N*-Isopropyl-*p*-(¹²³I)iodoamphetamine (IMP) SPECT Imaging of the Brain

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This study was carried out to design a new collimator for the present ¹²³I-IMP SPECT imaging of the brain, which is hindered by the contamination of ¹²⁴I and ¹²⁶I. In this study we intended to increase spacial resolution along the transaxial direction and, at the same time, to compensate for the decrease of sensitivity by sacrificing the resolution along the axial direction to some extent. For this purpose, we developed 4 kinds of slit type units; ultrahigh resolution (UHR), high resolution (HR), high sensitivity (HS), and ultrahigh sensitivity (UHS). In practice, either UHR or HR is set to the detector together with either HS or UHS. After testing 4 kinds of combinations, we found that the combination of UHR-HS gave us far better images than those obtained with the conventional medium energy parallel hole collimator and was best suited for ¹²³I-IMP SPECT imaging of the brain at present. We are now thinking of fusing these two units together into one collimator.

Key Words: *N*-isopropyl-*p*-(iodine-123)iodoamphetamine, brain, single photon emission computed tomography, collimator

Fundamentally, radionuclide images reflect pathophysiological condition of the organs of interest and, in this sense, their clinical significance is highly appreciated. However, recent advancement of other imaging modalities, such as echography, X-ray computed tomography (CT), nuclear magnetic resonance (NMR), etc. are remarkable. Subsequently, it is now apparent that, for radionuclide imaging, improvement of image quality as well as development of new radiopharmaceuticals are very important. Fortunately, in the field of cerebral nuclear medicine, *N*-isopropyl-*p*-(¹²³I)-iodoamphetamine (¹²³I-IMP) was developed in

1980^{1,2)} and was found to be useful in investigating cerebrovascular disorders on single photon emission computed tomography (SPECT) images^{3,4)}. At present, however, commercially available ¹²³I-IMP is contaminated with ¹²⁴I and ¹²⁶I with the ratios of less than 5% for the former and less than 0.3% for the latter on the assay date⁵⁾. The main γ energies of ¹²⁴I and ¹²⁶I are 603 keV and 389 keV, respectively, which are higher than that of ¹²³I (159 keV). This fact brings about some trouble in selecting the appropriate collimator. At present, medium energy parallel hole collimators (MEPCs) are being used in many places to keep the high

energy γ rays and scattered rays at a minimum. In spite of these efforts, image quality is generally quite unsatisfactory, and various other methods are being used such as slant hole collimators and special cut-off detectors which allow closer access to the object^(6),7).

Under these circumstances, we have carried out an experimental study on the collimator for ^{125}I -IMP SPECT imaging of the brain and following results were obtained.

1. Principle of Our Design

Resolution and sensitivity of the collimator are always contrary to each other. To solve this conflict, we decided to increase sensitivity by sacrificing the resolution in the axial direction while still retaining high resolution in the transaxial direction.

As we did not know to what extent we could decrease the resolution along the axial direction, we developed four kinds of slit-type units, namely "ultra high resolution (UHR)", "high resolution (HR)", "high sensitivity (HS)", and "ultra high sensitivity (UHS)", each having different slit widths and septal thicknesses (Fig. 1).

Fig. 1 Schematic drawings of 4 kinds of slit type units.

In practice, either UHR or HR is set to the detector together with either HS or UHS. The former is always set to the detector so that the direction of the slits is always parallel to the rotating axis to retain a high resolution in the transaxial direction. The latter is set to the former so that the direction of the slits is at a right angle to that of the former.

2. Specification of Each Unit

As shown in Table 1, each unit has slits of different widths and septum thicknesses but the same depth. UHR has the narrowest slit width,

Table 1 Specification of each unit

	Depth (mm)	Space width (mm)	Septum thickness (mm)
UHR	30	0.9	0.5
HR	30	1.5	0.85
HS	30	3.2	1.5
UHS	30	5.2	2.0

Fig. 2 External appearance of 4 units.

0.9 mm, and UHS has the widest slit width, 5.2 mm. As for the septum thickness, UHR is the thinnest, 0.5 mm, and UHS is the thickest, 2.0 mm. Wood is inserted in the slits to prevent bending of the lead septa. Figure 2 shows our four units.

3. Spatial Resolution of Each Unit

In this series Shimadzu scintillation camera, LFOV-E (modified type), was used.

The spatial resolution of each unit was

Fig. 3 Measured spatial resolutions of 4 units.

checked only in the direction right angle to the slits. The results are shown in Fig. 3 together with that of MEPC. As compared with MEPC, the resolutions of UHR and HR are apparently superior, but those of HS and UHS are inferior. Thus, we expected HS and UHS to compensate for the decrease in sensitivity caused by UHR and HR.

4. Spacial Resolution and Sensitivity of Each Combination

The spacial resolution and sensitivity of each combination of units are shown in Table 2 and Table 3 together with those of MEPC.

As far as the resolution of the transaxial slices is concerned, all four combinations are superior to MEPC as had been expected from previous results. Especially, when UHR is used, FWHM is 15.9 mm, which is 55.4% of that of MEPC, indicating far better resolution.

As for the axial direction, however, FWHM in all four combinations are inferior to MEPC with the minimum FWHM, being 31.4 mm in the case of UHR-HS, which is 106% of that of MEPC.

The relative sensitivity of the combination of UHR-HS, which has the best resolution, is 57% as compared to MEPC. However, if

Table 2 Spacial resolution of each combination at the center of rotation (FWHM in mm)

	Transaxial direction	Axial direction
MEPC	28.7	29.5
UHR-HS	15.9	31.4
UHR-UHS	15.9	36.5
HR-HS	23.2	33.3
HR-UHS	23.9	40.7

Table 3 Sensitivity of each combination

	cps/(μ Ci ml slice)	Relative sensitivity to MEPC
MEPC	243	1.0
UHR-HS	123	0.57
UHR-UHS	191	0.86
HR-HS	180	0.80
HR-UHS	274	1.16

(1 μ Ci=37 kBq)

the conventional MEPC is remodeled to increase its resolution to that of UHR, the sensitivity will theoretically be decreased to nearly 1/6 of the present MEPC. Therefore, it can be said that our design successfully increased the resolution while retaining substantial sensitivity.

5. Phantom Study

An axial view of the phantom used for our experiment is shown in Fig. 4a. This phantom is composed of an acrylic cylinder with an inner diameter of 20 cm containing rods with various diameters therein. The cylinder is filled with commercial ^{123}I solution having a concentration of 81.4 kBq/ml (2.2 μ Ci/ml).

SPECT was performed by rotating the detector every 6 degrees while maintaining a radius of 20 cm and digital images were taken in a form of 64×64 matrices.

The transaxial SPECT images taken with UHR-HS, HR-HS, and MEPC are shown in Fig. 4b. Both images taken by our collimators

a) An axial view of the phantom used in this study.

b) Transaxial SPECT images obtained with MEPC, HR-HS, and UHR-HS.

Fig. 4 Phantom study.

a) SPECT images obtained with UHR-HS.

b) SPECT images obtained with UHR-UHS.

Fig. 6 Comparative study of UHR-HS and UHR-UHS. See the text.

a) Transaxial SPECT images.

b) Sagittal SPECT images.

c) X-ray CT image.

Fig. 7 A case of metastatic brain tumor in the left temporal lobe.

the quality of the original images and the images reconstructed parallel to the O-M line obtained with the combination of UHR-HS is much better than those of UHR-UHS. Such a result had been expected from the basic experiment mentioned before.

Figures 7a and b were obtained with the combination of UHR-HS on a case having a metastatic lesion in the left temporal lobe from esophageal cancer. A clear-cut defect of good image quality in the area corresponding to that of the lesion which had been noticed by X-ray CT (Fig. 7c) can be seen on the transaxial slices. Sagittal images on the same case also show good image quality which is thought to be acceptable.

8. Comment

Recent advancement of positron nuclear medicine has brought about tremendous knowledge of cerebral physiology; such as blood perfusion, oxygen utilization, glucose metabolism, neuroreceptors, etc.⁸⁻¹⁰⁾

For this, however, cyclotron and positron imaging equipments are essential, and these equipments are, at present, limited to institutions and medical centers. Therefore, conventional nuclear medicine using single photon emitters is still important. In the field of cerebral nuclear medicine, recently developed ¹²³I-IMP has been found to be very useful for investigating cerebral perfusion by SPECT. However, currently available ¹²³I-IMP is contaminated with ¹²⁴I and ¹²⁰I, deteriorating the SPECT image quality.

An effort to increase the shielding capability of the collimators inevitably decreases their sensitivity. Although this problem may be solved by increasing the dose, there are limitations in clinical practice. In fact, we can only give 111 MBq (3 mCi) of ¹²³I-IMP to a patient. This factor led to our designing a new collimator in which the sensitivity along the rotating axial direction was increased by sacrificing the spacial resolution while still retaining high resolution in the transaxial direction. However, because we did not know at first to what extent we could decrease the spacial resolution along the axial direction in clinical practice, we designed four different slat-type units, two of

which were to increase spacial resolution in the transaxial direction, namely UHR and HR, and the other two were to increase sensitivity along the axial direction, namely HS and UHS. Subsequently, all four combinations were tested and the combination of UHR-HS gave us far better images than the conventional MEPC, and was found to be best suited for ¹²³I-IMP SPECT imaging of the brain.

Based on the results of our experiments, we are now thinking of fusing these two units together into one collimator. Finally, we would like to conclude by saying that this kind of collimator will be very useful in our practice in which there are limitations in the dosage to be administered to patients.

Recently, however, we noticed that Jaszczak had reported on a design for a collimator for SPECT imaging, which was based fundamentally on the same idea as ours^{11,12)}. Therefore, we would like to pay our respects to his excellent prescience and also we wish our data presented here to be worthwhile for developing the apparatus in this field.

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Additional comment: Already, we developed a new collimator of fused type of two units suggested in this paper and the results of which will appear in near future.

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要 旨

脳のイソプロピルヨードアンフェタミン (^{123}I -IMP) SPECT の解像力の 改善を目指したコリメータの開発に関する研究

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^{123}I -ヨードアンフェタミン (IMP) による脳の single photon emission computed tomography (SPECT) にさいしては、混在核種からの γ 線の影響を避ける目的で、中エネルギー用のコリメータ (MEPC) が一般的に使われ、その結果画質の劣化を招いている。われわれはそれを避ける目的で、横断方向の解像力をあげ、そのぶんだけ劣化した感度を回転軸方向の分解能をすこし犠牲にすることによって補うというタイプのコリメータの開発を試みた。それは4種類の slat type units, すなわち超高分解能 (UHR), 高分解能 (HR), 高感度 (HS), 超高感度 (UHS) のうち、前2者のいずれかと、後2者のいずれかを、互いのスリットが直交するように組合せる方式である。その結果、UHR と HS の組合せが最も良好な結果をもたらし、その画質は MEPC を用いたものよりかはるかによかった。