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Performance of a multislice fan beam collimator for SPECT imaging of the head

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A multislice fan beam collimator was designed for a SPECT system with a rotating scintillation camera, and it was constructed by the lead casting method which was devised in recent years. The focal length from the surface of the detector side of the collimator is 75 cm. In order to reconstruct the SPECT images we modified the interpolation method which was developed for reconstruction of the X-ray CT and applied it. Primary photopeak data were obtained with a 20% energy window centered at 140 keV for ^{99m}Tc and 159 keV for ^{123}I. The fan beam collimator reduces the field of view, and it would therefore be limited to use only for the head and neck region at present; however, both resolution and sensitivity were ~20% better than those of the parallel hole collimator. A fan beam collimator is a useful implement for the SPECT study.

Key words: fan beam collimator, SPECT, gamma camera

INTRODUCTION

A rotating gamma camera system is widely used to acquire projection data for Single Photon Emission Computed Tomography (SPECT).[1] There is a great advantage to this system. Multislice tomographic sections are available from a single study, and they allow for the generation of sagittal, coronal or any oblique angle set.[2,3]

The major problem associated with this system is the constraint imposed by the collimator. The resolution and sensitivity of the system are incompatible. However, there are a few methods for improving the resolution without decreasing the sensitivity. We used a multislice fan beam collimator (FAN) which has parallel collimation along the cephalic-caudul axis of a patient and converging collimation within planes that are perpendicular to that axis.[4–7]

Previously we had studied various problems concerning a FAN by computer simulation methods[8] and by using a DIV/CON collimator,[9] whose mid plane on the conversing side produces similar data to a FAN.

A multislice fan beam collimator was designed and constructed for a SPECT system with a rotating scintillation camera. The FAN was constructed by the lead casting method.[10] The algorithm[8] which we had previously developed was used to reconstruct the SPECT images. The fundamental abilities and some SPECT images of the FAN are described in this paper.

MATERIALS AND METHODS

The key components of our SPECT system (Toshiba GCA-70A) are two opposed gamma cameras (Toshiba GCA 401-5 TOKU), a minicomputer (GCA 55A), and a bed to support the patient between the detectors. If both detectors are used to acquire the projection data, the data for reconstructing a SPECT image are collected during the 180° rotation of the detector. If either detector is used, the data are collected during 360° rotation.

The block diagram for the fan beam SPECT image is shown in Fig. 1. The projection data were stored in a minicomputer. These data were transferred

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through a magnetic tape to a medium-sized electronic computer, and used in calculation for image reconstruction. Then the images were transferred back to the minicomputer and displayed on a CRT.

Details of the FAN used in this study are shown in Fig. 2. The collimator holes in the transverse reconstructed image plane converge to the same focal point. In the longitudinal direction, the collimator holes are straight and parallel for data collection of contiguous image slices. The focal point is 75 cm from the surface of the detector side of the collimator. Because we have only one fan beam collimator at present, the 360° rotation mode is adopted.

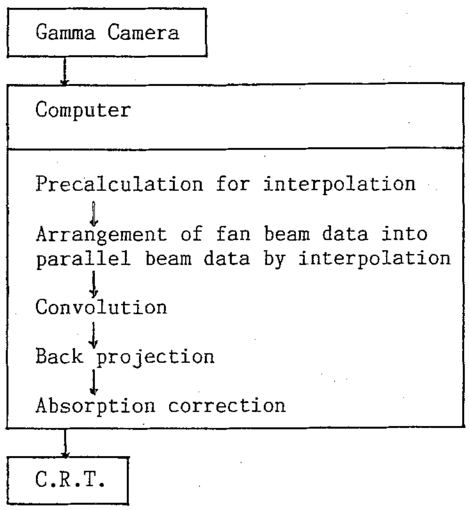

Fig. 1 Block diagram for the fan beam SPECT. The SPECT image was reconstructed with a medium-sized electronic computer. The algorithm is detailed in the literature.[8]

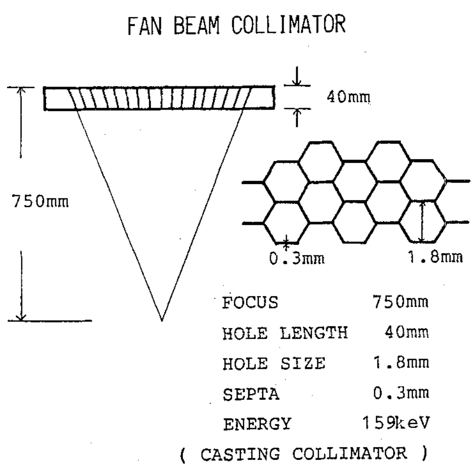

Fig. 2 The illustration of the fan beam collimator. This collimator, constructed by the lead casting method, has hexagonally shaped holes and a focal length of 750 mm. In the longitudinal direction, the collimator holes are straight and parallel for data collection of contiguous image slices.

Seventy-two or ninety projection images which had been digitized in 128×128 matrices were stored. These data, obtained from the FAN, were arranged into parallel beam data by the interpolation method,[8] They were then reconstructed by the convolution method with a Shepp & Logan's filter.[11] A parallel hole, low energy, high resolution collimator (PARALLEL) was used for the parallel beam studies. The reconstruction filter[11] in both cases was the same. Primary photo peak data were obtained with a 20% energy window centered at 140 keV for ^{99m}Tc and 159 keV for ^{123}I.

RESULTS

The relative sensitivities of the FAN and the PAR-

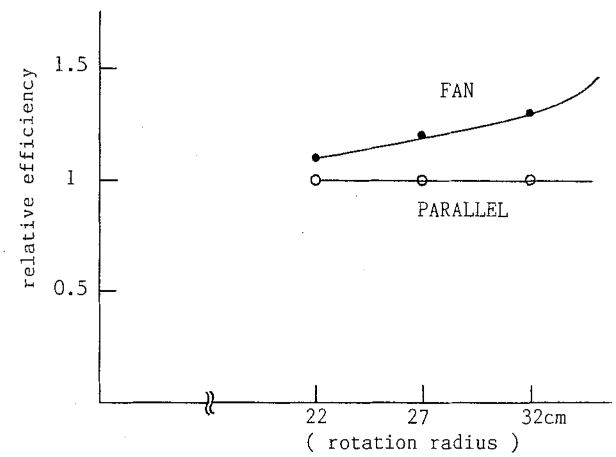

Fig. 3 Relative efficiency of the FAN and the PARALLEL as a function of rotation radius. A point source of ^{99m}Tc was located at the center of the SPECT image. Rotation radius was measured from the surface of the detector side of the collimator.

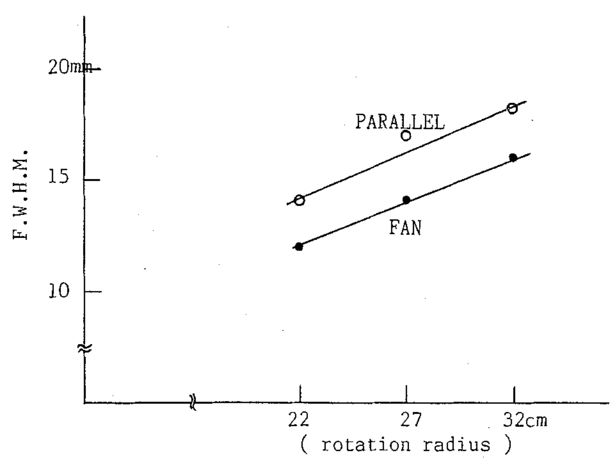

Fig. 4 Spatial resolution of both collimators expressed in full width at half maximum. The line source of ^{99m}Tc was located at the center of the SPECT image. The SPECT images were reconstructed from 90 views.

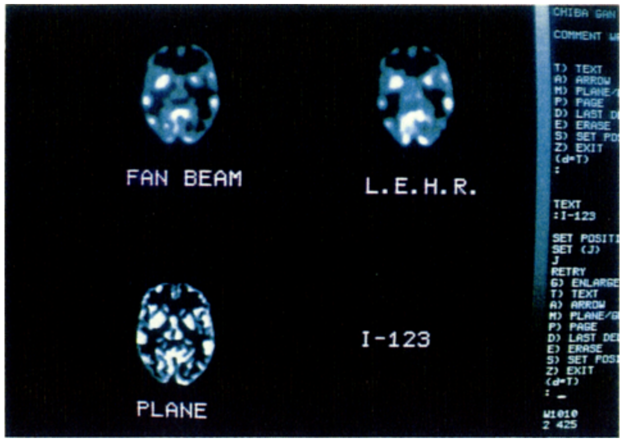

Fig. 5 Images of the "Hoffman Phantom" filled with ^{123}I solution. SPECT images were reconstructed from 90 views. The acquisition time for each collimator at each step was 30 seconds.
(upper left) SPECT image through the fan beam collimator.
(upper right) SPECT image through the parallel hole collimator.
(lower left) top view.

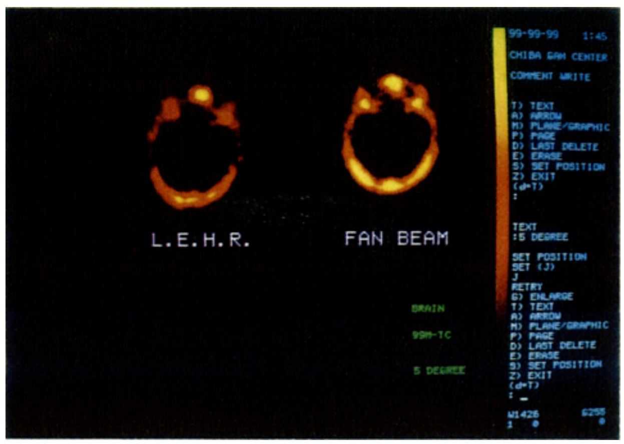

Fig. 6 SPECT bone images of a skull. The projection data were collected three hours after the injection of 740 MBq of ^{99m}Tc-MDP. These images were reconstructed from 72 views. The acquisition time for each collimator at each step was 10 seconds.
(left) through the parallel hole collimator.
(right) through the fan beam collimator.

ALLEL as a function of the rotation radius are shown in Fig. 3. The sensitivity of the FAN increased with the rotation radius. For the PARALLEL it did not change. Spetial resolutions expressed in full width at half maximum (FWHM) are shown in Fig. 4 as a function of the rotation radius. ^{99m}Tc was used as a radionuclide. These results indicated that the FAN was ~20% better than the PARALLEL in terms of both sensitivity and resolution. The thickness of the FAN and the PARALLEL are 4 cm and 2 cm, respectively. Rotation radius was measured from the surface of the detector side of the collimator.

The "Hoffman Phantom" is commonly used as a human brain phantom. Figure 5 shows the top view and the SPECT images obtained by using the FAN and PARALLEL. The phantom was filled with diluted ^{123}I solution. The top view shows the best resolution, and this would be the goal of the SPECT image. Comparing the two SPECT images, the FAN has far better resolution than the PARALLEL. The rotation radius of each collimator was minimized as much as possible.

Figure 6 shows the SPECT bone images of a skull.[12] The projection data for the SPECT were collected three hours after the injection of 740 MBq of ^{99m}Tc-MDP. The image resolution and the image contrast of the FAN are superior to those of the PARALLEL. The rotation radius of each collimator was minimized as much as possible. The FAN has far better resolution than the PARALLEL. The slice thickness was 0.54 cm, and the acquisition time for each collimator at each step was 10 seconds.

DISCUSSION

To produce better SPECT images it is important to improve their sensitivity and resolution. There are several ways to increase the system sensitivity and resolution. The use of an exclusive device for SPECT which arranges many detectors around a patient is one way, but the cost and the space to install the device become a problem.

A rotation gamma camera system is currently being used for SPECT in many institutions. Acquisition with a non-circular[13] orbit is one way to improve the system resolution because of the closer access of the detector to the object at each projection angle; however, this method does not improve the system sensitivity.

The application of a FAN is another method. This collimator improves system resolution slightly because of its magnifing properties.[14-16] At the same time, it also increases the system sensitivity by utilizing a full fraction of the crystal area. A FAN attached to a gamma camera reduces the effective field of view, so it can be used only for the head and neck regions at present. However, it does improve both system sensitivity and resolution.

The reconstruction algorithm developed for a PARALLEL is not applicable for a FAN. Therefore, an interpolation method, which was developed for an X-ray CT of the fan beam and modified for SPECT, was utilized to reconstruct SPECT image with a FAN. This algorithm had already been confirmed through a computer simulation method.[8]

The system sensitivity and resolution of the FAN and PARALLEL shown in Fig. 3 and Fig. 4 were used with ^{99m}Tc as a radionuclide. The FAN used in this study was designed preferably for use with ^{123}I as a radionuclide, so that the degree of system sensitivity and resolution improvement would be even more remarkable in a brain perfusion study with ^{123}I-IMP.

The projection data for the "Hoffman Phantom" were obtained in a situation in which the rotation radius of each collimator was minimized as much as possible. In SPECT imaging of the human head, the patient's shoulder interferes with the approach of a collimator. The FAN is thicker than that of the PARALLEL, therefore the FAN in clinical use can be brought closer to a human head than the PARALLEL. Therefore, comparing the SPECT images obtained with each collimator, the improvement in image quality would be more remarkable for clinical images than for the "Hoffman Phantom" image in Fig. 5.

Lim et al.[7] compared a parallel hole collimator system and a fan beam collimator system for SPECT by a computer simulation method and reported that both the system sensitivity and spatial resolution could be simultaneously improved by using a fan beam collimator.

Jaszczak et al.[4] and Tsui et al.[6] constructed a multislice fan beam collimator. From the results of phantom and clinical studies, they reported that a fan beam collimator system, when compared with a conventional parallel hole collimator system, produced simultaneous improvements in SPECT system sensitivity and resolution. The results of our study agree with theirs. We, however, don't think that the actual SPECT images obtained by using their fan beam collimator were improved considerably. They constructed it by means of stacking corrugated sheets of lead, and only ^{99m}Tc was used as a radionuclide. We constructed a fan beam collimator by the lead casting method which was developped in relatively recent years. The actual SPECT images obtained by the fan beam collimator could be improved considerably. Moreover, it is recognized that a fan beam collimator is effective not only for ^{99m}Tc but also for ^{123}I. By using larger detector, this technique can also be applicable to SPECT study of bodies as they are. A fan beam collimator is a useful implement for the SPECT study.

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