Improvement in the Quantification of Striatal Tracer Uptake in Single-photon Emission Computed Tomography With ^{123}I-ioflupane Using a Cadmium-zinc-telluride Semiconductor Camera

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This study examined the utility of cadmium-zinc-telluride (CZT) semiconductor camera for quantifying striatal tracer uptake in single-photon emission computed tomography (SPECT) with ^{123}I-ioflupane (DaTSCAN). An anthropomorphic striatal phantom was prepared with ^{123}I-ioflupane. The phantom images were obtained using a CZT camera and a traditional Anger-type camera for 5 min and 30 min, respectively. Phantom image quality was visually evaluated, and the contrast between the striatal and cerebral parenchyma (background region) was examined via count profile analysis. Then, the specific binding ratio (SBR), which indicates ^{123}I uptake in the striatum, was measured. There were no visual differences in striatal shape between the scans, but the CZT/SPECT scan exhibited better image contrast. The SBR obtained from the CZT/SPECT images were higher than those acquired from the Anger/SPECT images and were closer to the true values. Performing CZT/SPECT using DaTSCAN might enable more accurate evaluations of striatal function while reducing the imaging time.

Key words: dopamine transporter, single-photon emission computed tomography, cadmium zinc telluride, phantom study

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INTRODUCTION

Dopamine transporter single photon emission computed tomography (SPECT) imaging with ^{123}I-ioflupane (DaTSCAN; GE Healthcare, Buckinghamshire, UK) has been widely used for the *in vivo* evaluation of striatal neurodegeneration, including in Parkinson's disease [1-3]. ^{123}I-ioflupane binds selectively to dopamine transporters in the striatum, and SPECT scans can visualize dopaminergic dysfunction. Furthermore, using commercially available software, ^{123}I uptake can be quantitatively analyzed to improve diagnostic accuracy [4, 5].

In DaTSCAN, ^{123}I uptake can be observed in various organs or tissues that are larger than the striatum [6]. Therefore, the ^{123}I activity in the striatum is markedly lower than the total injected activity [7], which means that long SPECT scans are required to obtain high quality striatal images. A new SPECT system (Discovery NM530c; GE Healthcare) equipped with a cadmium-zinc-telluride (CZT) semiconductor camera (CZT/SPECT), which possesses excellent energy resolution and γ-ray count sensitivity, has recently been developed [8], and several studies have demonstrated that this system resulted in a reduction in imaging time during myocardial perfusion imaging [9, 10]. Although this SPECT system is designed for cardiac SPECT studies, it has attracted particular interest as a tool for reducing imaging time in DaTSCAN. Farid *et al.* previously reported that during scans involving DaTSCAN the CZT/SPECT system made it possible to reduce the imaging time without any loss of image quality compared with traditional SPECT systems equipped with Anger cameras (Anger/SPECT) [11], but its utility for ^{123}I uptake analysis remains unclear.

Accordingly, the aim of the present study was to investigate the utility of CZT/SPECT scans using DaTSCAN for ^{123}I uptake analysis. We visually evaluated the quality of striatal images obtained during a CZT/SPECT scan and calculated ^{123}I uptake values from the images. The results were compared with those obtained from an Anger/SPECT scan.

MATERIALS AND METHODS

Striatal phantom

An anthropomorphic striatal phantom was obtained from Radiology Support Devices (Long Beach, CA, USA). The volumes of various brain structures in the phantom were as follows: left caudate nucleus: 4.8 mL, right caudate nucleus: 4.7 mL, left putamen: 5.9 mL, right putamen: 5.5 mL, and cerebral parenchyma: 1202 mL. Each region was filled with ^{123}I-ioflupane (Nihon Medi-Physics, Co., Ltd., Tokyo, Japan) according to the method of Skanjeti *et al.* [12]. Briefly, the putamen and caudate were filled with 40 kBq/mL of ^{123}I-ioflupan in saline solution. The cerebral parenchyma was filled with 5 kBq/mL of the solution to indicate background activity. ^{123}I-derived radioactivity was measured using a well-type gamma counter (CRC-55tW, CAPINTEC, Inc., Ramsey, NJ, USA).

Fig. 1. Phantom setup for the cadmium-zinc-telluride (CZT) /SPECT scan. The phantom was scanned in a seated position using CZT/SPECT for 5 min. The sagittal plane of the phantom ran perpendicular to the gantry axis.

SPECT scan

The Anger/SPECT scan was performed using a Discovery NM/CT 670 Pro scanner (GE Healthcare) equipped with low-energy high-resolution (LEHR) collimators. The phantom was placed in the supine position and scanned for 30 min according to the manufacturer's recommendations.

The CZT/SPECT scan was conducted using a Discovery NM530c scanner (GE Healthcare) equipped with multi-pinhole collimators. The CZT/SPECT system potentially has a 5 to 10 times higher γ-ray count sensitivity compared with conventional Anger/SPECT systems [13]. The effective field of view of the CZT/SPECT system was smaller than the phantom, and the serial alignment of detectors in the CZT camera is focused on heart location. In the preliminary study, the shape of striatum in the CZT/SPECT image became distorted when the phantom was placed in the supine position. Similar results were demonstrated in the preliminary clinical study. For these reasons, the phantom was placed in the sitting position (Fig. 1) and scanned for 5 min in the present study. The SPECT scan parameters are listed in Table 1.

All SPECT images were created using a GE Xeleris 3.1 workstation. The CZT/SPECT and Anger/SPECT images were reconstructed using the maximum likelihood expectation maximization (MLEM) algorithm and ordered subset expectation maximization (OSEM) algorithm, respectively. The reconstruction parameters are listed in Table 2. A senior radiologist with 30 years of experience of diagnostic SPECT imaging visually examined phantom image quality. He evaluated image noise (^{123}I uptake in the background region) and the shape of the striatum on axial slices.

^{123}I uptake analysis

^{123}I uptake in the striatum was analyzed using the DaTQUANT software (GE Healthcare). Briefly, phantom images were spatially normalized into the Montreal Neurological Institute (NMI) atlas space using a striatal template image included with

Table 1. SPECT scanning conditions

Parameters	CZT/SPECT	Anger/SPECT
Collimator	Multi-inhole	LEHR
Sampling angle	180°	360°
Projection (views)	19	120
Imaging time (min)	5	30
Field of view (cm)	18 × 18 × 20	54 × 40
Matrix size	32 × 32	128 × 128
Photopeak energy window (keV)	159 ± 10%	159 ± 10%

Table 2. Image reconstruction parameters

Parameters	CZT/SPECT	Anger/SPECT
Algorithm	MLEM	OSEM
Subset	NA	10
Iteration	100	6
Butterworth filter (cycles/mm)	0.6	0.6
Attenuation correction	NA	NA
Scatter correction	NA	NA
Resolution recovery correction	A	NA

A ; applicable, *NA* ; not applicable

DaTQUANT. Volumes of interest (VOI) were automatically defined so that they included the caudate nucleus, anterior and posterior putamina, and occipital cortex (the background region). Specific binding ratios (SBR), which indicate specific ^{123}I uptake in the striatum, were then calculated as follows:

$$SBR = \frac{VOIs - VOIo}{VOIo} \quad (1),$$

where *VOIs* and *VOIo* are the count concentration (counts/voxel) in the striatum (caudate nucleus, anterior putamen, or posterior putamen) and occipital cortex, respectively.

Image contrast

Image contrast was examined using count profile analysis. Briefly, CZT/SPECT and Anger/SPECT scans were spatially normalized into the NMI atlas space, and the count profiles of the bilateral caudate nuclei were obtained from axial slices located at the same level. The count profile curve was normalized to the peak values of the relevant profile.

RESULTS

Visual assessment of striatal image quality

Fig. 2 shows Anger/SPECT and CZT/SPECT scans of the phantom obtained at almost the same slice level. The shape of the striatum was similar on both scans. However, the perceived noise level of the CZT/SPECT scan was lower than that of the Anger/SPECT scan.

^{123}I uptake

Table 3 shows the SBR of the striatum as analyzed using the DaTQUANT software. The true SBR value was calculated to be 7 using equation (1). The CZT/SPECT image showed SBR of 4 to

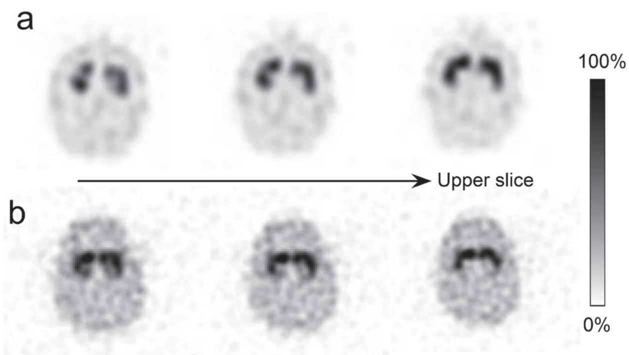

Fig. 2. Cadmium-zinc-telluride (CZT)/SPECT and Anger/SPECT scans of the phantom. The CZT/SPECT scan (a) showed lower image noise (background count) than the Anger/SPECT scan (b). The striatum exhibited a similar shape on both scans. The grayscale bar represents γ-count intensity.

Table 3. Specific binding ratios (SBR) in each part of the striatum

Camera	Striatum		Caudate		Anterior putamen		Posterior putamen	
	R	L	R	L	R	L	R	L
CZT	6.3	5.8	7	6.8	6.2	5.6	5.4	4.5
Anger	2.5	2.4	2.9	2.5	2.3	2.5	1.8	1.8

R ; right, *L ;* left

7 in each part of the striatum, whereas the Anger/SPECT image exhibited SBR of 1 to 3, which were much lower than the true value.

Image contrast

We examined image contrast by assessing the count intensity of the striatum relative to that of the background region. As shown in Fig. 3, the CZT/SPECT images exhibited better image contrast between the striatum and background region compared with the Anger/SPECT images. The profile curve of the CZT/SPECT images rose more sharply at the edge of the striatum.

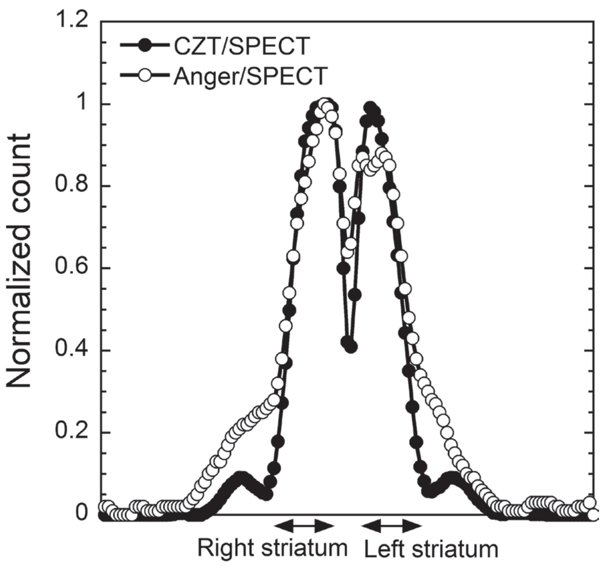

Fig. 3. Count profile curve for the bilateral caudate nuclei. Better image contrast between the striatum and the background region was seen on the cadmium-zinc-telluride (CZT)/SPECT scan than on the Anger/SPECT scan. The CZT/SPECT scan displayed an approximately 41 times higher peak count (2738 counts) than the Anger/SPECT scan (66 counts).

DISCUSSION

Here, we showed that CZT/SPECT provided more accurate information about striatal ^{123}I uptake than Anger/SPECT during scans performed with DaTSCAN. Compared with traditional Anger/SPECT, CZT/SPECT has been reported to result in a shorter imaging time and a lower radiation dose without any loss of image quality. Duvall *et al.* showed that performing myocardial perfusion CZT/SPECT scans with a low-tracer-dose protocol achieved more than 50% reduction in the effective radiation dose without deteriorating the quality of diagnostic images [14]. In the present study, the perceived image quality of the CZT/SPECT and Anger/SPECT scans was similar. Although similar results were obtained in a clinical DaTSCAN-based study by Fraid *et al.* [11], the findings we obtained in our count profile analysis suggested that CZT/SPECT improved image contrast to some extent, even over a shorter imaging time. This can be explained by the excellent energy resolution of CZT semiconductor detectors. CZT detectors exhibit better energy resolution than NaI scintillators [8], which allows more accurate discrimination of scattered from unscattered γ-rays.

In the present study, the assessment of ^{123}I uptake provided further evidence that CZT/SPECT is more useful for DaTSCAN-based neuroimaging. SPECT scans of small structures, such as the striatum, often result in the underestimation of tracer uptake due to the partial-volume effect, which is associated with the limited resolution of SPECT systems [15]. In this study, the SBR obtained in the CTZ/SPECT scan were similar to the true SBR values in each part of the striatum, whereas the SBR acquired in the Anger/SPECT scan were markedly different from the true values. These results indicated that CZT/SPECT is able to provide more accurate information about striatal ^{123}I uptake compared with Anger/SPECT. This can be attributed to the higher γ-ray sensitivity of CTZ detectors. In the profile curve analysis, the CZT/SPECT scan displayed an approximately 41 times higher peak count (2738 counts) and a shorter imaging time than the Anger/SPECT scan (66 counts), indicating that CZT/SPECT scans make efficient counting of γ-rays from the striatum possible.

The present study had several limitations. The visual evaluation was conducted by a single radiologist, and SPECT image quality was not examined quantitatively. In addition, we did not investigate the performance of CZT/SPECT in a clinical DaTSCAN-based study. A more detailed study will be needed to clarify the usefulness of CZT/SPECT for diagnosing neurodegenerative disease during DaTSCAN-based imaging.

In conclusion, compared with conventional Anger/SPECT, CZT/SPECT could provide more accurate information about ^{123}I uptake and resulted in a shorter imaging time during a DaTSCAN-based phantom study. Its use might enhance the diagnostic utility of DaTSCAN for assessing neurodegenerative diseases and reduce the imaging time of such scans.

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