Three modality image registration of brain SPECT/CT and MR images for quantitative analysis of dopamine transporter imaging

Yuzuho Yamaguchi[1], Yuta Takeda[2], Takeshi Hara[1], Xiangrong Zhou[1]
Masaki Matsusako[3], Yuki Tanaka[3], Kazuhiko Hosoya[3], Tsutomu Nihei[3]
Tetsuro Katafuchi[4], Hiroshi Fujita[1]

[1] Department of Intelligent Image Information, Graduate School of Medicine, Gifu University, Gifu, Japan
[2] Faculty of Engineering, Gifu University, Gifu, Japan
[3] Department of Radiology, St. Luke's International Hospital, Tokyo, Japan
[4] Faculty of Health Science, Gifu University of Medical Science, Gifu, Japan

ABSTRACT

Important features in Parkinson's disease (PD) are degenerations and losses of dopamine neurons in corpus striatum. 123I-FP-CIT can visualize activities of the dopamine neurons. The activity radio of background to corpus striatum is used for diagnosis of PD and Dementia with Lewy Bodies (DLB). The specific activity can be observed in the corpus striatum on SPECT images, but the location and the shape of the corpus striatum on SPECT images only are often lost because of the low uptake. In contrast, MR images can visualize the locations of the corpus striatum. The purpose of this study was to realize a quantitative image analysis for the SPECT images by using image registration technique with brain MR images that can determine the region of corpus striatum. In this study, the image fusion technique was used to fuse SPECT and MR images by intervening CT image taken by SPECT/CT. The mutual information (MI) for image registration between CT and MR images was used for the registration. Six SPECT/CT and four MR scans of phantom materials are taken by changing the direction. As the results of the image registrations, 16 of 24 combinations were registered within 1.3mm. By applying the approach to 32 clinical SPECT/CT and MR cases, all of thecases were registered within 0.86mm. In conclusions, our registration method has a potential in superimposing MR images on SPECT images.

Keywords: 123I-FP-CIT, MR, SPECT/CT, image registration, segmentation

1. INTRODUCTION

123I-FP-CIT is used for the diagnosis of Parkinson's disease (PD) and Dementia with Lewy Bodies (DLB) [1]. It can visualize activities of dopamine neurons. The diagnosis of the SPECT images using 123I-FP-CIT includes subjective pattern classifications such as recognizing the shapes of comma or dot [2]. The change of the shapes depends on distributions of the neuron activity in the corpus striatum. The activity distributes within whole corpus striatum region in normal cases, but the activity in the region decreases in caudate nucleus area in abnormal cases. Therefore, the understanding of the shapes on SPECT images is relevant to the diagnosis results. Furthermore, the stable measurements of the activity will be required for the quantitative analysis of 123I-FP-CIT imaging. To obtain precise activities of 123I-FP-CIT in corpus striatum, the regions of left- and right-corpus striatum have to be determined on the SPECT images, but the shape information on the SPECT images were very limited because 123I-FP-CIT is mostly absorbed by normal dopamine neurons. The morphological information for the corpus striatum was hardly confirmed on SPECT image only. We assumed that the loss of shape information for corpus striatum reduces the accuracy of quantitative results. The purpose of this study was to realize a quantitative image analysis for the SPECT images by using image registration technique with

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brain MR images that can determine the region of corpus striatum on SPECT image precisely. The registration results can provide the shapes of corpus striatum on SPECT images by superimposing the segmented regions of corpus striatum on MR images.

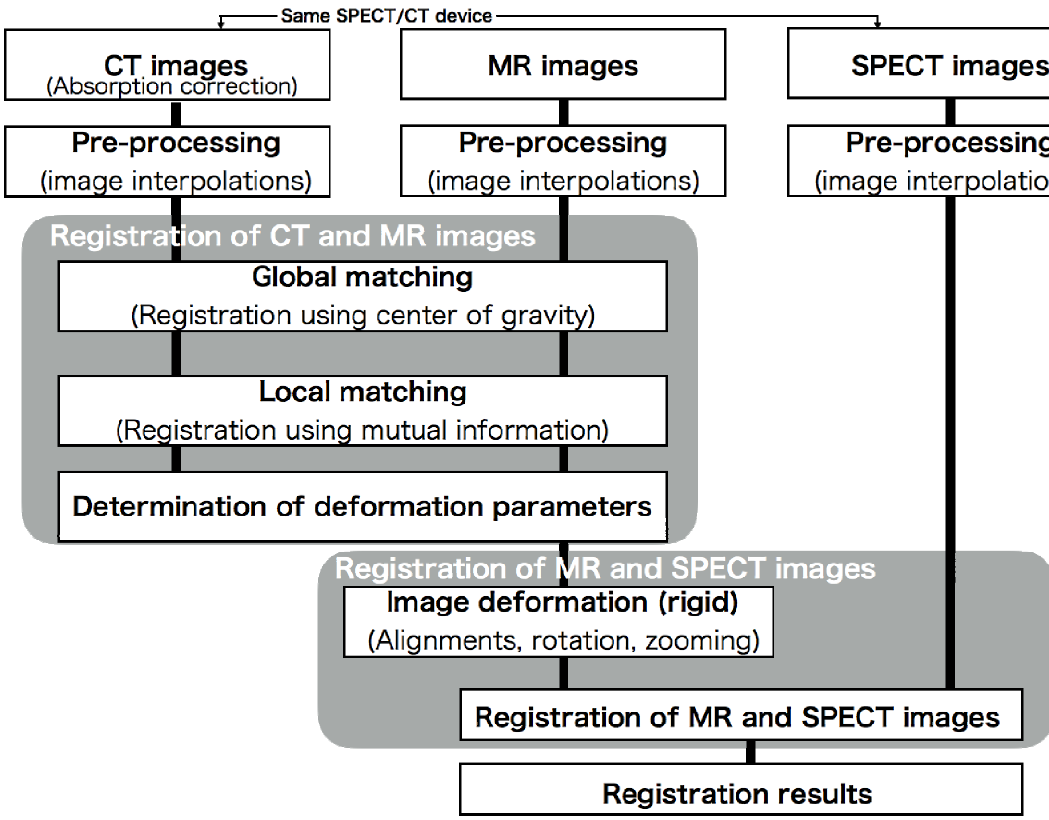

Figure 1 Overview of three-modality registration of SPECT/CT and MR

2. METHODS

We propose an image registration method for SPECT and MR images by intervening CT images for absorption correction taken by SPECT/CT devices. After the image registration between CT and MR images was performed, the locations of MR images can be transferred on to SPECT images. The SPECT/CT devices are general equipment integrated with gamma camera and multi-slice CT. The CT images on SPECT/CT device were obtained with very low dose and were used for the absorption correction to generate SPECT images with high image quality. The CT images were utilized for the image registration with MR images. The location of CT and SPECT images were mechanically registered because the images were obtained at the almost same time. Figure 1 shows an overview of the image registration process.

2.1 Pre-processing

Pixel spacing and slice thickness of three modalities (SPECT, CT MR) used in this study are different each other. The pixel spacing and the thickness are unified by using linear interpolation. Table 1 shows the spacing and the thickness of the original images. The pixel spacing and the slice thickness were unified into 0.43 mm and 1.5 mm, respectively. Consequently, the number of pixel on each cross-sectional image is also unified into 512*512 pixels.

2.2 Registration of CT and MR images

The center of gravities of CT and MR images are obtained in order to determine rough location as a global matching process. MR image is moved as a parallel translation to registered the two centers of gravity each other. After this global matching was performed, a local matching of the two images was carried out. We used the mutual information (MI) between the two images [3-6]. The MI is the amount that represents a measure of the mutual dependence of two random variables. It is often used as the image registration method of the different modalities. It can be expressed by following formula using joint probability $p(\mathrm{a_i} \cap \mathrm{b_j})$ and marginal probability $p(\mathrm{a_i})$, $p(\mathrm{b_j})$.

$$I(\mathrm{A, B}) = \sum_{\mathrm{i}=1}^{k} \sum_{\mathrm{j}=1}^{k} p(\mathrm{a_i} \cap \mathrm{b_j}) \log_2 \frac{p(\mathrm{a_i} \cap \mathrm{b_j})}{p(\mathrm{a_i})p(\mathrm{b_j})}$$

The calculation of the mutual information is carried out in three resolution images of 1/8-, 1/4-, and 1/1-resolutions in the number of pixel in length. First, rough locations and angles of rotation were determined by using 1/8-resolution images. Second, 1/4-resolution images were registered based on the registration parameters at the previous resolution results. Finally, maximum MI was calculated by using the 1/1-resolution images. A parallel computing method by using CUDA was also applied to reduce the computing time. CUDA is a general purpose computing processing using GPU. The computational environment was built on Windows 7 with Intel Core i7 CPU 980 3.33GHz, and GeForce GTX 580 (4 GB, 512 Core).

2.3 Registration of MR and SPECT images

The deformation parameters of parallel translation and rotation were determined by the CT and MR registration step. Based on the obtained parameters, the MR images were deformed rigidly by using affine trans formation. By superimposing the MR images on to SPECT images, the shape information on MR images can be used on SPECT images.

Table 1 Pixel spacing and slice thickness

	Pixel spacing	Slice thickness
SPECT	2.95 x 2.95	2.95
CT	0.98 x 0.98	2.50
MR	0.43 x 0.43	6.00

[mm]

3. RESULTS

3.1 Evaluation by using phantom materials

We used six SPECT/CT images and four MR images taken by changing the direction of a phantom material. The phantom material contained radioactive materials of corpus striatum shape when the SPECT/CT images were obtained. We tested all 24 combinations of image registration between CT and MR images. Sixteen pairs in 24 combinations were registered within 3 pixels (1.3mm) in approximately 10 minutes. Figure 2 shows examples of registration results that the registration errors were very small (<1.3mm), although the MR images contained metal artifacts around the brain regions.

3.2 Evaluation by using clinical cases

We used 32 cases (17 male and 15 female cases) of SPECT/CT and MR images with IRB approval for evaluations. All cases were registered correctly in subjective evaluation by two of authors. Figure 3 shows a registration result. The shapes of lateral ventricle on CT and MR images were registered correctly as shown on Fig. 3(c). As shown on Fig. 3(f), the activities around corpus striatum are observed at appropriate locations.

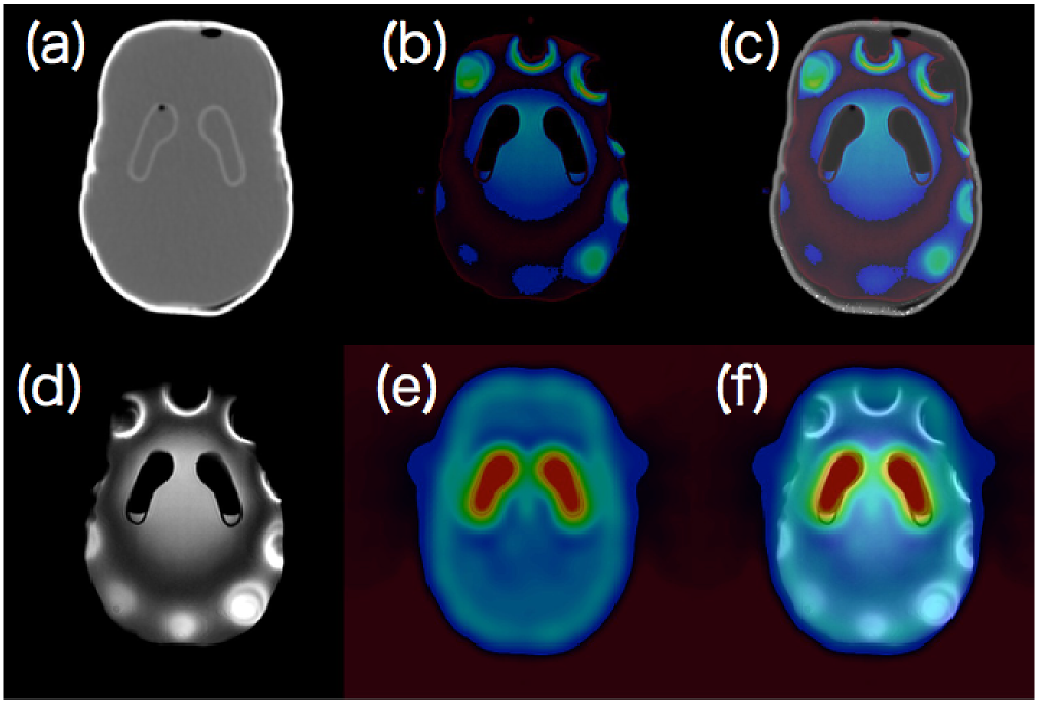

Fig. 2 Examples of registration results by using phantom materials
(a) Original CT image, (b) Colored MR image, (c) Registration image of CT and MR
(d) Original MR image, (e) SPECT image, (f) Registration image of SPECT and MR

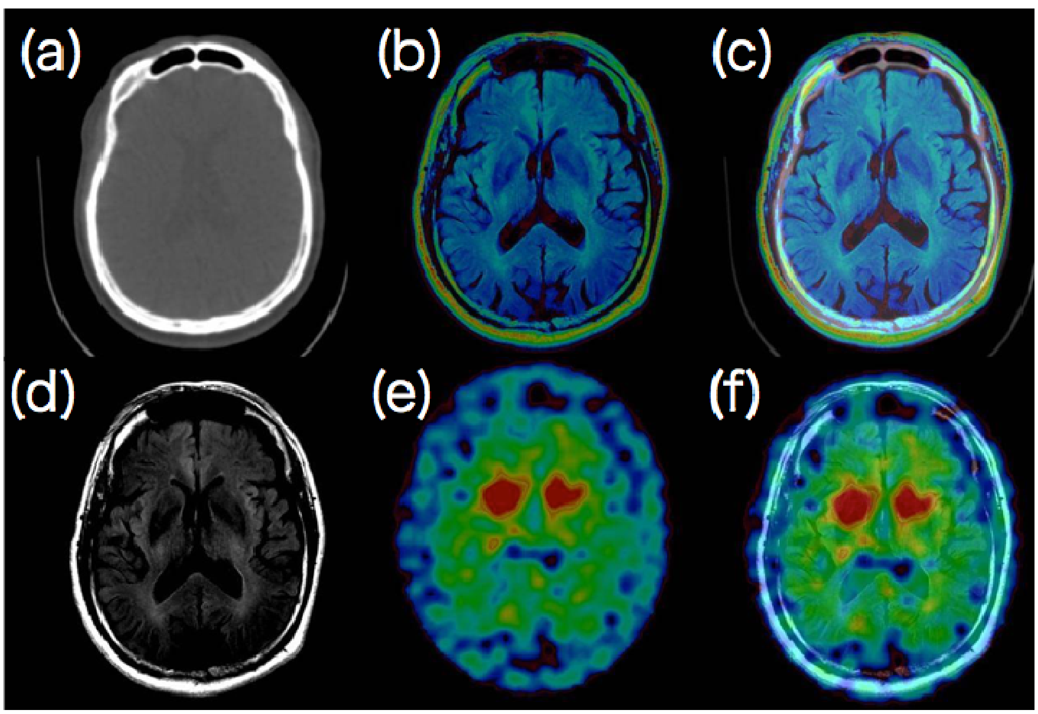

Fig. 3 Examples of registration results by using clinical cases
(a) Original CT image, (b) Colored MR image, (c) Registration image of CT and MR
(d) Original MR image, (e) SPECT image, (f) Registration image of SPECT and MR

3.3 Counting uptakes on SPECT images based on registration results

The anatomical information of corpus striatum on MR images can be imposed on SPECT images based on the image registration results of CT and MR images. Figure 4 shows examples for counting uptakes in corpus striatum regions on SPECT images. The corpus striatum regions can be extracted on MR images in advance. The shape information of the extracted ROIs can be also mapped on SPECT images based on the registration results of CT and MR. Based on the shape and the registration information, the regions of corpus striatum were localized on SPECT images precisely. The activities within the regions were obtained from the SPECT images. Table 2 shows the measurement results of uptakes in corpus striatum on SPECT images.

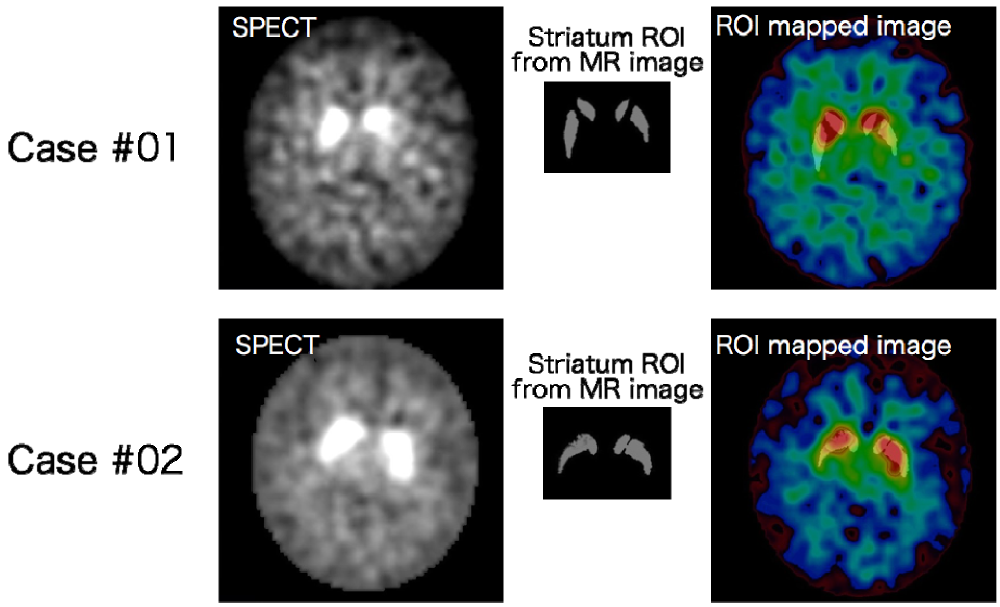

Fig. 4 Examples of counting uptakes from SPECT images based on extracted corpus striatum regions on MR images

Table 2 Count measurement

	Case #01		Case #02	
	L	R	L	R
Volume of corpus striatum	1.54×10^7	1.03×10^7	1.49×10^7	1.48×10^7
Sum of ROI count	9.62×10^4	7.74×10^4	8.11×10^4	8.56×10^4
Max. count within ROI	255	221	249	255
Min. count within ROI	62	55	60	72
Average of count	160.02	133.09	184.22	173.23
Difference between L and R	26.92		10.99	

4. CONCLUSIONS

We proposed an approach to register brain SPECT and MR images by calculating mutual information between MR images and low dose CT images taken by SPECT/CT device. The registration was performed with small errors of 1.3mm in our phantom studies. The shape information obtained from MR images could be superimposed on SPECT images based on our registration method to measure uptakes in corpus striatum on SPECT images.

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