Anatomic Labelling of PET Brain Images with Automatic Detection of AC and PC

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A new automatic method for finding anterior commissure(AC) and posterior commissure(PC) in positron emission tomography(PET) brain image without a reference image is discussed. For labelling and localizing anatomical structures, a PET image aligned in parallel to the detected AC-PC line is normalized spatially into the corresponding transaxial Talairach brain. This labelling system may provide practical application method to make the clinical evaluation of PET brain images easier.

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GENERALLY A REFERENCE image such as a magnetic resonance (MR) image is often used to identify the anatomic structures of PET image, because a PET image has a low resolution. It is possible to make clinical diagnosis easier with an identification of anatomic structures of PET brain images without MR images. For precise localization of task-activated regions or evaluation of abnormal regions, the PET image is required to be transformed into standard stereotactic space,¹ which can label anatomic structures. Several papers^{2,3} mentioned the methods of the image co-registration, especially in an iterative ways to find nine factors such as rotation, scaling, and translation required for image reslicing. The automatic method of rotational correction and centering of three-dimensional brain images⁴ of PET image is used for obtaining a midsagittal slice. And with the midsagittal slice, the new non-iterative automatic detection method of AC and PC is discussed through transforming the slice into the normalized coordinates.⁵ Because the Talairach brain atlas is originally aligned to the AC-PC line, the trans-

formed PET image can provide abundant information of anatomical structures using labels of Talairach atlas.

MATERIALS AND METHODS

Scanned data was 35 transaxial $H_2^{15}O$ activation PET or FDG PET images (128×128 resolution, 4.25 mm thickness) acquired on a GE Advance PET scanner. The AC and PC of the activated or FDG PET image are automatically detected and the image is re-oriented to make this AC and PC lie horizontally for correction of positional differences. The detection method of AC and PC is as follows: the CA is defined as an anterior ventral point and PB is defined as a posterior ventral point of boundary of corpus callosum. It is found that the line of CA and PB is passed through the AC point. So, AC(acx, acy) is figured out as

$$acy = Spc * (acx - cax) + cay,$$

and

$$acx = cax + (pbx - cax) * Lacca / Lpbca,$$

where

$$Spc = (pby - cay) / (pbx - cax)$$

and, for PC(pcx,pcy) point,

$$pcx = cax + (pbx - cax) * Lpcca / Lpbca,$$

and

$$pcy = acy$$

with Lacca is a distance between ac and ca and Lpbca is a distance between pb and ca. The proportional ratio of width to height of bounding box is denoted as Rwh. The PC is horizontally right-side of AC. In the mid-sagittal brain atlas of Fig 1, Lacca = 21, Lpbca = 58, Lpcca = 24 and Tan(Spc) = 6.39° and Rwh = 2.62.

The procedures of NADA(Non-iterative Automatic Detection of AC and PC in PET image) method are as follows: a mid-sagittal slice is reconstructed after correcting roll and yaw by an automatic rotational correction method, and then normal-

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Fig 1. Geometrical shape of Talairach midsagittal atlas is shown with AC, PC, CA and PB.

Fig 2. The procedures of NADA.

ized into the Talairach space using a mid-sagittal PET template. The AC and PC are located in the normalized mid-sagittal slice, using a geometrical relation of the corpus callosum as mentioned above. Then the final AC and PC are found in the original PET image by retracing the sequences back.^{5,6} The procedures are shown in Fig 2.

After re-orienting PET images using these detected AC and PC, linear scaling and non-linear resampling are performed for correction of morphological differences.^{7,8} The resampled im-

age is in Talairach space, so the corresponding brain atlas can provide information of labels.

RESULTS

NADA procedure is applied to the well-known PET template acquired by averaging transaxial slices of normal 48 adults containing $2 \times 2 \times 4\text{mm}$

Fig 3. (Left)The original PET image is shown. (Right)With a PET image aligned in parallel to the line of detected AC and PC, structural label (eg, putamen) and its coordinate are displayed according to the location of a mouse denoted by two crossed lines. For verification, detected AC and PC are marked in the transformed image.

Table 1. Single Patient Data Structure

Name	Val	Name	Val	Name	Val	Name	Val	Name	Val
0 ventricle	1178	15 putamen	1357	30 uncin/fasc	0	45 vl/thal	1380	60 dors/hypothal	0
1 globus1	1551	16 hippocampus	1278	31 chiasm	1602	46 dm/thal	1174	61 VM/hypothal	0
2 cortex	776	17 ant/comm	1440	32 pyram/crtx	0	47 lp/thal	968	62 outline	0
3 caudate	1126	18 backdrop	369	33 pyr2/arm	0	48 p/thal	1191	63 thalamic	0
4 FLS	1157	19 lat/genic	0	34 pyr3/legs/trnk	0	49 lm/thal	1215	64 Nucleus_ruber	0
5 fornix	1025	20 labels	0	35 pyr1/face	0	50 ld/thal	1277	65 Pulvinar	0
6 thalamus	1226	21 med/genic	0	36 lat/hypothal	1691	51 vpl/thal	1369	66 Corpus_pineale	0
7 globus2	1403	22 subthalamic	1221	37 post/hypothal	1349	52 vpm/thal	1183	67 suprapin/rec	0
8 FOF	1212	23 red/nuc	1206	38 POM/hypothal	1263	53 cm/thal	1085	68 post/comm	0
9 FLI	1510	24 optic/trac	1777	39 SO/hypothal	1401	54 nacs	0	69 adhesion	0
10 cingulum	1072	25 subst/nigra	1126	40 PV/hypothal	1392	55 Folf	0	70 central_sulcus	0
11 corpus	1208	26 hypothal	0	41 PaV/hypothal	1427	56 POL	0		
12 Ro	1043	27 mamm/body	1322	42 pyram/crtx	856	57 pyram/tract	0		
13 claustrum	1489	28 amygdala	1561	43 na/thal	1148	58 olfact/tract	0		
14 tapetum	1144	29 aqueduct	1484	44 va/thal	1367	59 Tub	0		

Note: The 70 different labels have own color index for labeling. The range of image values are from 0 to 4095. Each value in the table shows mean value of the corresponding anatomical structure. The structures which have value of zero aren't included in this scanned PET.

voxels,⁸ which was normalized into Talairach space. The results of $\text{Tan}(\text{Spc}) = 6.34^\circ$ and $\text{Rwh} = 2.58$ are obtained with the PET template. As compared with those of atlas, this shows error rate is less than 1.5%. Several physicians reviewed these detected AC and PC of template as correct locations of two commissures. This perfect match between atlas and template in Spc and Rwh proves the NADA has a proper geometric rule for finding AC and PC. For verifying the accuracy of NADA procedures in clinical cases, locations of AC and PC of the PET image are compared with those of MR. With the transmission PET scan containing skull information of the same patient, the error rate in rms was calculated by using surface matching method² which utilizes the skull boundary. As registration error of 6 cases, NADA shows $1.4 \pm 0.5\text{mm}$, whereas surface matching shows $1.8 \pm 0.4\text{mm}$.

Figure 3 shows the original test image and the

transformed image. As shown in fig 3, any PET images which are in Talairach space can be labeled.

Each average activities of 70 anatomical structures of the PET image are obtained by automatic detection of VOI (volume of interest) of brain atlas. Table 1 shows mean values of each structure for one patient's data. These values enable us to quantify a functional brain image.

DISCUSSION

The automatic labelling system of anatomic structures can provide the reduction of the manual steps to analyze a clinical PET image without a reference image. The recognition accuracy of structures was proved⁵ as compared with the co-registered PET and MR image of the same data. Also in clinical routine reading of functional images, this method may give wide understanding of brain images to a physician.

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