3D Transparent Image Display of Positron Emission Tomography using Volume Rendering Technique in Partial Epilepsies

IV. 10. 3D Transparent Image Display of Positron Emission Tomography using Volume Rendering Technique in Partial Epilepsies

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Introduction

PET studies reveal regions of cerebral dysfunction which differ spatially from pathological substrates or electrophysiological abnormalities in various pathological conditions such as in partial epilepsies[1)]. Difficulties exist, however, for human mind's ability to perceive accurately the information expressed in PET images because of low spacial resolution and absence of direct anatomical information, especially when forming a complete 3D brain image mentally by integrating series of 2D PET image slices.

To visualize 3D medical image data by rendering 3D images directly from an image volume, a wide variety of techniques have been utilized[2,3,5,8-10)]. Early approaches were based on rendering objects defined by polygonal surfaces, which had a difficulty in calculating the connectivity between adjacent contours. A similar technique based on pixel-sized cubes, named cuberille technique, was developed later to avoid the difficulty described above. This technique, however, still required binary segmentation of the image voxels into object and non-object voxels, which is difficult to apply for complex image volumes such as PET image data.

Volume rendering is a relatively new technique which was developed to visualize information from the entire volume of data rather than from an arbitrarily selected surface in data. To generate 3D images, a shaded color and an opacity are assigned to each voxel and 2D projection of the resulting colored semi-transparent gel is computed. The primary advantage of volume rendering technique over surface-based and binary voxel visualization techniques is that it retains more information in the final rendered image.

One drawback of this method, on the other hand, is that it requires more computational time and memory space to generate images. To solve this disadvantage, the authors have developed a method to ray-trace Value-Intensity-Strength volume (VIS volume) instead of color-opacity volume and to adaptively refine the generating images, and applied this technique to generate and analyze 3D PET images interactively[6,7,11)].

In this report, an imaging system to display PET in partial epilepsy patients as 3D semi-transparent brain images using volume rendering technique is described.

Materials and methods

We developed a software for supporting medical image analysis (11), named Clinical Planning Support System (CliPSS), on the IBM RS/6000 workstation in the X Windows environment and wrote it in C. This system provides a function for analyzing 3D medical image data by using volume rendering technique, in which data values to color and opacity were calculated for each voxel of volume data and projected to a screen by using ray-tracing method. To rotate and zoom a volume-rendered object and to interactively manipulate a function for transferring data values to color and opacity, we used a method to ray-trace a Value-Intensity-Strength volume (VIS volume) instead of a color-opacity volume, which reduced the computational time and memory space for generating 3D images. Automatic 3D boundary enhancement using a gradient-based classification technique was used to generate image directly from the volume data without extracting explicit surfaces. Aliasing artifacts are reduced by avoiding thresholding during classification and by carefully resampling the data during projection.

Ten cases of partial epilepsies were investigated by PET using fluoro-deoxyglucose (FDG) and MRI. PET images were generated as 3D transparent color display and rotated as a cine image so as to obtain a stereoscopic views. 3D anatomical brain images were generated based on 3 mm-sliced T1 weighted MRI and displayed with 3D PET images.

Results

Visualization of 3D PET brain images in its entirety has become possible using volume rendering method by choosing appropriate colors for each different level of activity and adjusting the degree of transparency to each assigned color. Brighter colors and lower values of transparency were assigned a region with higher metabolic activities and colder colors and higher values of transparency for lower activities. By assigning appropriate colors and transparency values interactively to each seven different category of PET values, brain activities in cortical areas and deep brain structures can be visualized as semi-transparent 3D brain images. In the cases of temporal lobe epilepsy hypometabolism in the temporal lobe were clearly demonstrated (fig. 1), the extent of which was easily recognized correlating with 3D MR images. Views from the basal and medial side of the hemisphere (fig. 2) were also helpful for demonstrating focal abnormalities in brain metabolism.

Simultaneous 3D cine image display of PET and MRI, which enables three-dimensional correlation of the images of different modality, was helpful for analyzing focal metabolic abnormalities in partial epilepsies. To registrate both PET and MRI 3D images in a single space, sagittal, horizontal and coronal planes of PET 3D images were adjusted to

3D MR brain images using a multiplannar imaging display. Once this interactive registration procedure was completed, any sets of PET and MR image data either as 3D or 2D images could be displayed as overlaid multimodal images by volume texture mapping technique (fig. 3, 4).

Discussion

It was revealed, in this report, that visualization of 3D PET brain images in its entirety has become possible using volume rendering method by choosing appropriate colors for each different level of activity and adjusting the degree of transparency to each assigned color. By assigning appropriate colors and transparency values, brain activities not only in cortical area but also in deep brain structures can be displayed and recognized as 3D brain images. This interactive visualization process may be analogous to such process as to visualize CT and MR slice images by adjusting window levels and window widths of image data. Stereoscopic view by generating stereo pairs of images and cine rotating animation greatly assisted stereo perception of 3D brain images.

In order to form a coherent image of the patient's brain anatomy and function, multimodal brain images generated from PET and MRI have been displayed[3-5, 8-10]. It should be noted that registration using 2D slice images taken at different times cannot be guaranteed to represent the same spatial section of the patient. Fiducial markers introduced at scanning time have been used for multimodal image registration with some success[4], but this technique requires the use of a rigid frame attached to the skull and was inconvenient for serial studies. Several external and internal anatomical landmarks such as the AC-PC line have been used to register multimodality images although this approach presented significant difficulties because of poor spatial resolution in PET images.

The use of 3D images made full six-degree-of-freedom registration possible not only for images taken at different times but images for different modalities. In searching for the matching transformation, such approaches as surface matching and Chamfer matching techniques have been reported[3,5,8-10]. Although these approaches using mathematical algorithms do not require experienced medical experts, a statistically significant value for the registration accuracy in such studies is difficult to determine. In this report, we registered 3D brain images both generated from PET and MRI by adjusting X,Y, and Z axes repetitively using multiplannar slice images in a single space coordinate system. This procedure was considered as simple, time-saving and practical for medical researchers without using any complex mathematical algorithms. 3D transparent image display of PET, therefore, enabled three-dimensional correlation of different modalities regardless of position and degree of the slice data obtained, which was considered helpful for analyzing brain metabolic changes in partial epilepsy patients.

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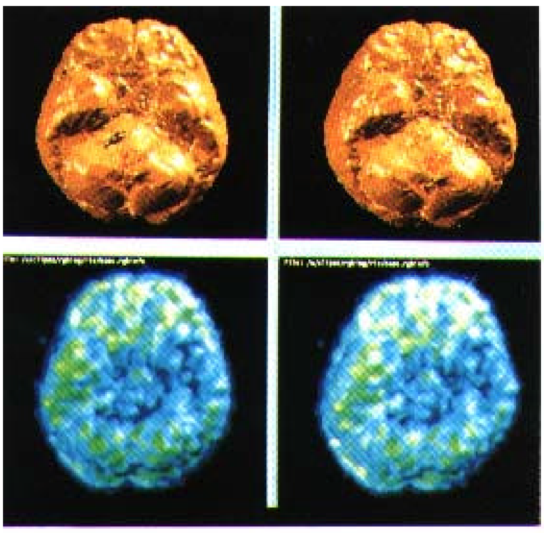

Fig. 1. 3D stereoscopic display of MRI (upper) and PET (lower) images in a case of left temporal lobe epilepsy. Hypometabolic zone (blue zone) in the left temporal lobe is clearly demonstrated in transparent PET brain images viewed from the base of skull.

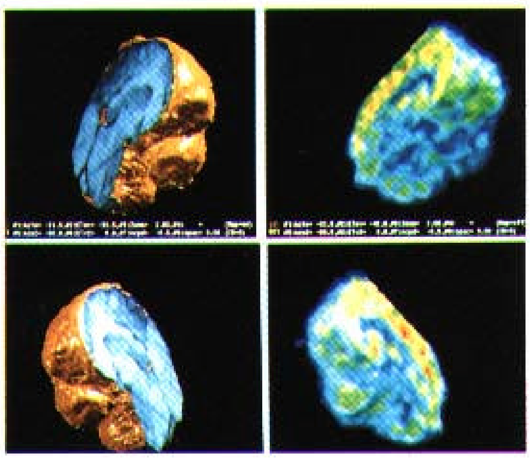

Fig. 2. 3D brain images split at the mid-saggital plane generated from MRI (left) and PET (right) data. The extent of hypometabolic zone in the medial aspect of the left temporal lobe is demonstrated (right upper).

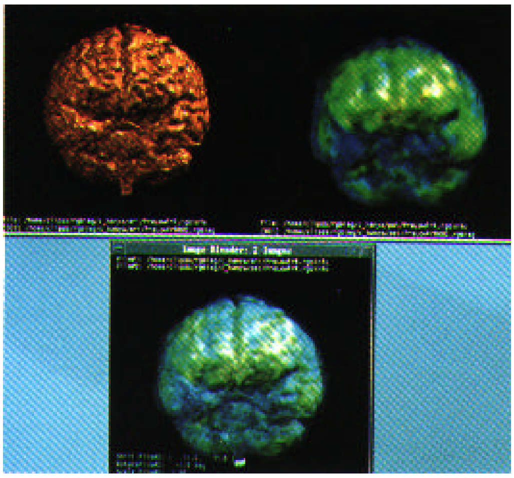

Fig. 3. 3D brain images of MRI (upper left) and PET (upper right) volume data registered in a single space (lower) in a case of right temporal lobe epilepsy.

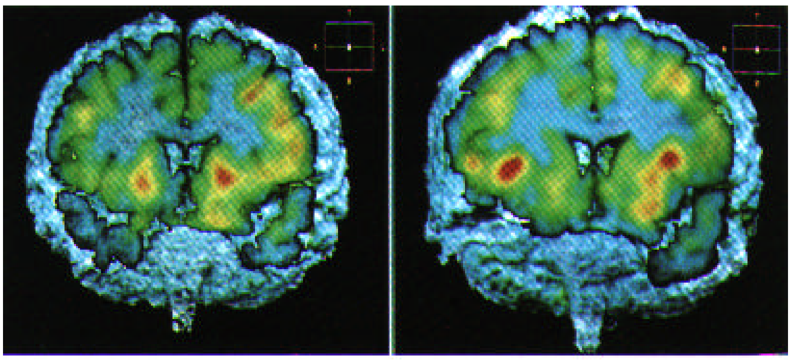

Fig. 4. Image display of cut surface of MRI and PET volume data registered in a single space in a case of right temporal lobe epilepsy. Pre-operative (left) and post-operative (right) studies.