Presurgical Visualization of Primary Breast Carcinoma with PET Emission and Transmission Imaging

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The aim of this study was to investigate a technique that visualizes findings from PET images in a context useful for surgery. **Methods:** Simultaneously acquired PET emission and transmission scans were used. By applying a multipurpose imaging, registration and rendering tool (MPM), displays of orthogonal and volume-rendered views or any combination thereof were obtained. The PET emission and transmission scans were acquired under routine conditions. The final user-customized display (with a combination of orthogonal cuts and rendered views) was processed in 10 min or less on commercially available hardware. Distinct features of the body shape were clearly visible on the volume-rendered transmission views. Hot spots, e.g., in primary breast cancer, from the emission scans could be easily assessed in their localization relative to the body outline. **Conclusion:** Rendering of the main signatures in a single comprehensive display makes this method potentially valuable for simple presurgical workup and therapeutic management of breast cancer.

Key Words: positron emission tomography; breast cancer; volume rendered images; image integration

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One of the main purposes of viewing nuclear medicine images is to detect abnormal tracer uptake within the human body. For example, in cases of suspected primary breast carcinoma, injection of ^{18}F-2-deoxy-2-fluoro-D-glucose (FDG) and subsequent examination with PET might be used to highlight areas of focal FDG uptake caused by abnormal processes. Routinely, such reconstructed PET images are provided as a series of two-dimensional transaxial cuts. These images, however, are often difficult to evaluate because abnormalities are normally scattered across a large volume with quite variable intensities. A first step to make these images more comprehensible and better relate them to the surrounding tissue is the three-dimensional display of orthogonal planes. Structures and focal lesions that extend across multiple two-dimensional planes, however, are difficult to combine in an understandable mental picture. It is even more difficult to convey the location about abnormalities and scattered hot spots to surgeons compared to radiologists. This is particularly true in cases when abnormalities detected with PET are only visualized to a much lesser extent in other routine imaging modalities, such as mammography or planar radiography. To overcome these limitations, various rendering techniques (*1*) to convert three-dimensional image data into an understandable form can be applied. Most of them, however, require a smooth, well-defined closed surface; hence, they are limited mainly to subjects examined with MRI or x-ray CT. For PET and SPECT, rendering techniques are mostly applied to brain studies and not those of the thorax, since the outlines of whole-body PET or SPECT images are rather coarse and not suited for most rendering algorithms.

Nuclear medicine images are also difficult in visualizing underlying anatomical structures. Although many techniques have been developed that align any combination of brain studies (*2*), multi-modality whole-body studies impose serious constraints. Compared to brain studies, where the head is regarded as a nondeformable rigid object, major difficulties arise from the larger variability in patient positioning during scanning (arms, legs, shape of patient pallet). Also, in a clinical environment, different types of images may not always be available in digital format and physicians have to make their diagnoses from radiographs and prints.

The aim of this study was to provide a simple means for localizing lesions in patients with primary breast carcinoma, based solely on PET emission and transmission scans.

MATERIALS AND METHODS

Data Acquisition

PET data originated from a clinical study of patients who were referred to the hospital and scheduled for surgery (Schiedhaver K et al., *unpublished data*, 1995) because of suspicious breast findings. Criteria for patient selection was suspicion of malignancy

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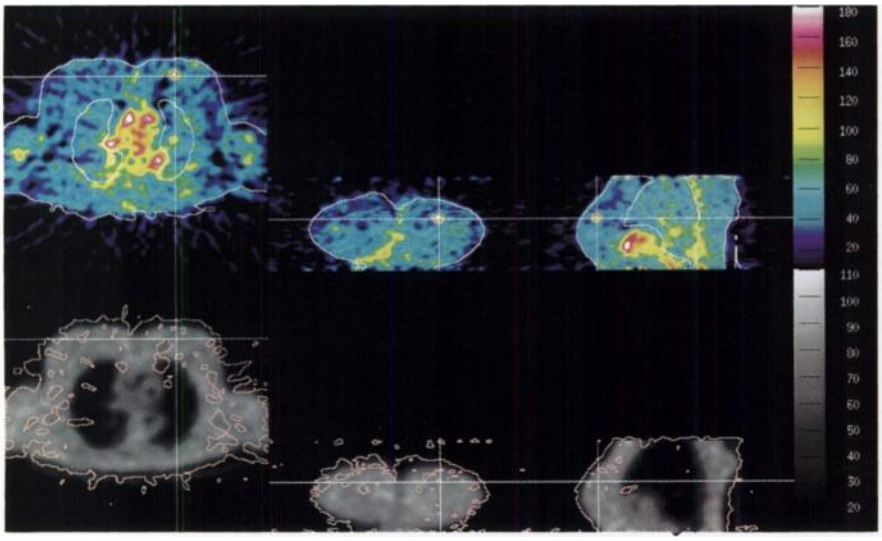

FIGURE 1. Typical display of a patient study as three orthogonal cuts (transaxial, coronal, sagittal) with a hot spot in the left breast marked by crosshairs. (Top) Emission data and (bottom) data from the corresponding transmission scan. Digital filters have been applied to extract the body outline. The contours have been exchanged, i.e., contours calculated from the transmission data (bottom) have been superimposed onto the emission data and vice versa.

based on clinical and/or radiological (mammography, ultrasound) evidence. PET data were acquired on an ECAT EXACT scanner (Siemens-CTI, Knoxville, TN) after intravenous injection of 370 MBq ^{18}F-2-deoxy-2-fluoro-D-glucose (FDG). The scanner provided 47 overlapping slices per bed position with transaxial resolution of 6.0 mm FWHM, approximately 5-mm slice thickness and 3.375 mm center-to-center distance (*4*). The axial field of view extended over 16 cm. Usually, one or two bed positions were examined to cover a sufficient portion of the thorax. To avoid missing relatively small spots of tracer uptake due to reduced sensitivity towards the edges of the field of view (FOV), the measurements at the two bed positions overlapped by approximately 2 cm. Imaging began 15 to 30 min postinjection; a 10-min transmission scan was acquired first followed by emission scan. The acquisition time was split into six frames of 5 min each to limit the amount of data lost due to cases of unwanted patient movement. Emission data were reconstructed by filtered backprojection with a Hanning filter with a cutoff frequency of 0.4 cycles per pixel. Emission data were corrected for attenuation based on the transmission scan. Also, transmission images were routinely available at the end of the reconstruction.

Imaging Protocol

The basic framework is a multipurpose imaging, registration and rendering tool (MPM, multipurpose matching), as previously described and validated for brain studies (*3*). The protocol was as follows:

1. Emission and transmission studies were displayed as three orthogonal cuts (transaxial, coronal, sagittal) and the relative alignment was checked, since patient movement between the transmission and emission studies might have occurred. We applied the image registration technique described in detail elsewhere (*3*). Basically, contours from both sets of images (transmission and emission) are extracted by edge detection techniques, such as applying a global threshold to remove all unwanted pixels and generating contours with a Laplace filter or Marr-Hildreth filter (*2*). The resulting contours were superimposed on the images. Levels were adjusted to extract a contour that correctly outlines desired details such as the shape of the thorax, breasts, etc. Exchanging the overlaid contours of both images (transmission versus emission and vice versa) allows the user to control proper image alignment. Alternatively, the contours themselves were overlaid in a separate display. Finally, a cursor operating simultaneously on the three orthogonal views was applied. All these tools enable the user to assess image registration. Misregistration would result in imperfect contour overlays or misplaced landmarks located with the cursor on one image and checked on the other.

   Figure 1 shows an example of a display with emission (top) and transmission (bottom) images and the contours exchanged. Small adjustments on the order of 1 pixel (2.5 to 3.5 mm) were applied when necessary, however, displacements larger than this would invalidate the use of the transmission scan to correct the emission data for attenuation.
2. The original transverse images were resampled by linear interpolation to obtain a model with isotropic voxels, usually with a voxel size between 2.5 and 3.5 mm. Shifts and rotations detected with the alignment procedure were taken into account.
3. Integral shading (*5*) in the implementation as previously described (*6*) was applied: Starting at the surface voxel of the transmission scan, an optional number of voxels (usually 5 to 10) was integrated in the viewing direction. This calculation was performed on both datasets. The starting voxel for the integration, however, was determined with the transmission data only, owing to the much clearer, albeit smooth, body outline in these data. The location of the starting voxels was assessed by applying the same threshold as for the edge detection and contour generating step. Figure 1 displays this situation, since the contour superimposed on the emission images was extracted from the transmission images. Depending on the integration length, structures within a certain depth can be detected and visualized by this type of volume rendering technique.
4. Apply multiple cursors simultaneously in all three dimensions to localize abnormal tracer uptake.
5. A summary display was created from steps 2 and 3 and saved into a file or printed on a color printer and given to the surgeon. An example of a summary display is shown in Figure 2. The coronal and sagittal views were combined with rendered emission and transmission images at the position of the hot spot. On the rendered emission image (anterior view), the hot spot is shown in its spatial relation-

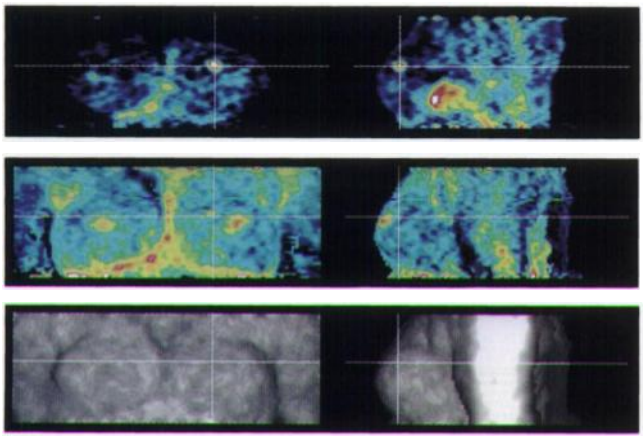

FIGURE 2. The most relevant views are integrated into a single display, including crosshair cursors for relative spatial relationship of the structures under investigation. (Top) Orthogonal cuts. (Middle) Rendered emission images. (Bottom) Rendered transmission scans. The rendered images were generated by integrating over 6 voxels in the viewing direction starting at a surface threshold determined on the transmission images.

ship with respect to other areas with higher, albeit normal, tracer uptake. On the left lateral rendered emission image, the areolar uptake site is visible. The crosshairs at the position of the suspected hot spot visible on the sagittal view (top right) provide an estimate of the depth of the hot spot inside the breast.

The time needed to process the data to obtain such a display is about 10 min on commercially available hardware.

DISCUSSION

A simple strategy was developed to make the findings from ^{18}FDG PET studies potentially useful for surgical planning. Clearly, the best approach would be to combine the images from functional (PET) and morphological (MRI, CT) data. In a clinical environment, however, patient data from the different modalities might not always be available in digital form. Therefore, the surgeon has to decide on the best strategy for surgery based on knowledge from completely different sources: radiographs, computer printouts, planar two-dimensional images and three-dimensional orthogonal slices. He or she has to mentally fuse all information in an understandable picture. Our technique provides a relatively simple, albeit essential method, to enable surgical localization of a hot spot, i.e., abnormal uptake, relative to the body outline. The precision of localization is limited by the resolving capabilities of the PET scanner and the relatively smooth appearance of body outlines. Variability in body shape between the PET study and patient positioning during surgery might be the limiting factor. PET studies, however, can be made in the supine position with arms oriented parallel to the body axis, providing nearly the same position of the patient as on the operating table. This is an advantage compared to mammography (which compresses the breasts during data acquisition) and MRI [where patients lie in the prone position in specially designed beds and coils (7)]. Although these two methods are highly sensitive to small lesions, precise re-localization of the lesions during surgery is difficult because of differences in patient positioning during data acquisition and surgery. The method described here is based on PET emission and transmission data acquisition. A specific protocol was not applied and special patient handling prior to scanning was not necessary.

Displays such as those shown in Figure 2 might be sufficient for defining the spatial relationship between areas of pathological tracer uptake and body outline and, thus, could guide surgery for excision of the suspected area for histologic examination. This is especially valuable and necessary for nonpalpable tumors (Scharl A et al., *unpublished data*).

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REFERENCES

1. Toga AW, Payne BA. Surface rendering. In: Toga AW, ed. *Three-dimensional neuroimaging*. New York: Raven Press; 1990:251–271.
2. Pietrzyk U, Herholz K, Heiss WD. Three-dimensional alignment of functional and morphological tomograms. *J Comput Assist Tomogr* 1990;14:51–59.
3. Pietrzyk U, Herholz K, Fink G, et al. An interactive technique for three-dimensional image registration: validation for PET, SPECT, MRI and CT brain studies. *J Nucl Med* 1994;35:2011–2018.
4. Wienhard K, Eriksson L, Grootoonk S, Casey M, Pietrzyk U, Heiss WD. Performance evaluation of the positron scanner ECAT EXACT. *J Comput Assist Tomogr* 1992;16:804–813.
5. Bomans M, Höhne KH, Tiede U, Riemer M. Three-dimensional segmentation of MR images of the head for 3-D display. *IEEE Trans Medical Imaging* 1990;9:177–183.
6. Pietrzyk U. A rapid three-dimensional visualization technique to evaluate function in relation with anatomy of the human cortex. *IEEE Medical Imaging* 1993;1810–1812.
7. Heywang-Köbrunner SHG. Nonmammographic breast imaging techniques. *Curr Opin Radiol* 1992;4:146–154.