PERFORMANCE ASSESSMENT OF PHOTON ATTENUATION CORRECTION IN A NEW HYBRID PET/CT SCANNER

Vijaykalyan Yeluri, Santosh T Keni, Juan Franquiz

Biomedical Engineering Institute
Florida International University
Miami, FL

ABSTRACT

Background and purpose

Positron emission tomography (PET) imaging is unique in that it shows the chemical functioning of organs and tissues. In past years, PET images have been attenuation corrected using transmission images derived from a ^{68}Ge positron emission source [1]. This method requires a blank scan of the transmission source and a transmission scan of the patient before the administration of the radiotracer. The inconveniences of this procedure are: 1) time consuming because two PET scans are required per patient, and 2) the radioactive source produces noisy transmission images whose noise is propagated into the attenuation corrected PET image [2]. It is supposed that the inconvenience of noise propagation is overcome by attenuation correction using CT maps. These are high resolution, low noise transmission maps that could provide better quality in attenuation corrected PET images. This assumption will be demonstrated in the project. The second research issue is about the accuracy of attenuation correction using CT maps. The x-ray CT maps are obtained with x-rays with maximum energy of 140 keV, while the attenuation must be corrected in PET for photons of 511keV.

The attenuation correction algorithm needs to convert the attenuation coefficients for 140 keV derived from CT maps to the attenuation coefficients of 511keV photons emitted during positron annihilation. How this conversion affects the accuracy of attenuation-corrected PET images for different densities encountered in clinical studies is the other aspect to be investigated.

This project will investigate the performance of the hybrid CT/PET scanner related to its capability for quantifying the radiotracer uptake in lesions and the accuracy and reliability of the attenuation correction algorithm using the CT images.

Objective

The Main purpose of the research is to assess the performance of the attenuation correction of PET images using CT attenuation correction maps. The specific aims are: (1) Compare resolution, contrast, uniformity and noise of CT attenuation corrected PET reconstructions with those without attenuation correction or with attenuation correction using the conventional ^{68}Ge transmission source method [3]. (2) Determine the relation of proportionality between the attenuation coefficients determined from CT images with the density of the attenuating medium in a range of densities similar to that found in clinical studies. (3) Calculate the accuracy of radiotracer uptake quantitation in CT attenuation corrected PET reconstructions. Comparison of the radiotracer uptake quantitations with those determined without attenuation correction and with attenuation correction using the ^{68}Ge transmission source method.

Materials and Methods

The jaszczak phantom will be used for assessing multiple performance characteristics of the PET system. The phantom will provide consistent performance information on the contrast, spatial resolution, uniformity and noise of PET images [4] An Anthropomorphic chest phantom will be used for assessing the accuracy of quantitation of radiotracer uptake. The phantom consists of two chambers shaped to simulate lungs filled with Styrofoam beads to simulate lung attenuation. Two lesions will be simulated, one in soft tissue and the other in the lung. The diameter of the lesions will be 3 – 7 mm [5]. Experiments will be conducted using the CT/PET scanner, Discovery LS (GE Medical Systems). Contrast media used would be iodinated contrast (gastrograffing) and barium suspension.

The Jaszczak phantom will be scanned according to the following protocols 1) With water being the only content, 2) water with 50% of iodinated contrast and 3) water with 50% of barium suspension. The activity of the radioactive solution of 18 FDG mixed with water will

be 10 mCi. The Chest phantom will have two lesions, one in soft tissue and the other in the lung. It will be first scanned in air without water, thus generating our standard reference, free of photon attenuation. Then, water will be added to the phantom and the phantom will be scanned again. The activity of the radioactive FDG will be 10 µCi. The source activity will be corrected for the decay of the radionuclide.

PET image reconstruction will be performed according to the protocols that follow: 1) With attenuation correction using the CT images, 2) without attenuation correction, and 3) with attenuation correction using the conventional 68Ge source transmission method.

Results

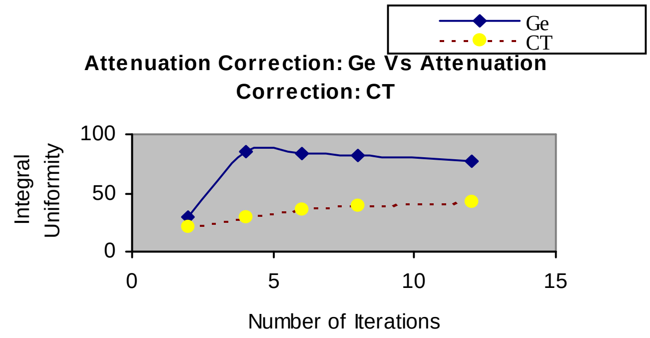

Figure 1.(a)

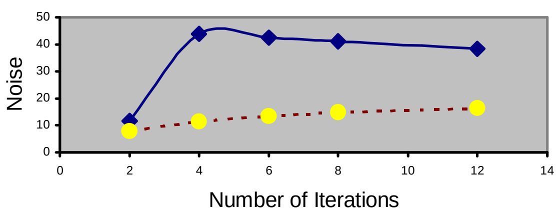

Figure 1. (b)

Figure 1 Integral uniformity (a) noise (b) in CT attenuation corrected images and attenuation corrected images using the ^{68}Ge source method

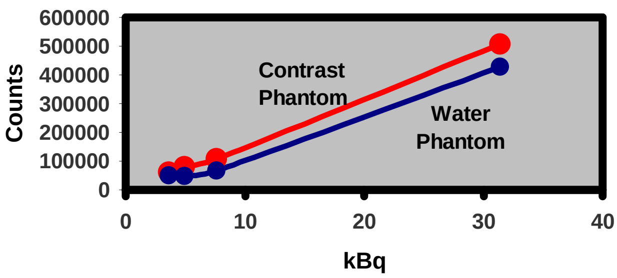

Figure 2. Number of counts when water is used around the lesion, and when a radiographic contrast is used around the lesion.

Discussion

The basic hypothesis of this research is that: the combined use of CT with PET images for attenuation correction is superior to other methods of PET imaging and will produce higher accuracy in quantitations, better resolution, contrast and uniformity and lower noise in reconstructed images. How the resolution, contrast, uniformity and noise is improved in comparison with other methods of PET imaging? How much is improved, the accuracy of quantifying the radiotracer uptake in a lesion? How is the performance of attenuation correction of PET images for different materials encountered in clinical studies?

Conclusions

The results show an increased superiority of the CT attenuation correction methods over the ^{68}Ge transmission source method. The noise level in images with the ^{68}Ge transmission source method at 4 iterations is four times the noise level, when using CT for attenuation correction. For the 68Ge source method, the noise level increases from 11% to 38%. While for the CT attenuation correction method, the noise level increases from 8% to 16%. It indicates that the rate of increment is higher with the ^{68}Ge source method.

The optimal compromise for the performance parameters, uniformity, noise, spatial resolution, and contrast is, using the CT images as attenuation correction maps, reconstructing the images with 14 subsets, and the number of iterations limited to a maximum of 2. The optimal values obtained are uniformity (16 %), Noise level (6.3 %), score of 0.79, and a contrast value of 0.41.

Using a radiographic contrast with the cardiac chest phantom demonstrated an over-correction in the number of counts in the CT attenuation corrected image. Thus the lesion may appear to be larger than it actually is. The percentage value of over-correction mainly depends on the kind of radiographic contrast used with the phantom. With iodine the over-correction in the number of counts was around 20%, but with a gastroffin contrast, the over-correction in the number of counts was about 60%.

References

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