Improved PET Detection of Focal Brain Activity Using Subset-dependent Relaxation 'Dynamic' Row-action Maximum Likelihood Algorithm (DRAMA)

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Abstract: The SHR-7700 scanner (Hamamatsu Photonics, K.K.) is a high-resolution 20 cm bore research scanner that is used to acquiring images from both animals and human brains. The scanner has a reconstructed resolution of 2.5 mm and can image small amounts of tracer. To improve the recovery of low signals the DRAMA reconstruction method was implemented for the Hamamatsu scanner. To improve the signal-to-noise ratios the algorithm of subset-dependent relaxation 'dynamic' row-action maximum likelihood algorithm (DRAMA) [1] was evaluated using a data set of three groups of subjects (n=9, 9, and 8) received 5 mCi of [F-18] fluorodeoxyglucose at rest and during delayed recall task on 2 separate days. The optimum filter will be determined by varying the filter size. One filter has been evaluated and the resulting data was evaluated with a pixel wise one-sample t statistics were performed between task-resting conditions following pixel normalization and 3D Gaussian smoothing (9mm FWHM). Evoked brain activities were recorded with Z scores and spatial coordinates for comparisons. Significant task-evoked brain activities were detected by FBP and DRAMA (chi-square $p<0.001$) in all 3 groups, but DRAMA produced 6.9 times more pixels than expected from random chance in comparison to 5.3 times by FBP. This method will be applied to the rest of the filter choices. This method will be also applied to a small animal study where the injected dose was only 15 to 25 μCi of activity to see if there is any improvement in the results. These results indicate a potential for DRAMA to improve the statistical power of brain-activation test.

1. Introduction

The SHR-7700 is used, primarily, to detect very small changes in tracer amounts within non-human and human brains. Our studies are either using very small amounts of tracers or are tracking the changes between to states in the brain with very small changes. Therefore a reconstruction method, which reduces variance while maintaining spatial resolution, is very desirable. Using FBP the noise in the images will cause streaks and mask the small changes that are close to the noise. On the other hand DRAMA is a form of OS-EM, which recovers low signals. This style of reconstructions improves the signal-to-noise ratio. DRAMA is a special case of DOSEM. The difference is that DRAMA uses a constant **B,** which is determined form the geometrical correlation coefficient and provides a reasonable signal-to-noise ratio. The other fixed (constant) is g, which constrains the number of iterations. This allows a performance with faster convergence than standard DOSEM but not as fast as FBP. The reconstruction times were measured for the same data set. For a 3D two positions 5 frame (each position), the time was 45 minutes for FBP and 75 minutes for DRAMA reconstruction.

Tanaka and Kudo who developed Drama have tested the algorithm with simulated data. The results were that when DOSEM (dynamic OS-EM) is operated with a larger OS level there is no lose of signal-to-noise ratio. Drama, which is a special case of DOSEM, provides similar performance with a fastest convergence and smallest computer burden.

Our data will evaluate this reconstruction method and find the optimum filter size to reconstruct data of both high and low tracer activities. This will allow more information to be extracted from our studies.

The reconstruction with a single filter has been done on the total data set and has demmonstrated an inprovement. We will evaluate multiple filters on the whole data of human brain scans and then apply the method to the very low (15 to 25 μCi) tracer activity in the rat studies and measure the differences.

2. Material and methods

Three groups of subjects (n=9, 9, and 8) received 5 mCi [F-18] fluorodeoxyglucose at rest and during delayed recall task on 2 separate days. PET data were acquired in 3D for 50 minutes starting at 35 minutes post-injection using an SHR-7700 scanner (Hamamatsu Photonics K.K., Japan). Following convolution subtraction of scatter and Fourier rebinning (FORE) of 3D data, images were reconstructed by 1) FBP (Hanning filter) and 2) DRAMA (6 iteration, gamma 0.1) algorithms implemented on a LINUX workstation. The gamma was varied. The images were reconstructed using gamma values of 0.08, 0.1, 0.12, and 0.16. Reconstructed image sets from the same subjects were co-registered and warped to the standard stereotactic coordinate system using identical transformation parameters for FBP and DRAMA data (NEUROSTAT, University of Washington). Pixelwise one-sample t statistics were performed between task-resting conditions following pixel normalization and 3D Gaussian smoothing (9mm FWHM). Evoked brain activities were recorded with Z scores and spatial coordinates for comparisons.

3. Results

Significant task-evoked brain activities were detected by FBP and DRAMA (chi-square $p<0.001$) in all 3 groups, but DRAMA produced 6.9 times more pixels than expected from random chance in comparison to 5.3 times by FBP (130% increase by DRAMA). Pooled variance within the gray matter decreased from 7.58% by FBP to 7.18% by DRAMA in comparison to a small change in activation

magnitude of 0.1% (averaged over largest 3 peaks). Final image smoothness measured on statistical maps was 13.9 mm FWHM for FBP and 13.5 mm for DRAMA. Averaged discordance in peak localization was 2.7 mm (pixel size 1 mm). The increase in peak Z scores by DRAMA was more prominent for smaller activation (9% increase for peak Z<3, 6% for 3<Z<4, and 5% for Z>4). Average reconstruction time was 7.5 minutes for a data set in comparison to 4.5 minutes by FBP.

4. Conclusion

DRAMA permits better detection of focal brain activity, in particular smaller changes, by decreasing noise levels and without inconsistency in signal localization. This method can be applied practically in research and clinical settings and, alternatively, may reduce tracer dose or scanning time to achieve similar delectability of brain activity to FBP.

Figure 1

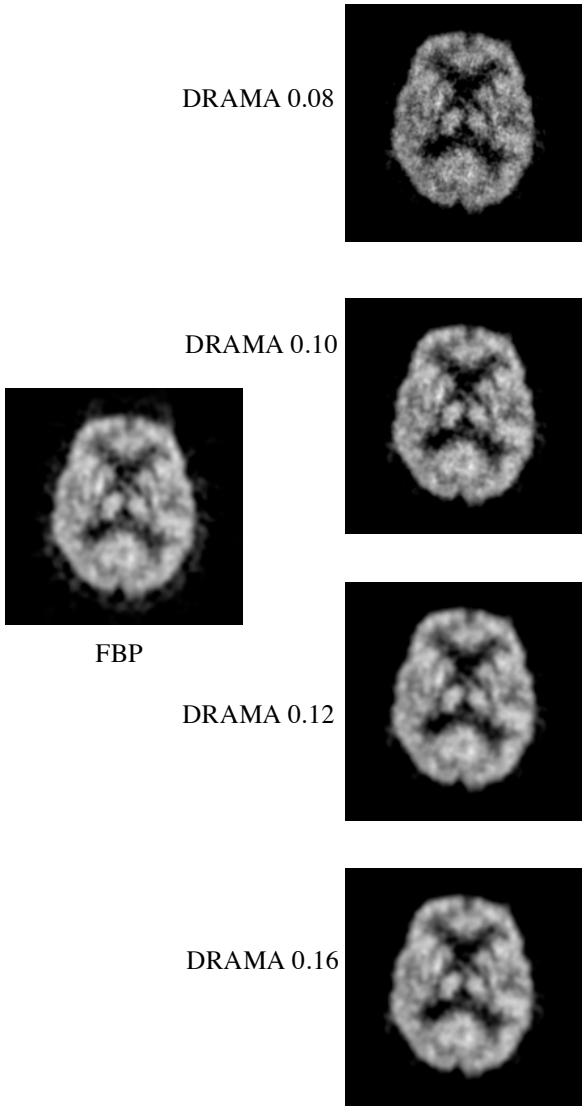

Figure1: Example of image reconstruction with FBP and DRAMA using four different gamma values (0.08, 0.10, 0.12, 0.16) for typical human brain scan with 5 mCi injection for subject.

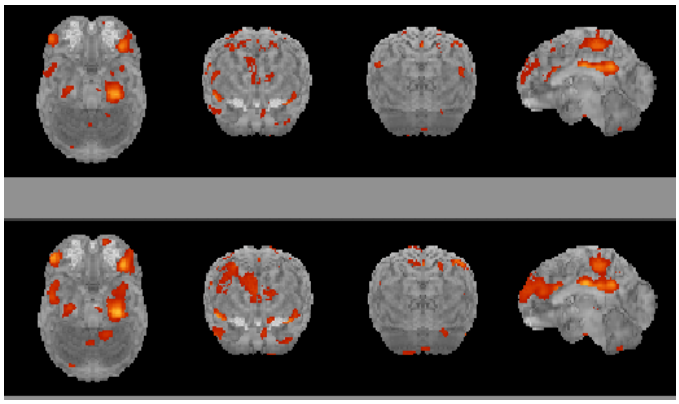

Figure 2: Example of processing of FBP (top) and DRAMA with gamma = 0.08 (bottom) reconstruction from a single patient study. The highlighted area are those where significance differences between the pre and post task scans were found. These images show the improvements that are obtained from DRAMA.

5. Discussion and Future Work

DRAMA reconstruction with 3D data sets has improved our extraction of information in our NEUROSTAT analysis and qualitatively appears to offer higher contrast images. We are proceeding to evaluate DRAMA in small animal studies using a protocol similar to that described here with adjusted doses appropriate to the animal weight.

The protocol is: Two groups of subject (n=6) received 15 to 25 μCi of [F-18] fluoride and 15 to 25 μCi of [F-18] labeled fluoride. Scans were done on separate days. PET data were acquired in 2D for 2 hours dynamically starting at injections time using an SHR-7700 scanner (Hamamatsu Photonics K.K., Japan). The reconstructed images sets from the same subject will be co-registered and warped to the standard stereotactic coordinate system using identical transformation parameters for FBP and DRAMA compared (NEUROSTAT, University of Washington). Evaluation of the differences will show the increased signal recovered by DRAMA for the data sets.

6. References

1. Tanaka, E.,H Kudo. *Subset-dependent relaxation in block-iterative algorithms for image reconstruction in emission tomography*

7. Acknowledgment

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