A COMPARISON OF BONE SPECT IMAGE QUALITIES OBTAINED FROM OSEM AND FBP ALGORITHMS

Chiraporn TOCHAROENCHAI[1] PhD (Biomedical Engineering),
Surachai NGAMRATANAPAIBOON[2] ME (Biomedical Engineering),
Chulaluk KOMOLTRI DrPH (Biostatistics)[3]

ABSTRACT

The aim of the study was to compare the image qualities of bone SPECT obtained from ordered subset expectation maximization (OSEM) and filtered-backprojection (FBP) image reconstruction algorithms for bone SPECT imaging. This study was divided into two parts; the optimal numbers of subset and iteration of OSEM using a Zubal brain phantom were firstly determined. The projection datasets of the phantom were generated with 128x128 matrix sizes and 120 views over 360 degrees. Poisson noise and collimator-detector blur were added to the projection data for simulating the clinical condition. Then OSEM image reconstruction was performed with various numbers of subset and iteration. The minimum mean square error (MSE) was used as an index of the optimal parameter. The second part was to evaluate the image qualities of bone SPECT images obtained from OSEM compared to that from FBP. Thirty-two patients with lower back pain requested for bone SPECT imaging were used. A pilot study was conducted to find the preferable algorithm using a preference study. Two nuclear medicine physicians with experiences in bone SPECT images were participated. The frequencies of the scores and the agreement between readers were investigated. The results showed that the combination of the 6th subset and 2nd iteration gave the minimum MSE and less time-consuming. For preference study, two readers preferred OSEM to FBP with the agreement of 65.6%. In conclusion, the optimal numbers of subset and iteration of OSEM were 6 and 2 respectively. The OSEM algorithm gave better image quality of bone SPECT than FBP.

Key Words: OSEM, iterative method, image quality, Bone SPECT

INTRODUCTION

In nuclear medicine, single photon emission tomography (SPECT) is performed to obtain tomographic images. SPECT camera(s) has to rotate around the patient and the pictures of radioactivity distribution inside the patient are taken at different angles. The procedure, called image reconstruction, is done afterward by mathematically putting all the pictures together to obtain SPECT images. Two methods of image reconstruction; analytical and iterative, are commonly used in nuclear medicine. The most popular algorithm of analytical method is filtered backprojection (FBP) which is fast but its streak artifacts is a drawback, especially when a small region of interest contains high activity.[1,2] Iterative

---

[1] Department of Radiological Technology, Faculty of Medical Technology, Mahidol University.

[2] Biomedical Engineering Program, Faculty of Engneering, Mahidol University

[3] The Department of Research and Development, Faculty of medicine Siriraj Hospital, Mahidol University.

image reconstruction has been becoming popular for many reasons. Firstly, image noise is easily modeled and handled, especially low count imaging. Secondly, poor spatial resolution due to depth-dependant blurring can be recovered. Thirdly, the quantitative capability can be improved because of easily incorporating a model of the physical factors influencing the absolute quantitation, such as photon attenuation and scatter in organs. The ordered-subset expectation maximization (OSEM) algorithm is one of the most popular iterative methods because it produces better image quality than that of FBP. It also shortens the reconstruction time compared with other iterative algorithms.[3-5]

In nuclear medicine, bone SPECT imaging is useful because it provides three-dimensional data resulting in improving image contrast and the location of abnormal lesions. Moreover, the accurate sites of abnormalities may help to differentiate between degenerative bone and bone metastases leading the appropriate treatments. The image quality obtained from FBP is mostly poor due to streak artifacts. Therefore, to improve the image quality of bone SPECT is of interest. The aim of this study was to compare the image qualities of bone SPECT images obtained from OSEM and FBP algorithms.

MATERIALS AND METHODS

This study was divided into two parts, the first part was to determine the optimal numbers of subset and iteration of OSEM algorithm. The second one was a pilot study to compare the image qualities between images obtained from OSEM and FBP using a preference study.

Determination of the optimal numbers of subset and iteration of OSEM algorithm

Anthropomorphic Phantom

A Zubal brain phantom[6] was used to mimic a human brain. This phantom allows users to flexibly assign the activities in the brain. In this study we experimented the activities that gave the projection data similar to the patients' data. Then the emission data of the phantom was created as shown in Fig.1.

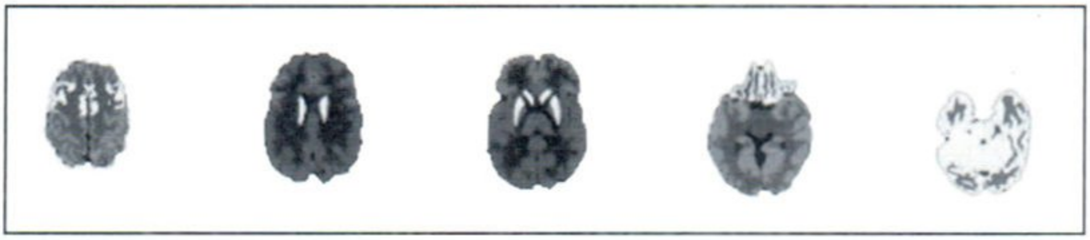


Fig. 1 A Zubal brain phantom (emission data) at different slices.

The 128x128 matrix size with 120 views of projection data of the phantom were generated. Poisson noise and collimator-detector blur (with 5 pixels width of gaussian distribution) were added to projection data for making noisy data similar to clinical studies. Then OSEM image reconstruction was performed with various numbers of subset and iteration. The number of subset ranged from 2 to 30 with the increment of 2 and the number of iteration ranged from 1 to 20 with the increment of 1 were used. No compensations for image degrading factors such as attenuation, detector response, or scatter, were applied. Fig 2 showed the reconstructed images of the brain phantom obtained from OSEM using 6 subsets and different numbers of iteration. The image reconstruction software was developed using Interactive data language (IDL) version 5 on window platform. It consumed less than 3.25 sec/slice for image reconstruction using OSEM.

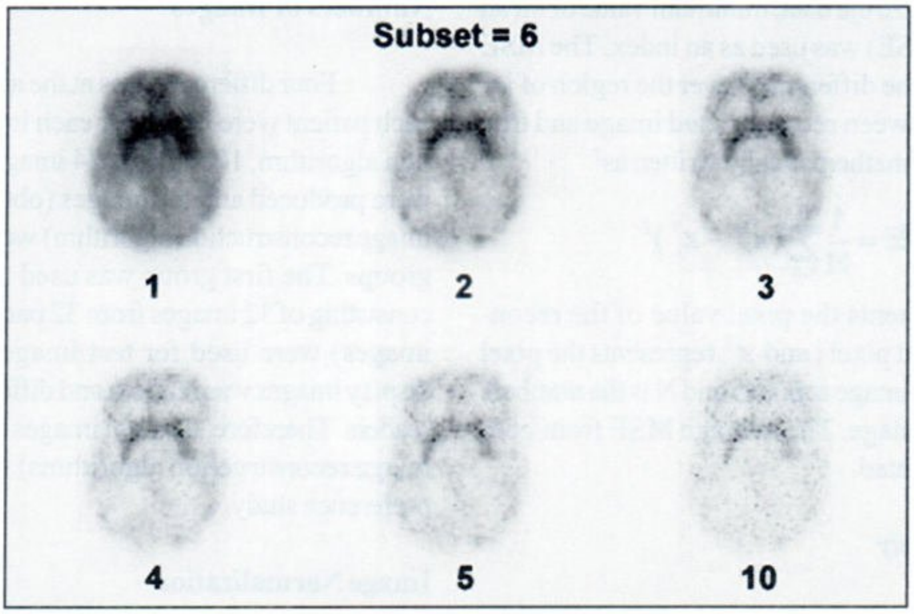


Fig. 2 The reconstructed images of the brain phantom using OSEM algorithm using 6 subsets with different numbers of iteration.

Data Analysis

A reconstructed image of each condition was analyzed. Two 5x5 pixel ROIs were drawn over the image (one for the left and one for the right) as shown in Fig 3. The pixel count within each ROI was recorded and then the average pixel count was calculated. Similarly, the average pixel count of true image was determined.

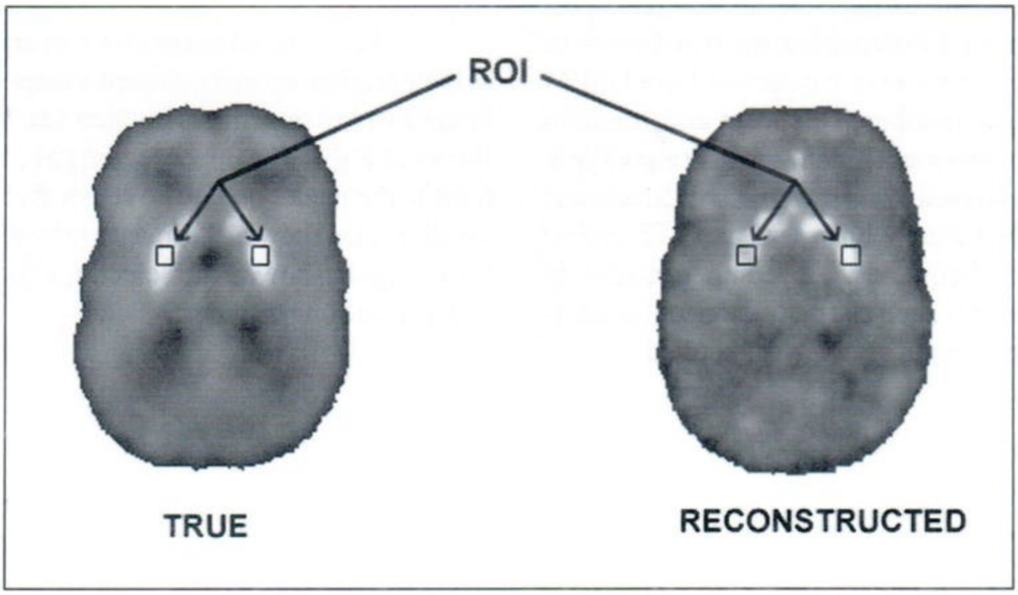


Fig. 3 The ROIs over the OSEM reconstructed and true images.

To analyze the data, minimum value of mean square error (MSE) was used as an index. The MSE was defined as the differences over the region of interest (ROI) between reconstructed image and true image. It can be mathematically written as[7]

$$\mathrm{MSE} = \frac{1}{N}\sum_{i=1}^{N}(x_i^R - x_i^T)^2$$

where x_i^R represents the pixel value of the reconstructed image at pixel i and x_i^T represents the pixel value of the true image at pixel i and N is the numbers of pixel in the image. The average MSE from both sides was calculated.

Preference Study

In this part, a comparison between the image qualities obtained from OSEM and FBP algorithms were conducted. Due to the limitation in recruiting nuclear medicine physician, a preference study was performed instead of an human observer study.

Data Acquisition and Processing

Thirty-two patients with lower back pain and underwent bone SPECT imaging at Division of Nuclear Medicine, Department of Radiology, Faculty of Medicine Siriraj Hospital were retrospectively investigated. For each patient, two datasets of reconstructed images were obtained from OSEM (using optimal numbers of subset and iteration obtained from previous section) and FBP algorithms. All the reconstructed images were post-filtered using 2D Butterworth filter with order 5 and 0.25 cycles/pixel cut-off frequency. No compensations of degrading factors such as attenuation, collimator-detector response and scatter were applied.

Numbers of Images

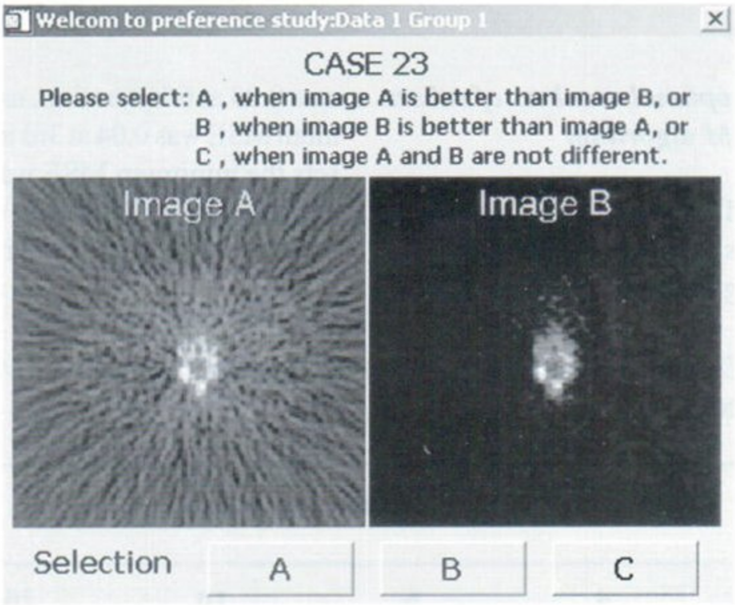
Four different slices at the areas of suspect of each patient were used. For each image reconstruction algorithm, 128 images (4 images x 32 patients) were produced and the images (obtained from each image reconstruction algorithm) were divided into 2 groups. The first group was used for a training set consisting of 32 images from 32 patient. The rest (96 images) were used for test images. The order of display images was random and different for different readers. Therefore, the total images of 256 (from two image reconstruction algorithms) were used in this preference study.

Image Normalization

For maximizing the image contrast on the monitor display using a 256-level grayscale, all reconstructed images were normalized such that the pixel values of the display images ranged from 0 to 255. In normalization scheme, the maximum count in the image was determined and then scaled to 255. Negative values in the image will be normalized to zero.

Image Display

The displayed images were enlarged as twice as their original sizes by bilinear interpolation. The image display screen was divided into 3 regions as shown in Fig 4. The upper region gave the instructions to the reader on how to select the image. The middle region showed the images to be selected. The lower region showed the selections for readers to make by clicking on them.



Welcom to preference study:Data 1 Group 1

CASE 23

Please select: A , when image A is better than image B, or
B , when image B is better than image A, or
C , when image A and B are not different.

Fig. 4 Image display format used in the preference study. The instruction on how to select the image is shown in the upper part, The test images are displayed in the middle and the lower part shows the options to be selected.

Readers

Two readers were participated in this study. They are nuclear medicine physicians and familiar to bone SPECT images for more than 3 years.

Reader's Task

The readers were given full training in the preference study at the beginning to acquaint them. They were asked to carefully read the instruction of the study and were shown a demonstration of how to select the images. The readers were not told the details of the test condition of the images to avoid bias that might affect the results. Due to reader fatigue and time-consuming used for single session in the preference study, the 96 test images were split into 3 blocks and each block consisted of 32 different images (one image from each patient). The order of images was random. The readers were told to take their times and they could have a short break between each block of images. Two images of the same patient with different image reconstruction algorithms were displayed at the same time. The task of a reader was to select the best image quality which gave the best localization of hot lesion. Without streak artifacts was another criterion if both images were not different in localization. There were three options for readers to select. The reader was asked to select one of the three options; "A" represented the superiority of image A to image B and "B" represented the superiority of image B to image A. If the image qualities of both images were not different, the reader was asked to click "C".

Data Analysis

The frequencies of the scores obtained from each reader were determined. Individual preference was also evaluated and the agreement between readers was studied.

RESULTS

Determination of the optimal numbers of subset and iteration of OSEM algorithm

Table 1 showed the average MSEs obtained from different numbers of subset and iteration. The results showed that using 2 subsets the minimum MSE was 0.03 at 6th iteration, using 4 subsets the minimum MSE was 0.04 at 3rd iteration and using 6 subsets the minimum MSE was 0.01 at 2nd iteration. When using 10, 20 and 30 subsets the MSEs were increased as the number of iteration increased.

Table 1. Average MSEs at different numbers of subset and iteration. The minimum MSE of each combination was underlined.

Iteration Number	**Number of Subset**					
	2	**4**	**6**	**10**	**20**	**30**
1	22.90	7.35	2.34	0.25	0.80	0.88
2	7.35	0.80	0.01	0.25	0.95	0.51
3	2.48	0.04	0.20	0.50	1.13	0.51
4	0.78	0.13	0.42	0.61	1.35	0.83
5	0.19	0.32	0.55	0.70	1.55	0.93
6	0.03	0.45	0.62	0.77	1.72	0.99
7	0.05	0.55	0.68	0.85	1.86	1.03
8	0.14	0.62	0.72	0.91	1.96	1.07
9	0.24	0.66	0.77	0.98	2.06	1.10
10	0.33	0.71	0.81	1.04	2.15	1.13
11	0.41	0.75	0.86	1.10	2.23	1.16
12	0.48	0.79	0.89	1.15	2.29	1.20
13	0.53	0.83	0.94	1.19	2.35	1.22
14	0.57	0.86	0.98	1.24	2.38	1.24
15	0.61	0.90	1.03	1.28	2.43	1.27
16	0.64	0.93	1.06	1.31	2.48	1.30
17	0.67	0.97	1.10	1.35	2.51	1.32
18	0.68	1.00	1.14	1.39	2.56	1.34
19	0.71	1.04	1.18	1.41	2.60	1.37
20	0.73	1.07	1.21	1.44	2.63	1.38
21	0.74	1.12	1.16	1.44	2.50	1.60
22	0.77	1.16	1.22	1.48	2.60	1.63
23	0.78	1.19	1.26	1.50	2.69	1.80
24	0.80	1.14	1.30	1.67	2.95	1.85
25	0.82	1.17	1.25	1.71	2.89	1.87
26	0.79	1.21	1.26	1.73	2.96	1.89
27	0.77	1.15	1.35	1.76	3.03	1.92
28	0.78	1.15	1.38	1.79	3.10	1.88
29	0.80	1.19	1.41	1.85	3.03	2.03
30	0.82	1.13	1.44	1.87	3.10	2.53

Preference Study

Table 2 reported the frequencies of the scored from two readers. The results showed that reader 1 preferred image B (OSEM algorithm) to image A (FBP algorithm) with 65.6% (63 of 96 images) and image A to image B with 18.8% (18 of 96 images). There was no difference between image A and B with 15.6% (15 of 96 images). While reader 2 absolutely preferred image B to image A with 100%.

Table 2 Frequencies of scores from a preference study

	Score		
Number of Reader	**Image A better than Image B**	**Image B better than Image A**	**Image A equal to Image B**
1	18 images (18.8%)	63 images (65.6%)	15 images (15.6%)
2	none	96 images (100%)	none

DISCUSSION AND CONCLUSION

In this study, we found that using Zubal brain phantom the numbers of subset and iteration that gave small MSEs were 2 subsets with 6 iterations (0.03), 4 subsets with 3 iterations (0.04) and 6 subsets with 2 iteartions (0.01). Those three MSEs from three combination sets were quite similar and actually the numbers of image updates were the same (12 updates). Then we studied the computational time for each set and we found that 2 subsets with 6 iterations consumed 1.42 sec/slice, 4 subsets with 3 iterations consumed 0.73 sec/slice and 6 subsets with 2 iterations consumed 0.503 sec/slice. Therefore, the combination of 6 subsets and 2 iterations was optimal because it gave minimal MSE and less computational time. Although this number obtained from a Zubal brain phantom but it could be used as a guideline for any SPECT imaging. We implemented this number for bone SPECT imaging to compare the image qualities between OSEM and FBP algorithms. And we found that there were differences between two readers. Reader 1 undoubtedly preferred OSEM with 65.6%; however for large hot lesions these two algorithms provided similar information (with 15.6%). The performances of these two algorithms were not different with 18.8% because the reader was doubted with the image quality of OSEM even though it was superior. That means the numbers of training images are not sufficient for readers to get familiar to OSEM images. For reader 2 there was no doubted that the image quality obtained from OSEM was superior to that from FBP. Therefore, the agreement between these two readers was 65.6%. Although this study cannot recruit as many physicians as it should be, the numbers of test images are sufficient to conduct the study. However, more patient data and more readers will minimize the error and make a reliable result. Moreover, this study agrees with the superiority of OSEM to FBP algorithms and shows the optimal parameters of OSEM algorithm to be used.

In conclusion, the optimal numbers of subset and iteration of OSEM are 6 and 2 respectively. The image quality obtained from OSEM is superior to that from FBP in hot lesion localization and without streak artifacts.

ACKNOWLEDGEMENTS

The author would like to thank the Faculty of Medical Technology for supporting IDL software and the Division of Nuclear Medicine, Department of Radiology, Faculty of Medicine Siriraj Hospital for patients' data. The author also would like to thank generous readers for their co-operations and the Medical Imaging Research Group (MIRL) at the University of North Carolina, USA for the softwares.

REFERENCES

1. Philippe P. Bruyant, Jacques Sau, and Jean-Jacques Mallet. Streak Artifact Reduction in FilteredBackprojection Using a Level Line-Based Interpolation Method. J Nucl Med 2000; 41:1913-1919
2. Didier Blocklet, Alain Seret, Niculaie Popa and Andre? Schoutens. Maximum-Likelihood Reconstruction with Ordered Subsets in Bone SPECT. J Nucl Med 1999; 40:1978-1984
3. Hudson HM, Larkin RS. Accelerated image reconstruction using ordered subsets of projection data. I-EEE Trans Med Imaging. 1994; 13:601-609.
4. G.L. Zeng. Image reconstruction-a tutorial. Computerized Medical Imaging and Graphics 25 (2001) 97-103.
5 David S. Lalush and Benjamin M. W. Tsui. Performance of Ordered-Subset Reconstruction Algorithms Under Conditions of Extreme Attenuation and Truncation in Myocardial SPECT. J Nucl Med 2000; 41:737-744
6. http://noodle.med.yale.edu
7. Cliff X. Wang, Wesley E. Snyder, Griff Bilbro, Pete Santago. Performance evaluation of filtered backprojection reconstruction and iterative reconstruction methods for PET images. Computer in Biology and Medicine 1998 ;28: 13-25.