Assessment of OSEM & FBP Reconstruction Techniques in Single Photon Emission Computed Tomography Using SPECT Phantom as Applied on Bone Scintigraphy

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Abstract :

Filtered back projection (FBP) method and maximum likelihood expection maximization (OSEM) method are currently used for reconstruction of SPECT images in clinical studies. The aim of this work is to compare the image quality using different reconstruction techniques of a SPECT phantom as applied to bone scintigraphy. The resolution and contrast of the hot spheres were observed using a phantom insert with OSEM and FBP techniques. The activity profile, drown through the hot spheres demonstrates that the FBP image is often blurred and more noisy than the image which reconstructed iteratively using OSEM. This means that there is an improvement in resolution of the image with OSEM reconstruction technique. There is a decreasing in counts of reconstructed slices by FBP technique and increase in counts of the same reconstructed slices by OSEM technique. This shows an improvement in image quality and increased accuracy of the OSEM, technique to its algorithm accuracy. Thus OSEM can replace the FBP technique for its merits.

Key words:

SPECT, OSEM, FBP, Scintigraphy image reconstruction

Introduction :

The distribution of radioactivity in an object can be imaged using single photon emission computed tomography (SPECT). In this method, a gamma camera rotates around the object acquiring projection images. The technique, in which radioactivity profiles of the projection images are transformed into transversal slices, is called reconstruction. During the history of the reconstruction method development, several techniques for radionuclide image reconstruction have been investigated. Analytical reconstruction algorithms are one of the oldest methods and they can be classified into Fourier reconstruction and filtered back projection (FBP) method. The FBP has been successfully implemented in commercial systems and it is the most commonly used analytical algorithm in clinical use since 1970s (Rusinek 1976). In the FBP, the algorithm can be broken down into different steps. First one dimensional Fourier transforms is taken of each projection (for each projection bin) and the data are multiplied by frequency filter. Finally, the inverse Fourier transformed and filtered data are back-projected to form the image. The method contains two main operations, filtering and backprojection. There are also iterative reconstruction methods are available for reconstruction. Iterative solutions depend on iterations trying to yield successively better approximations. Iteration is a repeated calculation process in which the algorithm calculates all the projection data several times during the process. Calculations are repeated and hence the following iteration is always slightly better than previous one. The iteration continues until errors reach a prescribed limit.

A maximum likelihood (ML) approach to emission image reconstruction from projections was introduced by Rockmore and Macovski (Rockmore and Macovski 1976). This approach is an estimation of the measured radiation profiles trying to find the best result (likelihood) for the observed projection data. In the iterative calculation, it is possible to use expectation maximization (EM) algorithm on projection and backprojection calculation. The EM algorithm is an iterative technique for trying to find the maximum likelihood estimate. The ML-EM technique was found independently by Shepp and(Vardi 1982 and Lang and Carson 1984).

The *ML-EM* algorithm according to the formulation for SPECT gives

$$\lambda_j^{n+1} = \frac{\lambda_j^n}{\sum_i c_{ij}} \sum_i c_{ij} \frac{y_i}{\sum_R c_{ij} \lambda_R^n}$$

Where y_i : is the required set of projection, the estimate of the source λ_j^n activity map after nth iteration and cij the probability that a photon emitted by source element located in j will be detected at location i of the projection. The projection c_{ij} must include the photon attenuation and scattering in the patient body and the camera response function (Lange K, Carson R 1984 and Walrand SH, Van Elmbt LR, and Pauwels S 1996)**.**The **ML**-EM algorithm has proved to be effective, but unfortunately also a slow reconstruction in SPECT**.** Several methods have been proposed to accelerate the speed of the ML-EM algorithm (Byrne CL 1998 and Walrand SH, Van Elmbt LR, and Pauwels S 1996)). These were based on different accelerating algorithms, but without any one gaining wide spread clinical acceptance. One of the most widely used accelerating techniques in SPECT imaging is the order subset (OS) algorithm. It was introduced by Hudson and Larkin in 1994 and was added into the expection maximization algorithm so called ordered subsets expection maximization (OSEM) algorithm, has become a widely used reconstruction method in SPECT (Hudson HM, Larkin RS 1994 and Tomas G.G. et al. 2006).

In ML-EM, each iteration involves the estimation of all projections, whereas in OSEM the projection data are divided or grouped into ordered subsets, where each subset contains a set of regularly spaced projections. Thus each subset contains an equal number of projections. Thus each subset contains an equal number of projections. The conventional ML – EM algorithm reconstruction goes forward subset by subset. That is why the OSEM calculation accelerates reconstruction. The subset number is the speed-up factor and it is required that subsets are in the balance. The sum of counts in projections forming the subsets is equal for all subsets. The number of projections must be divisible exactly by the number of subsets. If only one of the subsets is selected, the situation is equivalent to the conventional ML – EM algorithm and in this case all the projections of the projection data will be calculated. Thus ML-ME is a special case of OSEM when the number of subsets is one (Dey D 1989 and Hudson HM, Larkin RS 1994). The aim of this work is to compare between the effects of different reconstruction techniques (FBP and OSEM) on the image quality using SPECT phantom and applied with bone scintigraphy.

Materiala and Methods :

The contrast and resolution measurements were performed using the SPECT phantom. .The phantom is an acrylic water tank was filled with uniform radioactive water. The diameter is 215mm and the tank is 300 mm long. The phantom tank consists of two different inserts. The first insert measures resolution simulating non-active "cold" lesions. The insert contains seven plastic rods, the diameters of which are 22.4, 17.9, 14.3, 11.4, 9.2, 7.3, and 5.9 mm. The other insert uses active “hot" lesions, containing nine pairs of holes, the diameters of which are 38.1, 22.4, 17.9, 14.3, 11.4, 9.2, 7.3, 5.9, and 4.7mm. The inserts of the phantom were placed into the water tank cylinder. The image acquisitions were carried out with Sopha DST-XLi double head gamma camera using ultra high resolution collimators. The number of PMTs was 98 per detector. SPECT acquisitions were performed using 180° orbit for each detector. A symmetrical 20 % wide energy window for the acquisition was centered. SPECT imaging was carried out with the matrix 128 x 128 matrix size at the rate of 20s per projection.

Discussion :

The major advantage of iterative over analytical algorithms is to accurately model emission and detection process. Furthermore, iterative algorithms allow statistical noise models to be included. Also, provided that some kind of regularization is used, images obtained with iterative algorithms are more acceptable. On the other hand, filter back-projection *(FBF)* as a linear algorithm produces images which are nearly spatially invariant and object independent resolution (Tomas, G.G. et al. 2006). Pure *OS-EM* produces images, which posse's unacceptable noise properties as the iteration number increases.

The resolution of the active rods was measured using a phantom insert where the hot lesions are in the non –active medium. We can show that the constant of active rods decreases when the diameter of the rods approaches zero. Iterative reconstruction techniques separate small lesions from each other better than the FBP method (Fig1). Activities profiles drown through the eight active rods demonstrate the separation of the small lesion. The first six rods are well seen when using iterative reconstruction methods, but FBP can not separate the fifth and six rods from each other. Rods seven and eight are scarcely appreciable, because their diameter is too small (5.9 and 4.7mm) for adequate separation. Also the edge artifact of the phantom tank is greater in the image reconstructed by the FBP algorithm(Gremillion T. and Hu D, 2008). Activity profile drown through the hot spheres demonstrate that the *FBP* image is often blurred also more noisy than image which are reconstructed iteratively *(OSEM*), this means that there is an improved in resolution in the image with *OSEM* reconstruction technique (Fig. 2). There is a decreasing in counts of reconstructed slices by *FBP* technique and increasing in counts of the same reconstructed slices by *OSEM* technique, this means that there is an improvement in image quality and quantitative accuracy with *OSEM* technique (Table 1). Therefore *OSEM* can displace the *FBP* technique.

Fig (1) : Transaxial image reconstruction of a cylindrical phantom filled with Tc-99m with different reconstruction technique, iterative reconstruction Technique (OSEM) and filtered back projection technique.

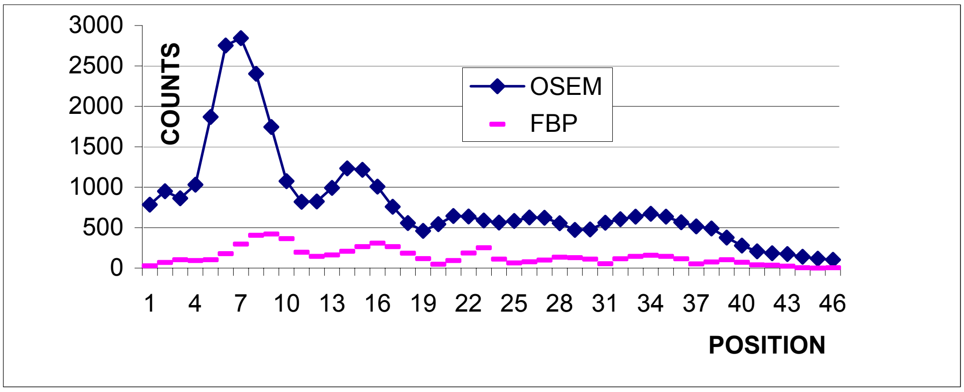

Fig (2) : Shows the counts profile with respect to position for different reconstruction technique.

Table (1)

Variation of slice counts with respect to different reconstruction techniques

Slice number	FBP technique			OSEM technique		
	Mean counts	**Max counts**	**Pixel position**	**Mean counts**	**Max counts**	**Pixel position**
1	85.48	1265	30 , 13	1129.7	14890	42 , 22
2	103.88	1633	36 , 19	11 61.85	16000	29 , 13
3	106.33	1470	36 , 16	1153.24	15628	31 , 13
4	105.78	1541	33 , 18	1110.18	15642	24 , 18
5	101.67	1390	34 , 16	936.74	13555	23 , 20
6	86.09	1330	31 , 17	731.35	10972	31 , 13
7	66.46	1067	25 , 18	569.10	8385	24 , 17

The *OSEM* method is promising for practical use. *OSEM* offers the benefits of *EM* without the computation burden that may hinder processing speed. An order reduction in computations will assist in making real time processing of *SPECT* data available with current technology. *OSEM* is also suitable for arbitrary sequence of projections, in case patient movement during the data acquisition. *OSEM* is applicable in *SPECT* where it provides an order-of- magnitude acceleration over FBP with suitable restoration quality.

The diagnostic accuracy of *SPECT* imaging depends on used reconstruction technique. Transverse slices with metastatic lesion detected in the right pedicle of the vertebrae with different reconstruction technique *(OSEM & FBP*) (Fig.3). From this figure we can see that the resolution with adequate contrast is improved with OSEM more than FBP reconstruction technique. This is clarified from the ability to distinguish between different ribs around the vertebrae, ability to distinguish between the body of the vertebrae and it's right pedicle which mean that more accurate localization of the tumor with *OSEM* reconstruction technique. Also results show that there is an increase in the noise of the center image with *FBP* technique which results in less accurate quantitative localization of the tumor in the *FBP* technique. It is possible to conclude that *OSEM* improve resolution, and gives good lesion detection and accurate quantization as also indicated by Boelloard R (2001)..

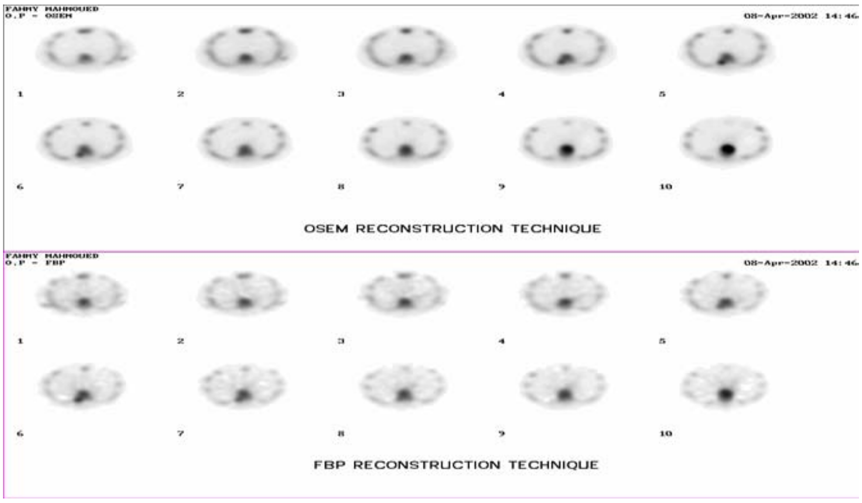

Fig. (3) : The transverse slices with metastatic lesion detected in the right pedicle of the vertebrae with different reconstruction technique (OSEM and FBP)

Conclusion :

The results obtained revealed that the total count with OSEM reconstruction is higher than that obtained in case of FBP which lead to improve the scintigarphic image quality in addition to good resolution due to the OSEM high algorithm accuracy. This parameters will enable the physicist to discover abnormality and interpret the scintigraphic image accurately

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التصوير بالإسقاط الخلفي المصفي (FBP) والتصوير بنظام أقصي احتمالية (ML) والتي هي جزء من منظومة النظام التصويري (OSEM) باستخدام الفوتون أحادي الانبعاث وتطبيقاته علي تصوير العظام

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الملخص :

يستخدم في عملية التصوير حاليا التصوير بالإسقاط الخلفي المصفي (FBP) والتصوير بنظام أقصي احتمالية (ML) والتي هي جزء من منظومة النظام التصويري (OSEM) المعروف وذلك لبناء الصور في الدراسات الاكلينكية . ويهدف البحث الحالي الي مقارنة جودة الصورة وذلك باستخدام النظامين السابقين وتطبيق ذلك علي شبح عظمي من اجل تصوير العظام وقد أمكن ملاحظة التباين في قوة التفريق الخاصة للسطوح الكروية الساخنة داخل الشبح لكل من النظامين. وقد أوضح منحني توزيع النشاط الإشعاعي المرسوم خلال هذه الأسطح الكروية الدائرية أن الصورة الناتجة عن FBP غير واضحة المعالم وبها الكثير من التشويش إذا ما قورنت بالصورة الناتجة عن OSEM . وهذا يعني أن هنالك تحسنا في قوة التفريق باستخدام نظام OSEM إضافة الي ذلك لوحظ نقص في العد بالنسبة للشرائح التي أعيد بناؤها بنظام OSEM وهذا يبين أنه قد حدث تحسن في جودة الصور والدقة النوعية وكل ذلك يؤكد أن نظام OSEM يمكنه أن يحل محل نظام FBP لما له من مميزات أثبتها البحث.