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Single Layer Acquisition Method (SLAM) as a new approach to nuclear medicine tomography

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Abstract: **Nuclear medicine imaging is an effective and valuable tool in the early diagnosis, treatment, and prevention of numerous medical conditions. It is believed that a new approach called Single Layer Acquisition Method, SLAM, can simultaneously detect the emitted photons of gamma emitter radioisotopes, such as 99Tc, from different projections around the patient and therefore, similar to PET; it would be useful for study of biological activity of the tissues. In this method there is no need to cyclotron and its high expenses, and absorbed dose of the patient would reduce a lot due to no positron ionization and also reduction of the time of scans.**

Material and Methods: In this paper a new SLAM configuration system, using 16 radial collimators, each of them having 128 holes of 50mm long, 0.8mm diameter and 0.15mm septa was introduced. Count efficiency and spatial resolution of the system at the center of gantry were simulated by Gate software, using MLEM reconstructed JASAC phantom images filed with 150MBq 99mTc.

Results and Conclusions: SLAM configuration with 16 radial collimators in a gantry of 61.3 cm diameter can be arranged for nuclear medicine tomography. The MLEM reconstructed images quality appreciates that it could be useful for clinical use.

Index terms - SPECT, nuclear medicine tomography, SLAM.

I. INTRODUCTION

Nuclear medicine imaging (also called radionuclide scanning) is an effective diagnostic tool. It shows not only the anatomy of an organ or body part, but the function of the organ as well. This additional "functional information" allows nuclear medicine to diagnose certain diseases and various medical conditions much sooner than other medical imaging examinations which provide mainly structural information about an organ or body part. Nuclear medicine can also be valuable in the early diagnosis, treatment, and prevention of numerous medical conditions and continues to grow as a powerful medical tool.

Great improvement in nuclear medicine imaging were happened by omitting mechanical movement; first on rectilinear scanner and introducing gamma camera and secondly by mechanical movement of gamma camera around the patient on SPECT and introducing PET for functional imaging.

It is believed that mechanical movement of gamma camera in SPECT can be omitted with a new approach called Single Layer Acquisition Method. In the SLAM, emitted photons of gamma emitter radioisotopes, such as ^{99}Tc, are detected simultaneously from all different projections around the patient and therefore, reduce the time of scan, hence similar to PET; it would be useful for functional study of biological activity of tissues.

Also PET has several advantages relative to SPECT [1], but there are few limitations that could be removed by the new purposed approach. In this method there is no need to cyclotron and high expenses [2] of the positron emitting radionuclide. Imaging with gamma emitter radioisotopes, such as ^{99}Tc, will perform with detection efficiency and spatial resolution of SPECT and time orders of PET scans. Absorbed dose of the patient will also be reduces due to no positron ionizations of the positron emitting radionuclide [3,4].

I. MATERIALS AND METHODS:

In this paper a new algorithm for data acquisition from ^{99m}Tc radionuclide tracer, is simulated with Gate software, to be used on 2D tomographic functional image. Acquired data has been transferred to MathLab software for image reconstructions by MLEM technique as described by Naji 2008[5].

The system composed of several collimators which are positioned on a gantry around the patient. Number of collimators in the gantry depends on the collimator holes diameter, septa thickness and number of detectors on each projections, which can vary from 64 to 128. The holes in the collimators can be arranged in parallel (linear collimator) or divergent (radial collimator) to increase the imaging field of view. In radial collimator the diverging angle of the holes are such that, emission photons from 32 x 32 cm FOV at the center of gantry can pass through holes and detect by CZT semiconductor detectors, positioned at the end of each hole.

High energy resolution of the semiconductor detectors causes to detect only primary photons passing through the holes and reject the scattered photons from phantom media and collimators. The scattered photons seems to be decreased by 33% as compared to data acquired using NaI(Tl) scintillators under the same condition [6].

Schematic diagram of systems composed of 9 linear and radial collimators arranged around a cylindrical gantry are shown on fig.1.

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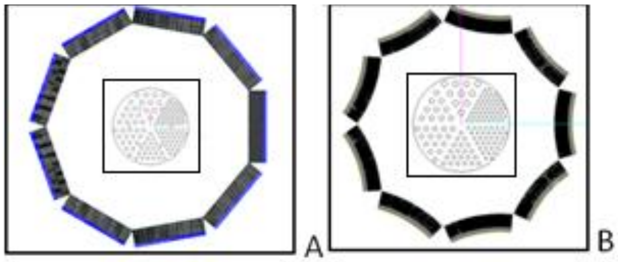

Fig1: Arrangement of 9, A: linear and B: radial collimators in a cylindrical gantry

Emission photons from 32x32 cm field of view at the center of a gantry with 88 cm diameter can be detected through 9 linear collimators, each of them have 128 parallel holes of 2 mm diameter and 0.5mm septa. In this configuration the acquired data bin is 128 x 9=1152 which is not adequate for reconstruction of an image with 128 x 128 pixels. To increase the data bin via increasing number of projections (collimators) with about the same gantry diameter and image FOV, the radial collimator with narrower holes and septal thickness can be used. Fig 2 shows the relation of holes diameter plus septal thickness with the number of collimators (each with 128 holes) using 32×32 cm FOV at the center of gantries with radius shown on the histograms. The gantry diameter would also reduce with narrower holes or septal thickness.

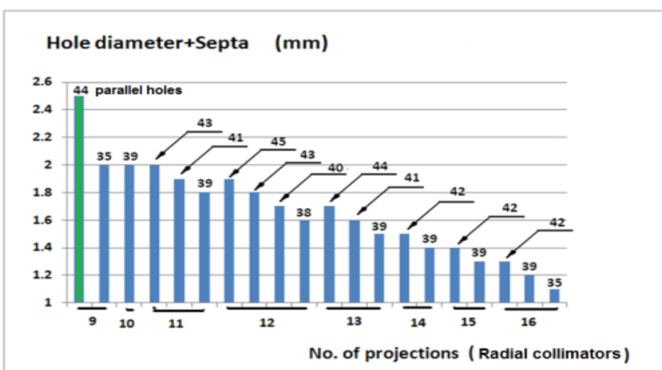

Fig. 2: Holes diameter plus septal thickness vs. No. of radial 128 holes collimator in a gantry with radius shown on the histograms.

In MLEM reconstruction algorithm, increasing number of data bin will maximize the expectation value of the image pixels faster and more accurate [7]; therefore it is preferred to use a larger number of collimators and holes in the gantry.

In parallel holes collimators for a defined FOV, increasing number of collimators would increase gantry diameter. But in radial collimator it is not the case and for a defined FOV and gantry diameter it is possible to increase the number of collimator and holes. Therefore, the SLAM system was simulated for 32×32 cm^2 FOV at the center of a gantry with 16 radial collimators and 62.3cm diameter. The collimators have 128 holes of 50 mm long, 0.8 mm diameter, and 0.15 mm septal thickness. This arrangement provides adequate data from emitting photons to reconstruct an image with 7.5 mm spatial resolution which seem reasonable for clinical use

II. RESULTS AND DISCUSSIONS:

To show the Performance of the SLAM technique on reconstructed image quality, a standard JASAC phantom with 21.6 cm diameter was simulated at the center of gantry and filled with 10MBq radioactive $^{99}Tc^{m}$. Emitting photons were measured via simulating few systems specifications such as different number of 128 holes radial collimators and gantry diameter as shown on table 1. In the Gate simulation program the photons were restricted to be emitted only on a tomographic plane.

Image resolution and count efficiency of photons (kc/MBq) were measured and shown on table 1. Spatial resolution of the system at the center of gantry wear measured using 5 mm diameter cylindrical rod filled with 3MBq of ^{99m}Tc. The geometrical resolution of its collimator at that point were also calculated from $R_g=d(1+Z/L_s)$ where d and Z are hole diameter and gantry radius, $L_s=L-2/\mu$ is the actual hole length L reduced by the effect of septal penetration of the collimator material with linear attenuation coefficient of μ, as described by Sander et al [8] for circular holes collimator.

Table1; SLAM system specifications for 32×32cm FOV and its image performance

No. of projections (collimators)	Collimator Hole Specification Len._Dia._ Sep. (mm)	Gantry diameter (cm)	FWHM of image at center (mm)		Count efficiency kC/MBq
			collimator	measured	
10	50 _ 0.8 _ 0.4	49.7	4.8	5.0	7.54
12	50 _ 0.8 _ 0.3	54.4	5.2	5.5	8.47
14	50 _ 0.8 _ 0.2	57.5	5.4	6.25	9.80
16	50 _ 0.8 _ 0.15	62.3	5.8	7.5	11.25

Reconstructed 128×128 pixels images of JASAC phantom with 12 iteration on MLEM algorithm from acquired data of 10 and 150MBq ^{99m}Tc with such configuration are shown of fig.2

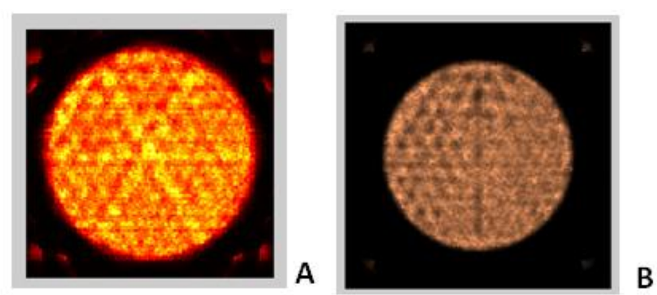

Fig.2 Reconstructed JASAC phantom images by MLEM algorithm with; A: 10MBq and B: 150MBq ^{99m}Tc

Although using 16 or more detectors will deteriorate the spatial resolution of the image; but this will increase the photon count efficiency and hence; improve signal to noise ratio and better precision of the pixels value.

The measured spatial resolution of a point source positioned at the center of gantry, shown as measured FWHM on table 1, appreciate that it could be useful for clinical use. It varies from

5 to 7.5 mm for 10 to 16 collimators. Image with 10 collimators have better spatial resolution but poor count efficiency and therefore low value of pixels. It was also reconstructed with less data bin which may not maximize the expectation value of the image pixels. Therefore, these situation leads to decrease signal to noise ratio of the images.

Figure 2 appreciate the image quality of the phantom acquired from 16 collimators, especially with high counts for clinical use. As the SLAM technique will reduces a lot on the time of scans, the high counts scans will be achievable even with low injected radioactivity.

Contrast of the images can also be improved up to 7% using contrast recovery via introducing collimator detector response on MLEM image reconstructions algorithm [9].

III. CONCLUSIONS:

SLAM configuration for nuclear imaging purpose can be arranged with 16 radial collimators in a gantry of 61.3 cm diameter. Spatial resolution of 7.5 mm can be achieved using 128 holes collimators, 50mm long, 0.8 mm diameter and 0.15 mm septal thickness. This configuration with data bin of 2048 and count efficiency of 11kc/MBq in the plane of tomography appreciate that it could be useful for clinical use.

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