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Comparison of Circular vs Non-Circular Orbit Data Acquistion using Single Head Single Photon Emission Computed Tomography(SPECT)

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= 국문초록 =

단일검출기 단일광자방출 전산화단층촬영술에서 원형(Circular)**과 비원형**(Non-circular) **회전방식 자료획득**(Data Acquisition)**의 비교**

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단일광자방출전산화 단층촬영술을 이용한 영상정보를 효과적으로 얻기위하여 고려되어야 할 사항으로는 1) 조준기(collimator)의 선택, 2) 기질(matrix)의 크기, 3) 회전각의 수(number of angles), 4) 360도 또는 180도 획득(acquisition), 5) continuous 또는 step& shoot, 6) 원형 또는 비원형회전 등이 있다. 저자들은 비원형회전으로 검체와 검출기 사이의 거리를 단축시킴으로써 직선성, 균일성, 대조도, 해상력에 미치는 영향을 알아보기 위하여 원형회전 방법과 비교하여 다음과 같은 결과를 얻었다.

(1) 비원형회전을 하여도 균일성(uniformity)과 직선성(linearlity)을 유지한다.

(2) 균일성, 대조도(contrast), 해상력(resolution)들이 비원형 회전을 한 경우에 보다 더 개선되었다.

(3) 영상 획득시간은 비원형회전인 경우에 더 소요되었다.(매스캔 당 10분)

따라서 검사자는 영상 화질의 개선효과와 상반되는 보정(calibration)과 설치(set-up)에 소요되는 시간(매스캔당 10분이상)을 비교하여 자료획득(data acquisition) 회전방법을 선택하여야한다.

Key Words: Jaszczak phantom, Circular orbit, Non-circular orbit

INTRODUCTION

The objective of this study is to evaluate the non-circular orbit(NCO) SPECT acquisition module on the Siemens Diacam single head camera and to compare it to the standard circular orbit (CO) acquisition package. We wish to determine whether the closer orbit of the NCO study yields improvements in image contrast and resolution sufficient to justify the increased set-up time and complexity of camera calibration.

MATERIALS AND METHODS

A Jaszczak SPECT phantom (Fig. 1) containing 500 MBq of ^{99m}Tc was employed to assess the linearity and uniformity characteristics of the NCO reconstruction algorithm and to compare CO and NCO image quality.

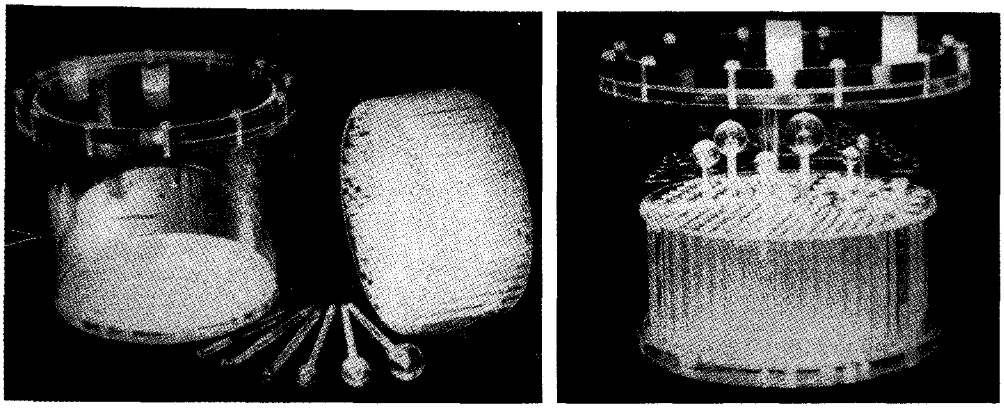

Fig. 1. Jaszczack phantom a) components. b) fully assembled.

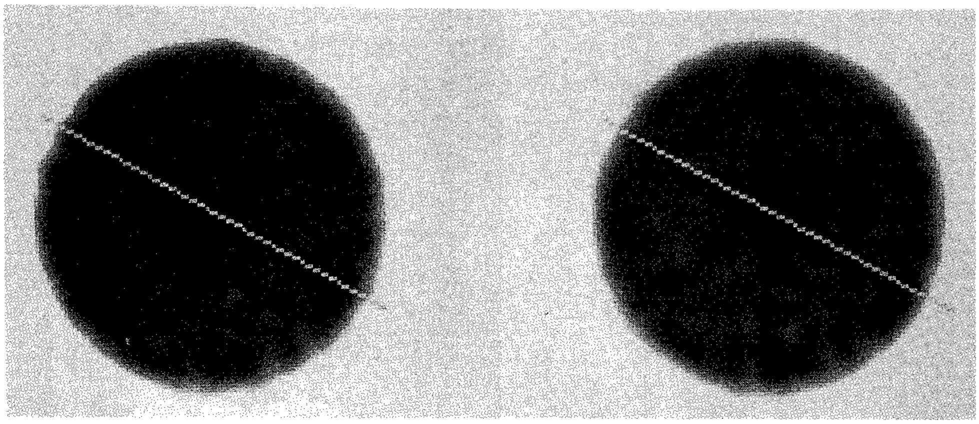

Fig. 2. Assessment of linearity on a) CO slice. b) NCO slice.

Table 1. Average Frame Counts for each Acquisition

Acquisition Type	64×64	128×128
CO	304,344	346,730
NCO	284,158	325,029

The camera used was a Siemens 'Diacam' with a 533×387*mm* rectangular field of view. This camera's intrinsic spatial and energy resolutions were 4.7mm FWHM and 11.0% FWHM respectively.

Four studies were acquired in all, two using the NCO module and two collected using standard CO acquisition (see Table 1)with a low energy high resolution parallel hole collimator. For both types of acquisition (CO and NCO) 64 views were taken over a full 360°. The scan time per view was 25 seconds and a software zoom of 1.5 was employed. Average frame counts for each acquisition is tabulated below. Frame counts decrease from their maximum as the activity in the phantom decays. The order of acquisition was determined by the expected noise properties of the projections(ie the 128×128 CO

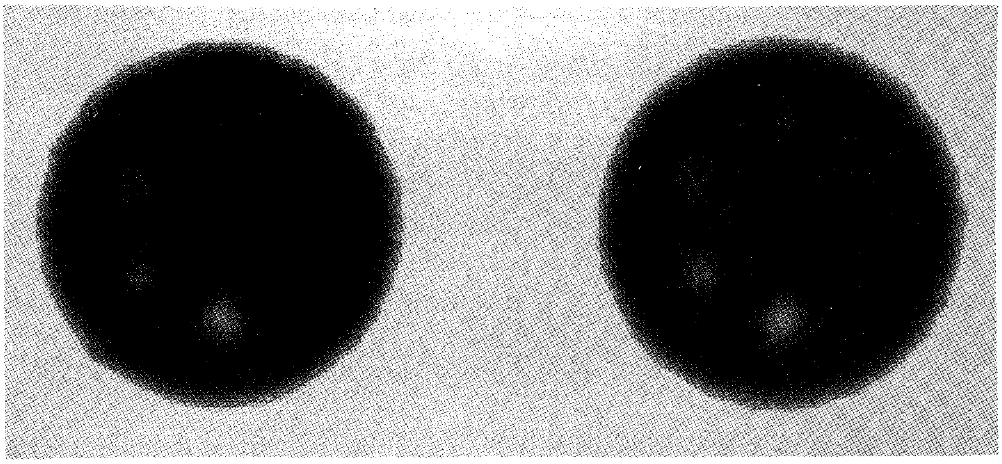

Fig. 3. Contrast region of jaszczak phantom. a) Circular orbit, transverse section. b) NCO, transverse section.

Table 2. Reconstruction Filter Characterisitcs for NCO and CO Acquisitions

Matrix size	Cut-off	Order
64×64	0.6	4
128×128	0.25	4

Table 3. Uniformity Data

		64×64	128×128
CO	min	720	721
	max	1000	1000
	mean	841	882
	variance	1762	2350
	coef. var	5.0%	5.5%
	contrast	16%	16%
NCO	min	760	767
	max	985	991
	mean	893	867
	variance	2068	1688
	coef. var.	5.0%	4.7%
	contrast	12%	13%

Table 4. Contrast Data for 38.1mm Sphere

		64×64	128×128
CO	min	299	202
	max	871	835
	contrast	49%	61%
NCO	min	207	177
	max	836	907
	contrast	60%	67%

Table 5. Contrast Data for 31.8mm Sphere

		64×64	128×128
CO	min	409	361
	max	963	879
	contrast	40%	42%
NCO	min	408	330
	max	932	958
	contrast	39%	49%

was expected to be most noisy, the 64×64 NCO was expected to be least noisy).

The diameter of the circular orbit was 50cm and the NCO orbit was set up with a major axis of 50cm and a minor axis of 30cm. The NCO module on the Siemens sytem requires a pixel size calibration.

Separate calibrations are required for each combination of collimator and zoom factor employed and each calibration takes 5 minutes to

Table 6. Contrast Data for 25.4mm Sphere

		64×64	128×128
CO	min	561	544
	max	945	930
	contrast	25%	27%
NCO	min	609	540
	max	945	930
	contrast	22%	27%

Table 7. Contrast Data for 19.1mm Sphere

		64×64	128×128
CO	min		605
	max		898
	contrast		19%
NCO	min		571
	max		995
	contrast		27%

complete. In addition, NCO acquisition on the Diacam requires that an orbit be established manually–this process takes between 5 and 10 minutes to complete.

Studies were reconstructed with a Butterworth filter and a single iteration of Chang's method[1] was used(with manually defined contours) to correct the studies for attenuation. The reconstruction filter parameters used are tabulated below:

The transverse sections from the reconstruction were grouped(3 images to a group) prior to assessment to reduce the effects of random noise.

The linearity of the reconstructed studies was assessed visually by comparing rows of cold rods in the phantom images with user defined line ROIs.

Uniformity was measured quantitatively by drawing circular ROIs on the uniform flood area of the phantom images. A coefficient of variation was computed across each region by dividing the standard deviation of pixel counts by the

Table 8. Resolution Data: Number of Visualised Cold Spheres

	64×64	128×128
CO	4	5
NCO	5	5

Table 9. Resolution Data: Number of Visualised Cold Rod Segments

	64×64	128×128
CO	2	1
NCO	2	3

mean pixel count. A measure of contrast was also determined according to the usual formula:

Contrast = (max–min) ÷ (max + min) × 100%

Where max is maximum pixel counts in the ROI and min is minimum pixel counts in the ROI. Contrast of cold spheres was determined using the same formula, applied to ROIs drawn to surroud the spheres. Resolution was assessed by determining the number of spheres and rod segments in the phantom that could be visualised in transverse section.

RESULTS

1) Linearity

Visual inspection of the cold rod alignment, using a straight line ROI as a guide, revealed no obvious distortion of the image in either CO or NCO studies(see Fig. 2).

2) Uniformity

For quantitative measurement of uniformity, a region of interest was drawn on a transverse slice through the CO image of the uniform flood portion of the Jaszczak phantom. This region was then copied directly to a corresponding slice through the NCO image. Minimum, maximum and mean pixel counts within the region were extracted, as was the variance of pixel counts. Coefficient of variation and contrast were computed. The results appear in Table 3.

From this data, there appears to be a small improvement in uniformity in the case of NCO acquisition.

3) Contrast

Regions of interest were drawn around each of the four visible spheres on one transverse slice through the CO image of the Jaszczak phantom (Fig. 3).

These regions were then copied to a corresponding slice on the NCO dataset. Minimum and maximum pixel counts within the regions were extracted and a contrast value computed for each region. The results are shown in Table 4, 5, 6, 7.

The NCO image slice through the 38.1 mm sphere(Table 4) demonstrates improved contrast for cold features with respect to the corresponding CO image slice. The difference is more marked on 64×64 images.

For the 31.8mm sphere(Table 5), contrast is improved with NCO acquisition for the 128×128 matrix but no improvement is seen for the 64×64 acquisition.

In Table 6(25.4mm sphere), it is seen that no contrast gains are obtained from NCO and there is a suggestion that contrast may actually be reduced for 64×64 matrix acquisition.

In Table 7, improved contrast is observed in the 128×128 NCO acquisition. The 19.1mm sphere is not visible in either 64×64 image set.

The contrast data indicates that whilst there are some improvements with NCO for large objects(~3cm)there is no substantial difference for objects of smaller size.

4) Resolution

The resolution of images was determined by visual inspection. For each study, the smallest resolvable spheres and rod sections were recorded(Table 8, 9).

It was observed that the spheres are more clearly defined in the 128×128 images.

From this data, it is clear that there is a slight improvement in resolution with the NCO acquisition.

Clinical Opinion

Finally, CO and NCO transverse slices were assessed visually by an experienced, unbiased 2 clinical observers. Slices through the rod area and sphere area of the phantom images were compared. According to the clinician, NCO provided better images of the sphere area, whilst CO produced better images of the rod area.

DISCUSSION

There are a number of practical considerations when acquiring SPECT data, such as collimator selection[2], matrix size, number of angles, 360° or 180° acquisition[3], continuous or step & shoot acquisition, circular or non-circular orbit acquisition[4].

The source-collimator distance is typically greater in SPECT than in planar imaging, causing a 'drop-off' in resolutuon. This 'drop-off' of resolution with depth is less for collimators with longer septa. The tradeoff between resolution and sensitivity is more complicated in SPECT. In general, a high resolution collimator is preferable to a LEAP collimator for SPECT[2].

Shannon's sampling theory[5] states that you must have at least 2 samples(pixel) per resolution element to faithfully reproduce the spatial frequencies in the image object. Note that improved sampling can also be achieved when imaging small objects by zooming, without increasing reconstruction time.

As well as linear sampling(matrix size), angular sampling must also be considered. Insufficient angular sampling results in streaking which is worse near the edge of the object. Practically, we usually use 64 angles over 360° for clinical objects such as heart.

However, for brain and spine SPECT, at least 128 angles is required.

Image artifacts and distortion occur in SPECT due to variable attenuation and spatial resolution[3]. The distortion is less in 360° studies because of the averaging of opposing views. However, 180° acquisition has some advantages when the organ of interest is close to the edge of the body such as in heart and spine.

Most early rotating single head SPECT systems only allowed images to be acquired at discrete angles. In newer SPECT systems, the detector can continuously acquire data as it rotates around the subject, without stopping called continuous acquisition.

A non circular orbit by a rotational and translational motion improves the resolution due to closer distance between patient and collimator, and increased lesion detectability due to the shifting of the detector center comparing the object center during the rotation[6,7].

In a circular orbit, the systematic nonuniformity of the projection causes ring artifacts. For avoid of ring artifact of the reconstruction center requires of the correction flood and smoothing of the projection[8]. The Jaszczak phantom has six sectors of non radioactive rods in a radioactive rods in a radioactive background 22cm in diameter. The rod diameters are 4.9, 6.4, 7.9, 9.5, 11.1 and 12.7mm. From our results the non-circular orbit significantly improved contrast for the 128×128 matrix, though slight improvement is seen for the 64×64 matrix, and the resolution is also slightly improved in non circular orbit.

Most SPECT systems now also offer 'body contoured' rotation. This means that the radius of rotation(ROR) is varied as the detector rotates to minimise the patient-collimator distance at each angle. The contour can be learned during patient set-up using laser.

CONCLUSION

We have compared the SPECT image quality of a 50×30cm elliptical orbit(NCO) and an equivalent circular orbit of 50cm diameter. We have performed quantitative measurements of uniformity and contrast and also some qualitative measures on linearlity and resolution. From our study we have seen that the NCO does not degrade uniformity or linearlity compared to CO and produces increased contrast in images of objects greater than 3cm diameter. The image resolution is improved for NCO mode in 128×128 matrix. All improvements were achieved without increasing noise, though slightly increasing scan time(10 minutes per scan). Potential users should consider other sources of SPECT image degradation such as organ motion as well as have to weigh the cost of increased system calibration and set-up requirements versus the benefit of improved image contrast.

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