Implications of the Partial Ring Design for a Clinical SPECT Insert

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***Abstract*—The INSERT system is a stationary SPECT insert designed for clinical SPECT/MRI. The system has been evaluated as a standalone SPECT scanner and here the image reconstruction is evaluated to determine the implications of its design. A two-step image acquisition can be implemented to overcome the limitations of the partial ring design. The image quality and activity linearity are evaluated through a set of point sources and vials of varying activity concentration. The evaluation highlighted areas where image reconstruction and data processing needed to improve before proceeding to simultaneous SPECT/MRI acquisitions. We have shown that the proposed dual acquisition method can produce improved image quality through the use of modified data acquisition and reconstruction protocols.**

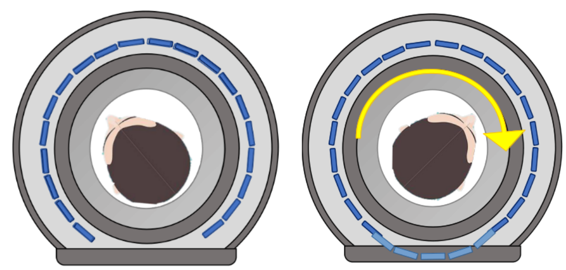

Fig. 1. The rotation acquisition can be used with a patient by using a head rest to acquire data at two angles.

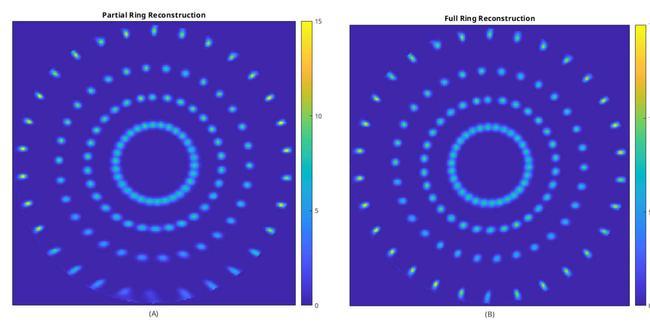

Fig. 2. The partial ring reconstruction (A) demonstrates the limited data in the detector gap the bottom region of the image.

I. Introduction

The INSERT scanner is a clinical SPECT imaging system designed for simultaneous use with clinical MRI [1]. The system has undergone a preliminary evaluation which has demonstrated the capabilities of the system as a standalone SPECT camera [2]. The INSERT is comprised of 20 stationary detector heads which form a partial ring. The design was chosen to fit a clinical MRI bore, limiting the number of detector heads. Simultaneous MR acquisition requires a stationary SPECT camera and MR compatible Multi Slit-Slat collimator [3]. As a result, the system suffers from limited sampling angles and loss of data in the detector gap. Here we assess how well this can be compensated through phantom/subject rotation. By acquiring the data at two angular positions, full ring reconstruction can be achieved using Maximum Likelihood Expectation Maximisation (ML-EM) [4]. Here we evaluate the effectiveness of the proposed acquisition strategy and assess the impact of the partial ring design on image quality.

II. Methods

A. Resolution

The system resolution was assessed through the acquisition of capillary sources at several positions across the detector FOV. A set of 1 mm glass capillaries were filled with 10 MBq of ^{99m}Tc positioned at 4 radial positions 25 mm apart and data were acquired at 30 angular positions $12°$ apart. The partial and full ring reconstructions produced individual images of the capillaries, from which FWHM was measured along the long and short axes. For the $72.25°$ detector gap, the missing data were recovered from the neighbouring detector heads which recorded data from rotated positions. A 25 detector head system is emulated by accounting for the offset between detector position and acquisition angle. The angle was set through the use of a fixed rotating stage.

B. Activity Linearity

The rotation is proposed to recover some lost data and improve image quality in the detector gap, however this process is not always practical. Here we determine the effect of the partial ring on data acquisition and image reconstruction. A phantom with 10 vials of activity was acquired to check linearity in the estimation of activity. The activity in each vial varied linearly from 0.47 MBq to 4.7 MBq of ^{99m}Tc. By reconstructing data with 16 and 25 detector configurations the recovery of linearity when angles are reduced is measured.

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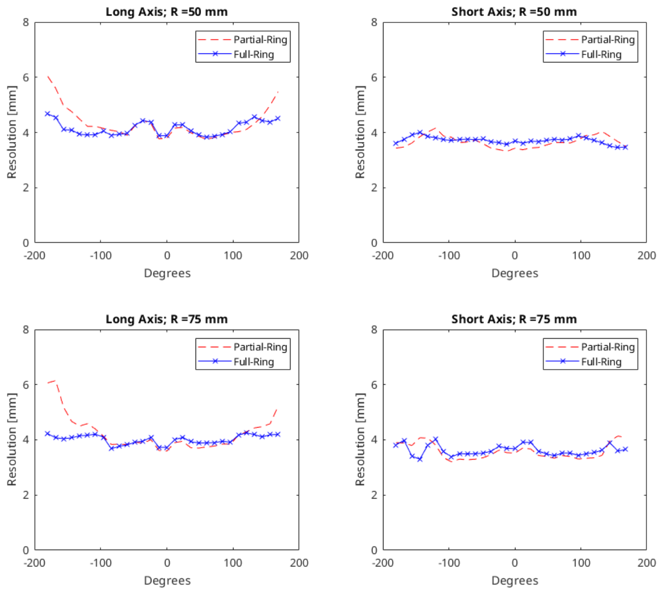

Fig. 3. The centre of the detector ring is defined at 0° and the missing detectors are located at the largest angles.

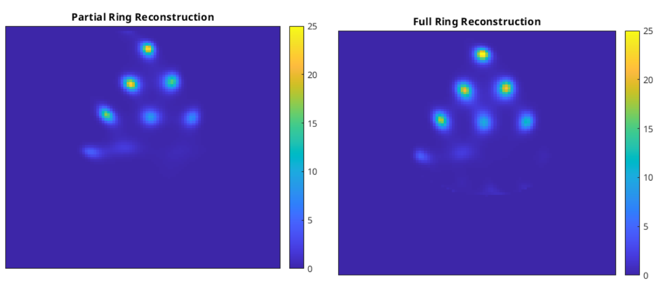

Fig. 4. The variable activity phantom is reconstructed with 16 and 25 detector heads.

C. Activity Uniformity

A second study was carried out with 6 test tubes filled with 3.5 MBq of ^{99m}Tc and 4 filled with 7 MBq. This was measured to determine the uniformity of the system with a 15, 25 and 45 detector configuration. The reduced 15-detector reconstruction represented an acquisition in the event of detector failure, we aimed to produce sufficient results without the need for rotation in this instance. The 45-detector reconstruction made use of all available data to determine the limitations of the stationary sampling.

III. Results

A. Resolution

The capillary images (Fig. 2) show that the resolution degrades towards the edge of the FOV especially within the detector gap region. Measurements of the FWHM for long and short axes are plotted for sources at radius of 50mm and 75mm (Fig. 3). There is clearly improvement with the full ring reconstruction, measuring an average of 4 mm resolution across all positions. These confirm the improvement in long axis resolution in the region of reduced angular sampling when full ring reconstruction is carried out.

Recon. Config.	3.5 MBq		7 MBq	
	Mean [cnt]	CoV [%]	Mean [cnt]	CoV [%]
15 Det.	22.6	13.3	86.1	45.7
25 Det.	23.6	12.2	91.7	29.3
45 Det.	29.1	10.4	92.7	31.5

TABLE I
MEASUREMENT OF ACTIVITY UNIFORMITY IN TEST TUBE PHANTOM

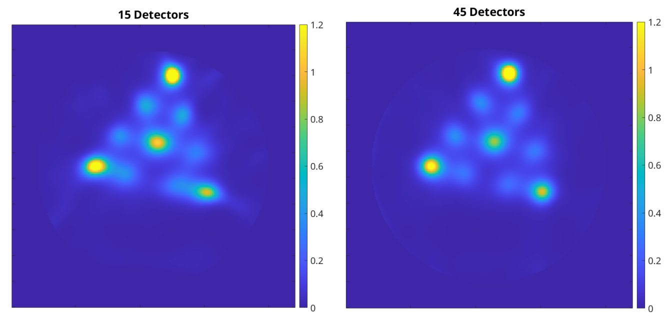

Fig. 5. Activity uniformity for test tubes with 15 and 45 detector reconstructions.

B. Activity Linearity

The vial phantom images demonstrate how the image quality can be conserved with a reduced number of detectors. Here partial ring reconstruction was carried out with 16 detector heads to simulate a partial ring with faulty detectors. This is able to produce an image of 8 out of the 10 vials (Fig. 4). Measuring the counts for each vial demonstrates the linearity is not badly affected due to missing angles. A linear fitting for each graph gives $R^2_{PartialRing} = 0.964$ and $R^2_{FullRing} = 0.975$. These results show that the stationary system is able to demonstrate linear response to activity despite loss of detectors.

C. Activity Uniformity

The uniformity between common activity in each test tube is determined by measuring mean counts and the coefficient of variation. The mean counts measured within the test tube area determines the loss in counts for each reconstruction configuration. The COV determined how well a reduced sampling reconstruction could maintain uniformity. Table I presents uniformity measurements for each reconstruction. The reconstructed images show greater uniformity and the improved resolution enhances the structure and contrast of the test tubes.

IV. Discussion and Conclusion

The combination of two acquisitions provides a practical means of compensating for the limited sampling due to the partial ring of detectors. In practice this would involve rotation of the head to two positions. An added advantage of the dual acquisition in the event of detector failure is that angular information is preserved by combining the two views. In practice the two acquisitions must be registered, based on the two partial-ring reconstructions, as a pure rotation cannot be guaranteed. The INSERT is designed to function within a clinical MRI, acquiring data simultaneously. So registration can be improved in the future by using MR image data to provide the necessary transformation.

The 70° rotation required for two acquisitions may not be feasible due to patient compliance; in this case the single angle images have been shown to capture sufficient information. Through the reconstruction of a reduced partial ring we are confident in the use of a 20 detector reconstruction. As the loss of data has been shown to mainly affect the detector gap region, an alternative procedure involves imaging the subject further from the detector gap to improve sampling.

The results shown here demonstrate the capability of the INSERT as a standalone SPECT system. The inclusion of dual-angle acquisition has potential to improve image quality if clinically practical. In future we aim to acquire simultaneous SPECT/MRI to produce improved SPECT and hybrid SPECT-MR images.

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