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Development of high resolution nuclear imaging technologies using triple-head SPECT

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1. Introduction

Micro-pinhole SPECT system with conventional multiple-head gamma cameras has the advantage of high magnification factor for imaging of rodents with sub-millimeter resolution. Sub- millimeter spatial resolution can be achievable using pinhole SPECT system with the aperture that has extremely small diameter. However, several geometric factors should be carefully calibrated to obtain the SPECT image with high spatial resolution and good image quality. We developed a simplified geometric calibration method for rotating triple-head pinhole SPECT system and assessed the effects of the calibration using several phantom and rodent imaging studies

2. Materials and Methods

Triad XLT9 triple-head SPECT scanner (Trionix, OH, USA) with 1.0 mm pinhole apertures were used for the experiments. There are three pinhole collimator gantries and each gantry has one pinhole aperture. The point source of 1.1 mm inner diameter filled with 1.85 MBq (50 μCi) of Tc-99m was used to track the angle dependent positioning errors mainly due to the gravitational effects by the heavy detectors and mismatch between axis of rotation and center of rotation. For tracking the angle dependent positioning error, approximately centered point source scanned for 2 hours with full angle (360˚) acquisition protocol. From the projection image at each angular position, (x, z) centroid of point source was determined by the center of mass calculation. The angular profile of x and z positions were then fitted to the sine curves to estimate the parameters for position of point source, center-of-rotation variation in transaxial direction by mismatch, and shift of the projection data in axial direction by gravitational effect. To verify the improvements by the geometric calibration, we compared the spatial resoluion of the reconstructed image of Tc-99m point source with and without the calbiration. SPECT image of micro performance phantom with hot rod inserts was acquired and several animal imaging studies, such as the bone scans of mice (~ 25 g) and rats (~300 g) with Tc-99m-HDP and the thyroid scan of rat with Tc-99m, were performed for partial angle (120˚) acquisition protocol. All the data set were reconstructed using filtered backprojection reconstruction algorithm with Ramp filter for point source and Hanning filter of 0.45 pixel/mm cut-off frequency for phantom and animal.

3. Results

Without the geometric calibration, the reconstructed image of point source looked like a tilted doughnut with 1~3 mm radius for each detector head. Exact sphere shape of the point source was obtained by applying the geometric calibration and axial resolution was improved by ~10%. Lesion detectability and image quality was also much improved by the calibration in the phantom and animal studies. After correction, all the hot rod inserts (diameter of smallest one = 1.2 mm) were resolved and detail skeletal structures, such as the spine segments and ribs, were clearly visualized. Reconstructed images with full angular data and combined data of the partial angular acquisition (120˚ for each detector) showed the comparable results.

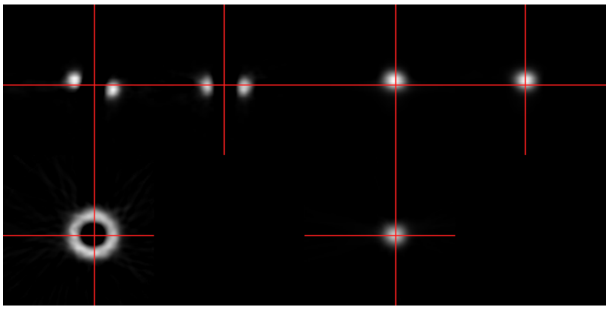

Figure 1. Results of point source scan. The point source looked like doughnut form before geometric calibration (left). The exact sphere form of point was obtained after geometric calibration (right).

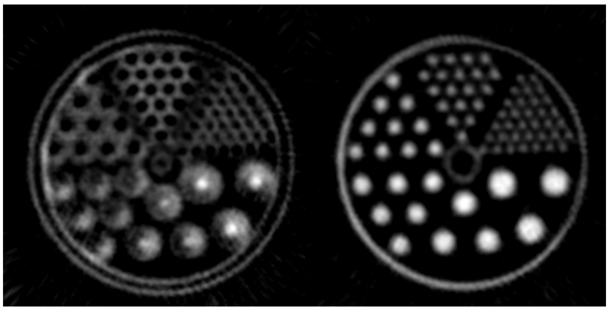

Figure 2. Transaxial slice of micro performance phantom before calibration (left) and after calibration (right). The smallest rod (1.2 mm) was observed after calibration. The phantom total diameter was 5 cm.

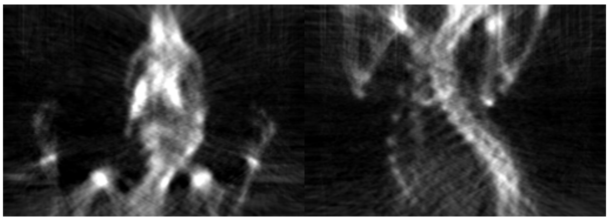

Figure 3. Result of bone scan of rat. Skeletal structure (left) and spine (right) was seen clearly.

4. Conclusion

Before calibration, the transaxial slices of all images have image deformations in addition to resolution degradation. These serious degradations of micro-pinhole SPECT images due to the geometric errors could be corrected using our developed simplified calibration method.

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