Comparison of advanced iterative reconstruction methods for SPECT/CT

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Abstract— On three SPECT/CT systems, manufactured by General Electrics, Siemens and Philips, all of them installed recently, a SPECT acquisition (360°, 6°/step, 40sec/frame) of a resolution and the NEMA NU2-2001 image quality phantom was performed. Reconstructions were done using Evolution for bone (GE), Flash3D (Siemens) and Astonish (Philips). The reconstructed slices were either analyzed directly or after additional post-filtering according to the manufacturers recommendation using in-house developed analysis tools. FWTM was 13.19.5 mm (filter/no filter) for GE, 11.4/9.0 for Siemens and 16.0/10.6 mm for Philips. If the OSEM/MLEM reconstruction is taken as gold standard we found a relative improvement in resolution of 9.0/34% (filter/no filter) for GE, 0/21% for Siemens and 0/29% for Philips. FWTM was 22.4/19.9 mm (filter/no filter) for GE, 20.9/17 mm for Siemens and 32.0/22 mm for Philips. Corresponding reference values were higher by 21.0/29% (filter/no filter) for GE, 0/18% for Siemens, 0/24% for Philips. We measured approximately the same percent contrast applying Evolution/Flash3D and Astonish and OSEM/MLEM for the two largest spheres (37 and 28mm) but found a significant improvement if the size of the spheres is decreased. Spatial resolution and percent contrast significantly improves using the nowadays-commercial available advanced reconstruction technology in a realistic clinical setting. Great care must be taken to avoid unnecessary filtering which might be the default setting in some protocols.

Keywords— SPECT/CT, image reconstruction, resolution recovery.

I. INTRODUCTION

After acquiring a SPECT/CT study the projection data of the emission scan are used to calculate transaxial slices. In the past, the filtered back projection method based the Radon transformation was used but nowadays usually iterative reconstruction methods are used. The schematic procedure of iterative algorithms is simple: after an initial guess how the voxel distribution of a transaxial slice may look, an acquisition is mathematically simulated. The result of the simulation is then compared with the measured projection data and the initial guess is updated in a way that the difference between measurement and simulation is minimized. This process is repeated for a number of updates [1]. Since a collimator of a gamma camera only accepts photons that impinge within a cone with some acceptance angle the resolution of the measuring system depends on the distance from the collimator. Developments to model corrective image reconstruction methods provide reconstructed images with a simultaneous improved spatial resolution and decreased noise level [2]. Although the basic principles of three-dimensional collimator beam modelling are known since many years only recently the use of this methods become commercially available.

The aim of this study was to compare three commercial available reconstruction algorithms: General Electrics (GE) Evolution for bone, Siemens Flash3D and Philips Astonish.

II. MATERIAL AND METHODS

Two different phantoms were used for evaluation: a special designed phantom to measure the resolution and the image quality phantom according the NEMA 2001-NU2 standard. The resolution phantom consists of the trunk of the IEC/NEMA body phantom into which three line sources were inserted after removal of the spheres, one in the phantom's central axis, the other two at peripheral positions, all parallel to the axis of rotation of the tomograph. The lines of the resolution phantom were filled with 99mTc (197 MBq/cc). To simulate patient conditions both phantoms were filled with a 99mTc solution, resulting in an activity concentration of 5.20 kBq/cc. The image quality phantom measurements were performed according to the NEMA 2001-NU2 standard with two lesion/background ratios (8:1 and 4:1). The tomographic acquisitions were done on three SPECT/CT systems from three different vendors, the Infinia (GE), the Symbia T6 (Siemens) and the Precedence (Philips). For all acquisitions the same protocol was used: 128x128 matrix, 360° SPECT with 6° steps, 30sec/frame. After the SPECT acquisition an additional x-ray CT scan was used to calculate the attenuation map. The
The reconstruction was done on the image processing workstations that are used routinely for SPECT reconstruction: GE’s Xeleris, Siemens Syngo and Philips JetStream. Reconstruction was done with iterative reconstruction algorithms incorporating the modelling of spatial variable resolution (GE’s Evolution, 2 iterations 10 subsets; Siemens Flash3D 12 iterations, 4 subsets; Philips Astonish 2 iterations 15 subsets) and for comparison, for GE and Siemens with the Ordered Subset Expectation Maximization (OSEM) algorithm using the already mentioned reconstruction parameters. Astonish was compared with the Maximum Likelihood Expectation Maximisation (MLEM) algorithm applying 12 iterations.

After reconstruction the transaxial slices were analysed directly or after using an additional post filter (GE: Butterworth 0.48 cut-off order 10, Philips: Hanning: 0.7, Siemens: Gauss: 7 mm). For the MLEM algorithm the data were post filtered using the standard Butterworth filter (0.5 cut-off, order 5.0). The analysis of representative transaxial slices was done with a self-developed analysis tools to measure the tomographic resolution (full width half maximum (FWHM), full width tenth maximum (FWTM)). Transaxial slices of the image quality phantom were used to analyse the contrast of the cold and hot spheres [3].

III. RESULTS

FWHM was measured 13.1/9.5 mm (filter/no filter) for GE, 11.4/9.0 for Siemens and 16.0/10.6 mm for Philips. If the OSEM/MLEM reconstruction is taken as gold standard we found a relative improvement in resolution of 9.0/34% (filter/no filter) for GE, 0/21% for Siemens and 0/29% for Philips. The calculation of the FWTM showed a similar situation: 22.4/19.9 mm (filter/no filter) for GE, 20.9/17 mm for Siemens and 32.0/22 mm for Philips. Corresponding reference values were higher by 21.0/29% (filter/no filter) for GE, 0/18% for Siemens, 0/24% for Philips. The analysis of the contrast was done for the new reconstruction algorithms clearly show the advantage of the new reconstruction algorithm over OSEM/MLEM if smaller structures are imaged. We measured approximately the same percent contrast applying resolution recovery and OSEM/MLEM for the two largest spheres (28 and 37 mm) but found a significant improvement if the size of the spheres is decreased (Fig. 1, 2).

IV. DISCUSSION

In this work we evaluated the performance of three commercial available reconstruction algorithms that uses an advanced iterative reconstruction incorporating the modelling of spatially variable resolution: GE’s Evolution for bone, Siemens Flash3D and Philips Astonish.