Initial tests of a new phantom for investigation of spatial resolution, partial volume effect and detectability in nuclear medicine tomography

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Introduction

• Characterization of SPECT and PET systems

• Find optimal conditions for different tomographic reconstruction algorithms
  • Total number of counts
  • Total number of projections
  • Matrix size

• Figures of merit
  • Spatial resolution
  • Partial volume effect (PVE)
  • Detectability

Illustration of PVE (V.C. Spanoudaki, S.I. Ziegler 2008)
The MADEIRA phantom

- Simultaneously provide different target to background activity ratios with linearly changing diameter of active or inactive lesions
Purpose

- Describe the phantom
- Perform initial measurements
  - Characterize different nuclear medicine tomographic systems and reconstruction algorithms
  - Performance and behaviour concerning PVE and detectability by varying the acquisition parameters and the count statistics
The MADEIRA phantom

- Acrylic glass

- Contains 16 separately fillable cones
  - Length = 19 cm
  - Inner diameter = 2-16 mm
  - Wall thickness = 1 mm

- The outer vessel fits into the RSD Alderson thorax phantom

Realistic conditions!
Phantom measurements

• Minimize the number of necessary acquisitions to get a fairly good sampling of all acquisition parameters

• Performed one SPECT and one PET measurement respectively with very good statistics

• Figures of merit
  • Spatial resolution – profiles across the center of the cones (‘FWHM’)
  • PVE – profiles in the center along the length of the cones
  • Detectability – ROI:s in and outside the cones (CNR)
SPECT measurements

- $^{99m}$Tc-solutions of different activity concentrations

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<th>Cone</th>
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<td>Relative activity concentration</td>
<td>10</td>
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- Initial activity 530 MBq
- Siemens Symbia T2 SPECT/CT
- $360^\circ$ non-circular orbit step and shoot mode
- Collimator – LEUHR
- Number of projections – 240
- Time/projection – 60 s
- Matrix – 256 x 256
- Reconstruction algorithm – ReSPECT 3.0 (Scivis)
SPECT images

- ReSPECT 3.0, 240 projections, matrix size 256, full statistics
Virtual SPECT measurements

- The number of projections was varied by taking a subset out of the total projections (240, 120, 80, 60, 48, 40, 30, 24)
- The total number of photons was varied by Monte Carlo simulations (increasing Poisson noise), intended to virtually simulate shorter acquisition time or activity
- The matrix size was varied by downsampling of projection matrix (256, 128, 64)
- Possible to investigate the influence of number of angles, count statistics and matrix size simultaneously by just one (real) acquisition
Evaluation of PVE

Reconstructed activity concentration [in units of background]

Diameter of cone [mm]

240 angles, matrix size 256, full statistics
The level of reconstructed activity concentration in the constant part was not affected by the number of projections, but the diameter of the cone where PVE starts was...
Reconstruction of the MADEIRA phantom from 15 angles with very poor statistics using compressed sensing (CS).

Conventional penalized likelihood reconstruction from 48 angles (more than 3 times the number of angles of the CS reconstruction).
PET measurements

- $^{18}$F-solutions of different activity concentrations

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- Initial activity 145 MBq
- Philips Gemini 16 PET/CT
- Scan time – 15 min / bed position
- Matrix – 144 x 144
- Reconstruction algorithm – LOR-TF-RAMLTA (“BLOB-OS-TF”)
The size of the uptake is reduced with lower activity concentration.
Evaluation of PVE

1 2 3 4 5

Graphs showing data over time with a descending trend.
Discussion

- Easy to fill and air bubbles could easily be avoided

- The cone walls were fabricated to be as thin as possible (1 mm)

- SPECT – a reduction of the number of projections will increase the importance of PVE

- PET – found no plateau before the starting point of PVE, shows the importance of the reconstruction process

- The phantom is a prototype and improvements will be performed before commercially available in the middle of 2011
Conclusion

• After minor improvements the MADEIRA phantom has the potential to be a useful and an important tool for comparison and optimisation of different acquisition and reconstruction parameters in nuclear medicine tomographic studies and to find the best working point of a given system as well as for comparisons between various tomographic units
Acknowledgements

- The work was carried out within the Collaborative Project “MADEIRA” (www.madeira-project.eu), cofunded by the European Commission through EURATOM Seventh Framework Programme (Grant Agreement FP7-212100).

Thanks for your attention!

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