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

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NUMEMA
NUCLEAR MEDICINE IN MALMÖ

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

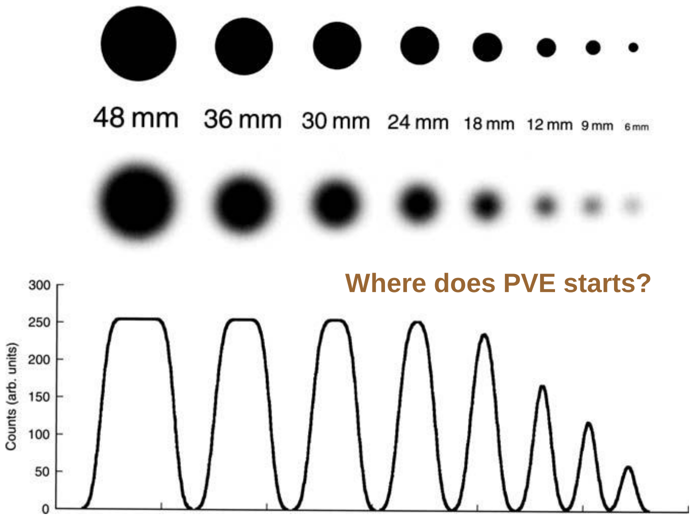
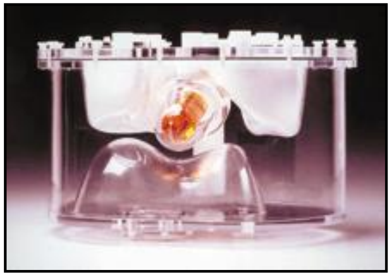
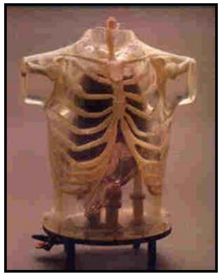
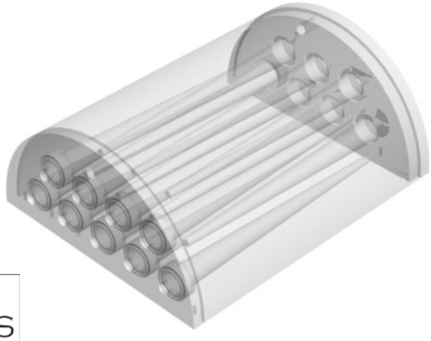


Illustration of PVE (V.C. Spanoudaki, S.I. Ziegler 2008)

Introduction



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

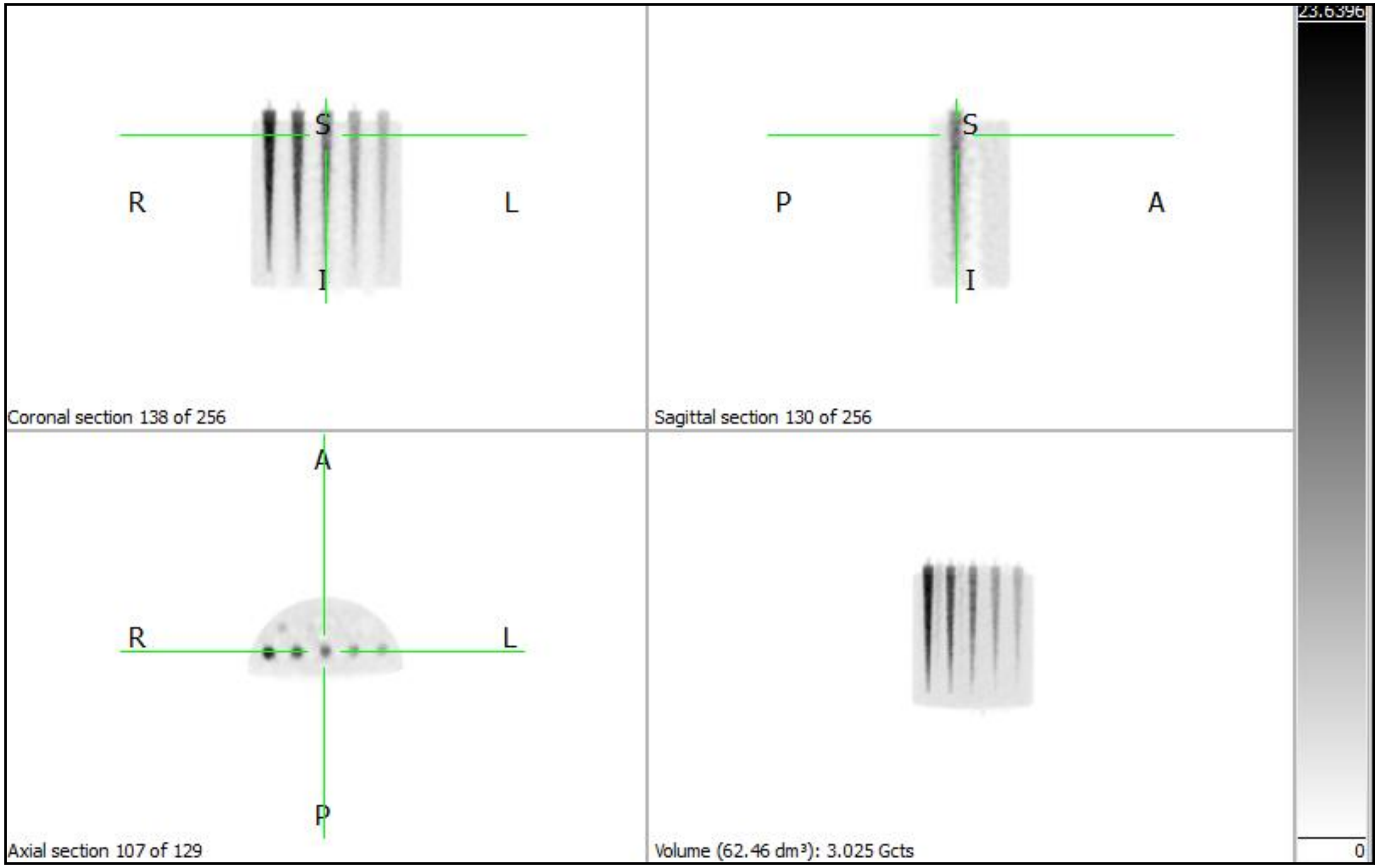
Cone	1	2	3	4	5	6	7	8
Relative activity concentration	10	7.5	5.61	4.21	3.16	2.37	1.78	1.33

Cone	9	10	11	12	13	14	15	16
Relative activity concentration	0.75	0.56	0.42	0.32	0.24	0.18	0.13	0.10

- Initial activity 530 MBq
- Siemens Symbia T2 SPECT/CT
- 360º 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

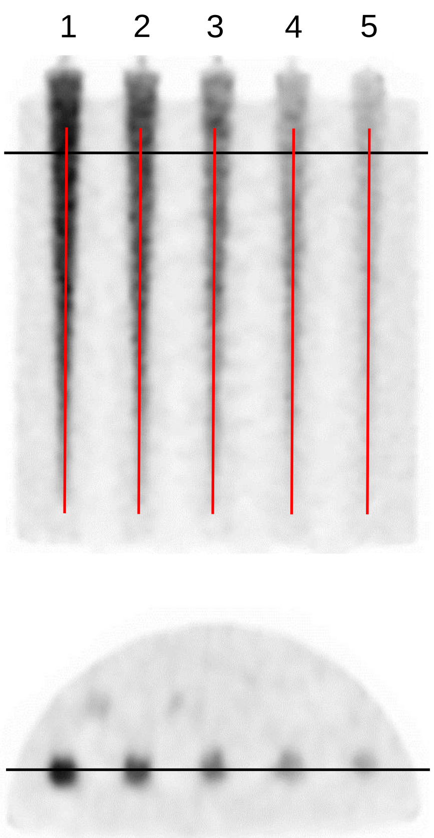


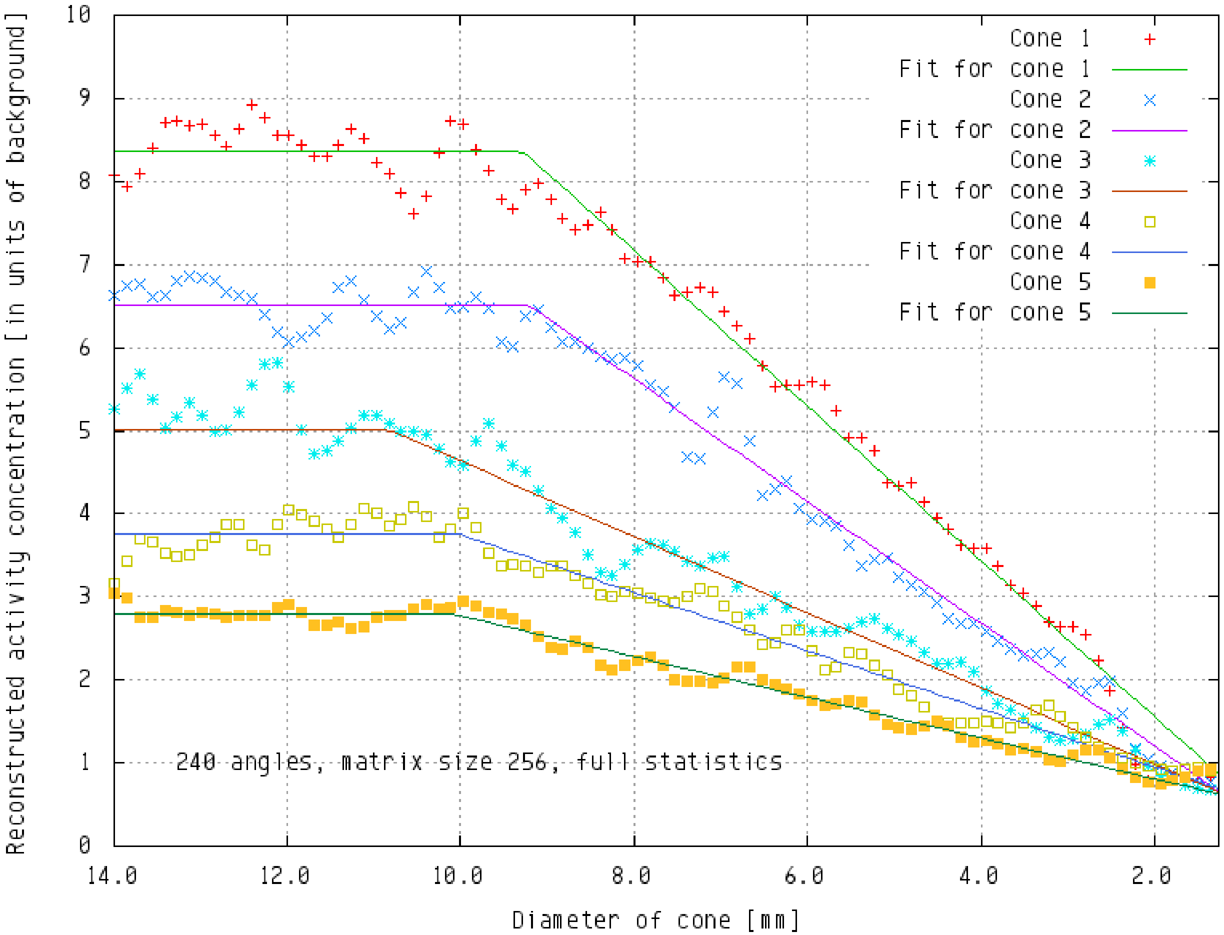
Virtual SPECT measurements

- 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)

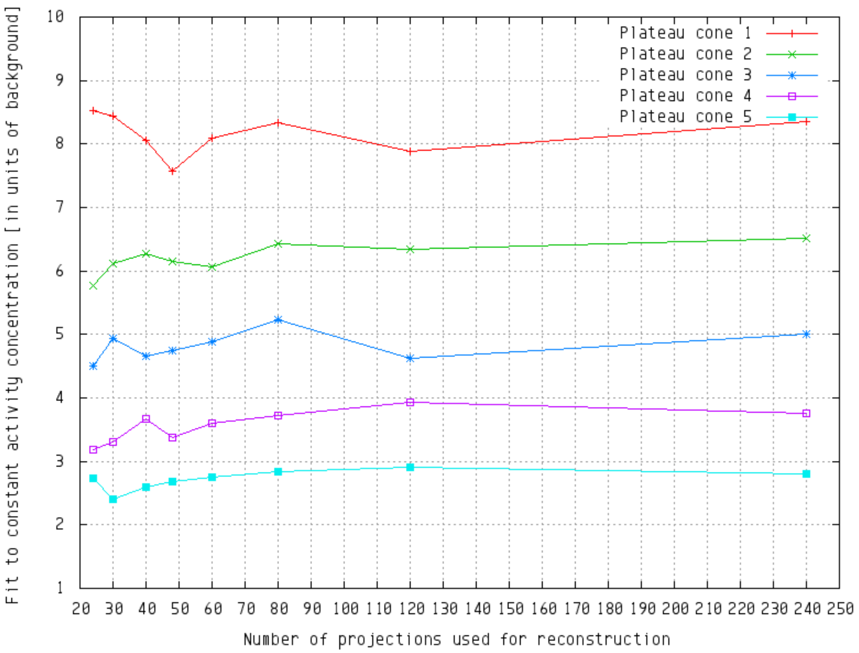
- Possible to investigate the influence of number of angles, count statistics and matrix size simultaneously by just one (real) acquisition

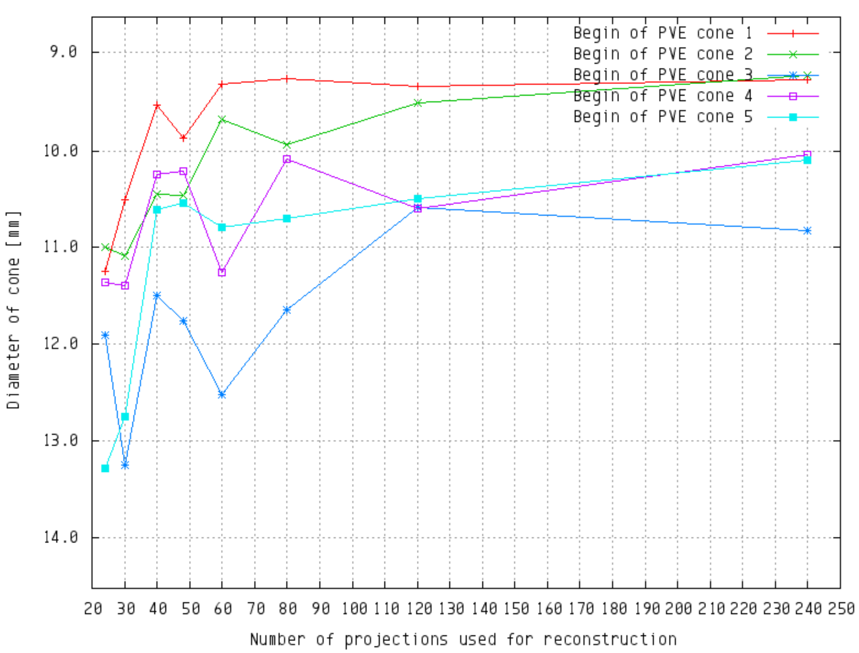
Evaluation of PVE





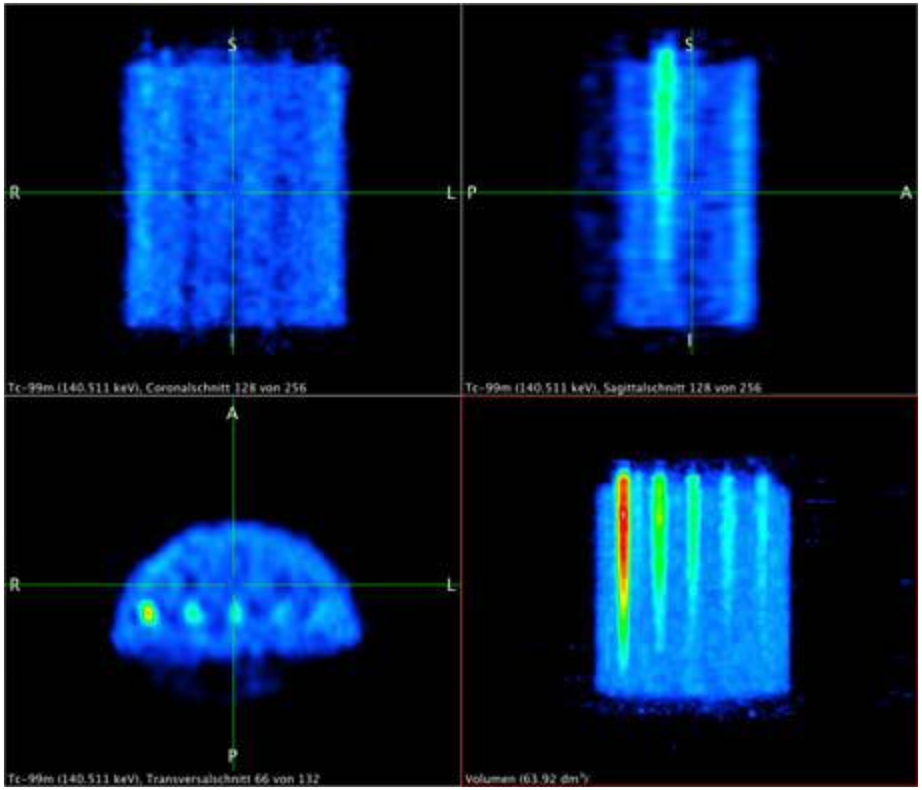
Evaluation of PVE

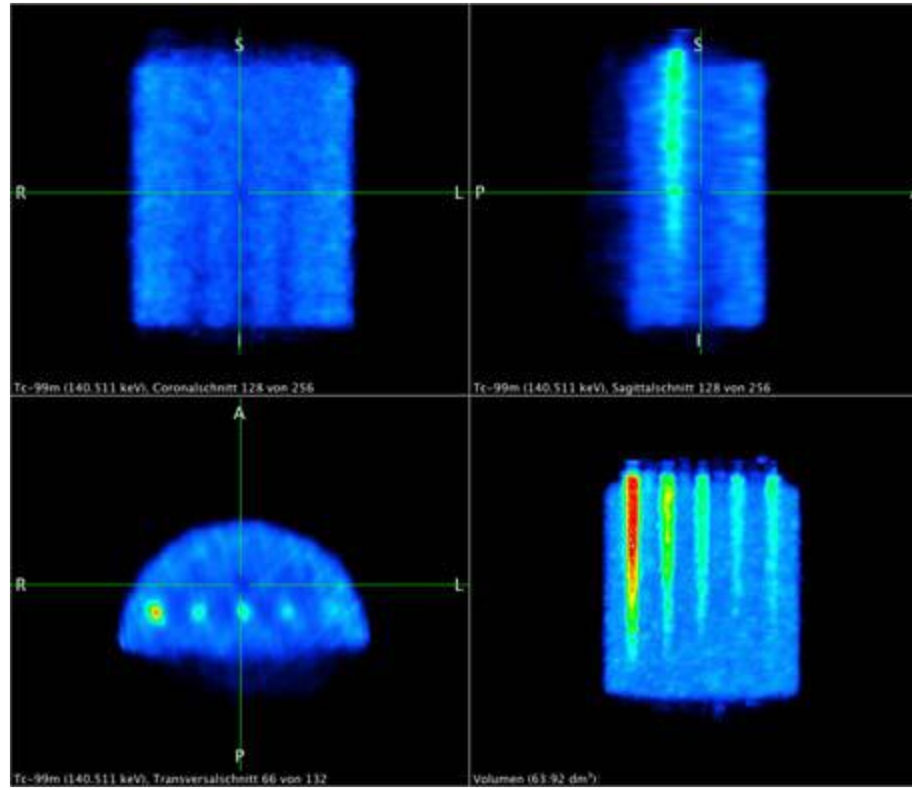




- The level of reconstructed activity concentration in the constant part was not affected by the number of projections, but the diameter of the cone where PVE starts was

Application…





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

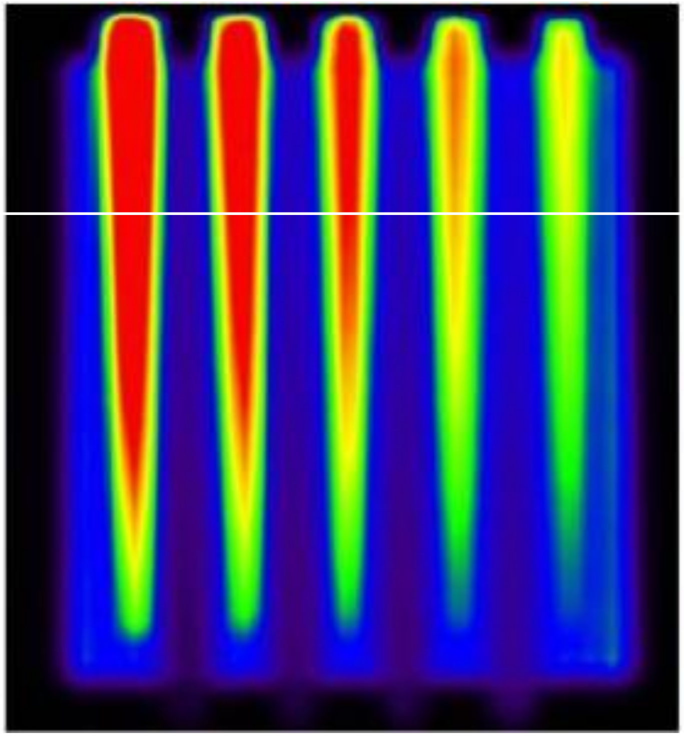
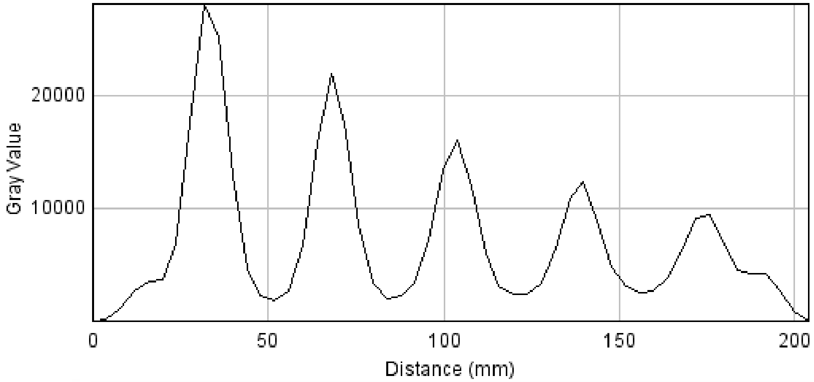
- ^{18}F-solutions of different activity concentrations

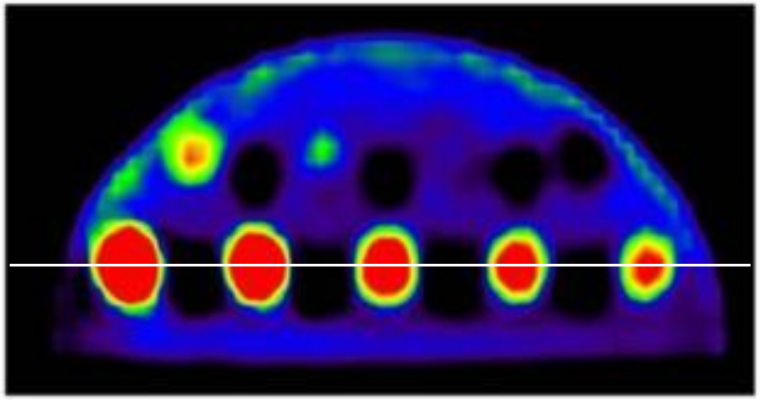
Cone	1	2	3	4	5	6	7	8
Relative activity concentration	10	7.5	5.61	4.21	3.16	2.37	1.78	1.33

Cone	9	10	11	12	13	14	15	16
Relative activity concentration	0.75	0.56	0.42	0.32	0.24	0.18	0.13	0.10

- Initial activity 145 MBq
- Philips Gemini 16 PET/CT
- Scan time – 15 min / bed position
- Matrix – 144 x 144
- Reconstruction algorithm – LOR-TF-RAMLA (“BLOB-OS-TF”)

PET images

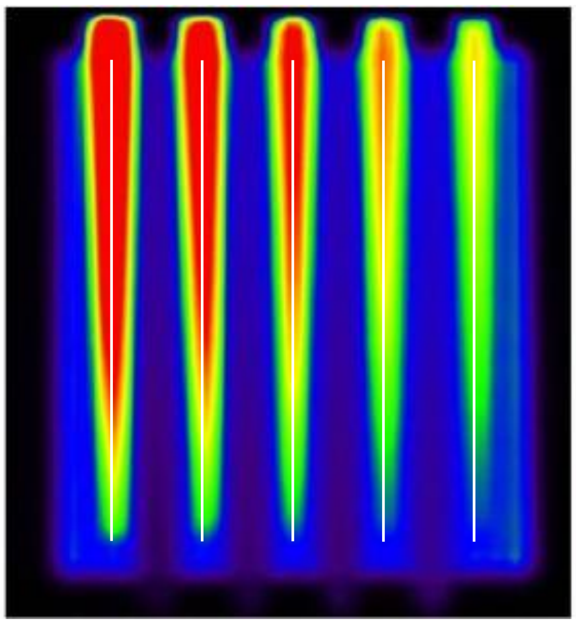





- The size of the uptake is reduced with lower activity concentration

Evaluation of PVE

1 2 3 4 5



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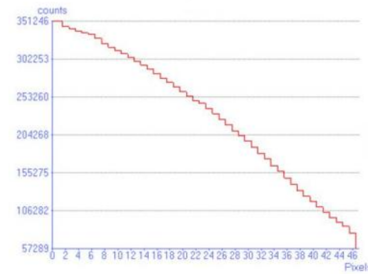

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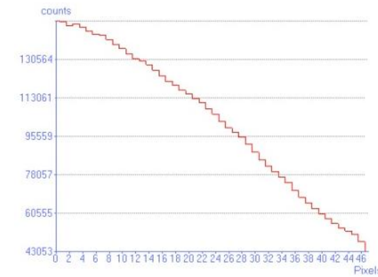

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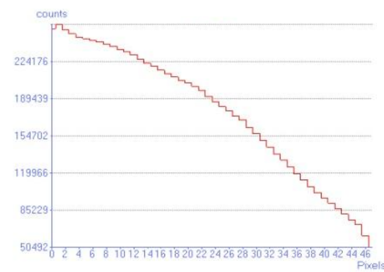

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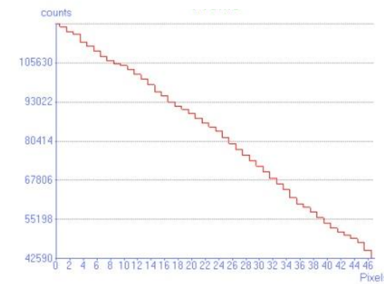

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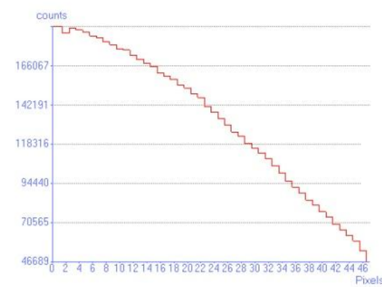
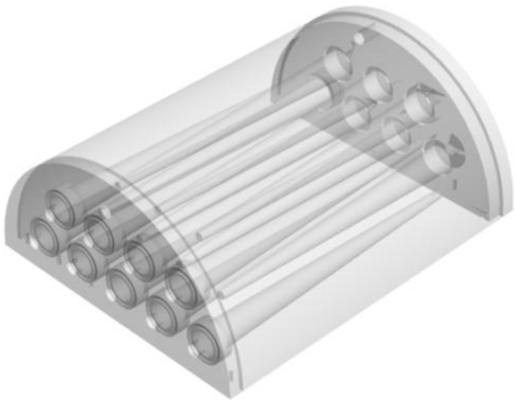


Discussion

- 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

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Thanks for your attention!

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