Universitätsklinikum Würzburg

Quantitative Imaging with Y-90 Bremsstrahlung SPECT (Single Positron Emission Computed Tomography)

S. Beykan, M. Lassmann, S. Schlögl

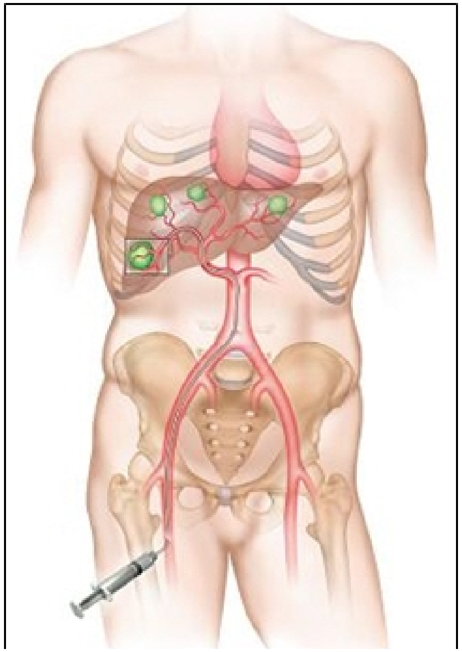
Klinik und Poliklinik für Nuklearmedizin
Direktor: Prof. Dr. A. Buck

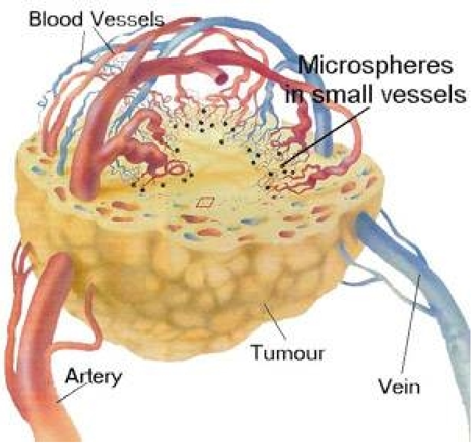
Structure

- Motivation
- Objectives
- Literature Survey
- Materials and Methods
- Results
- Conclusion

• Motivation

Example: Selective Internal Radiotherapy (SIRT)





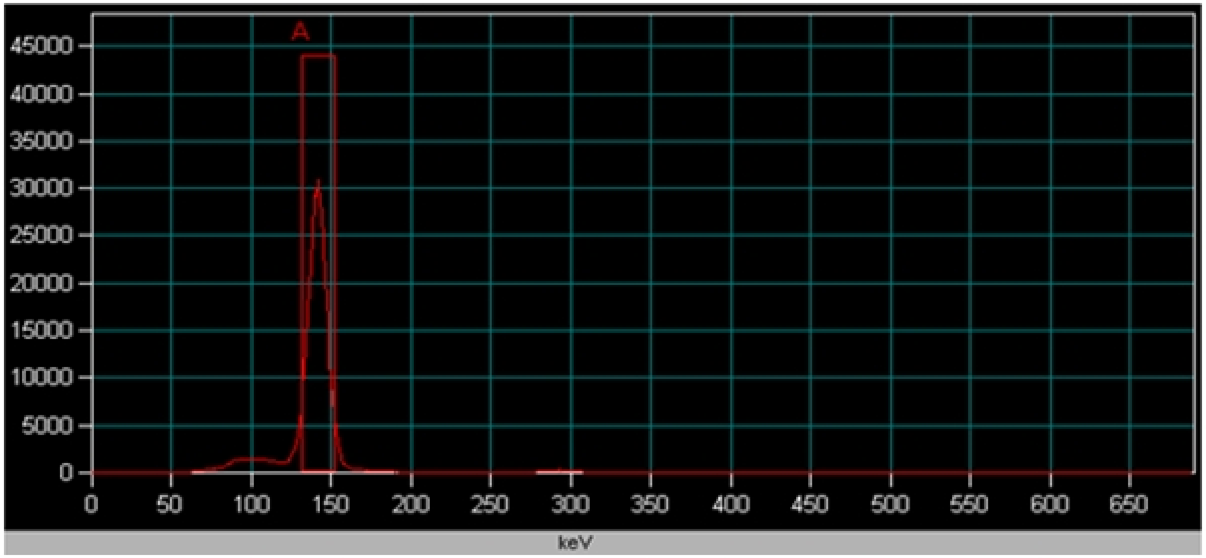
Transarterial embolization of radioactive labeled microspheres (Y-90)

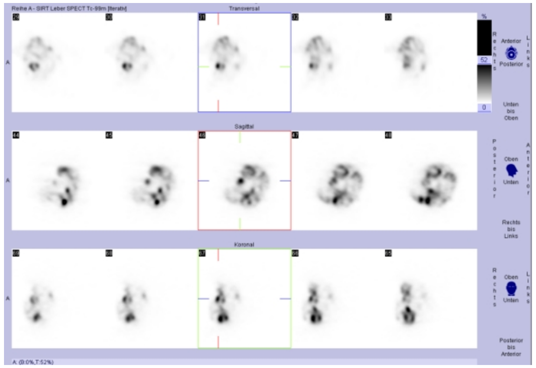
Highly selective tumor uptake by intra-arterial administration of the particles through the arteria hepatica

Image quantification for dosimetry

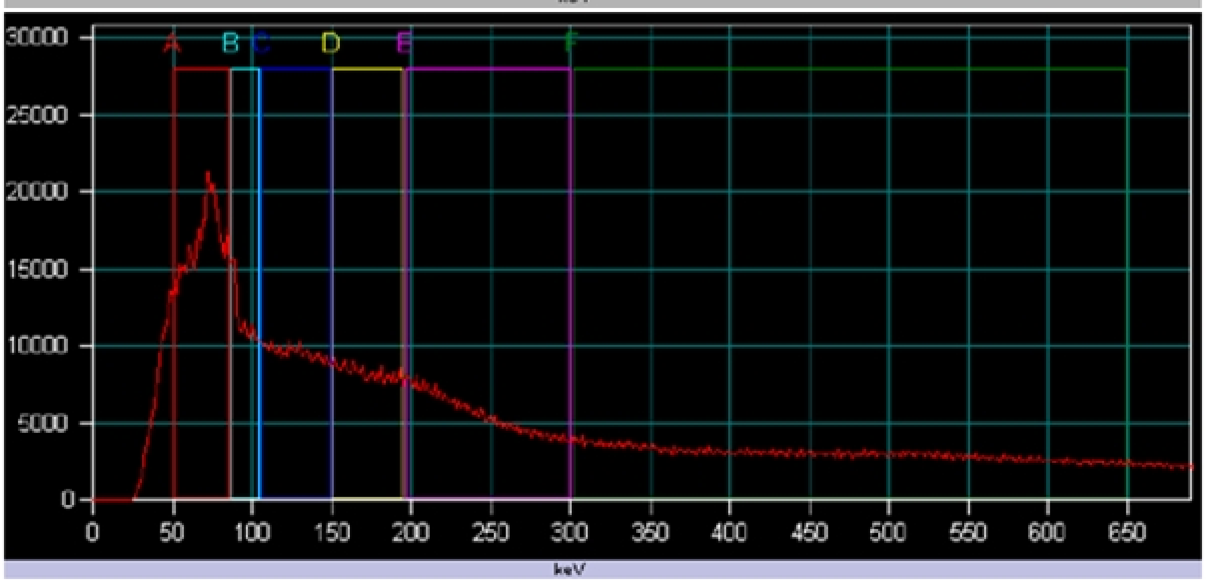
(Describes & analyses the physical effects which degrade image quality & affect the accuracy of quantification)

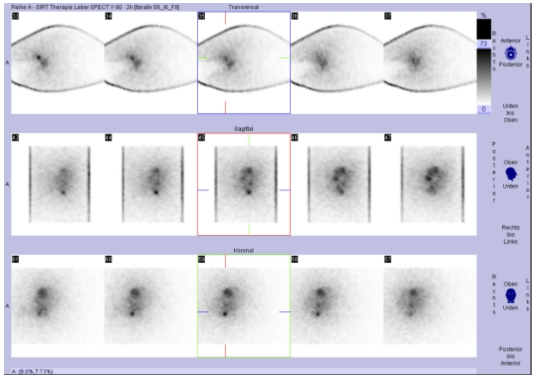
The Apparent Complexity & Limited Accuracy : Spectrum of Tc-99m and Y-90





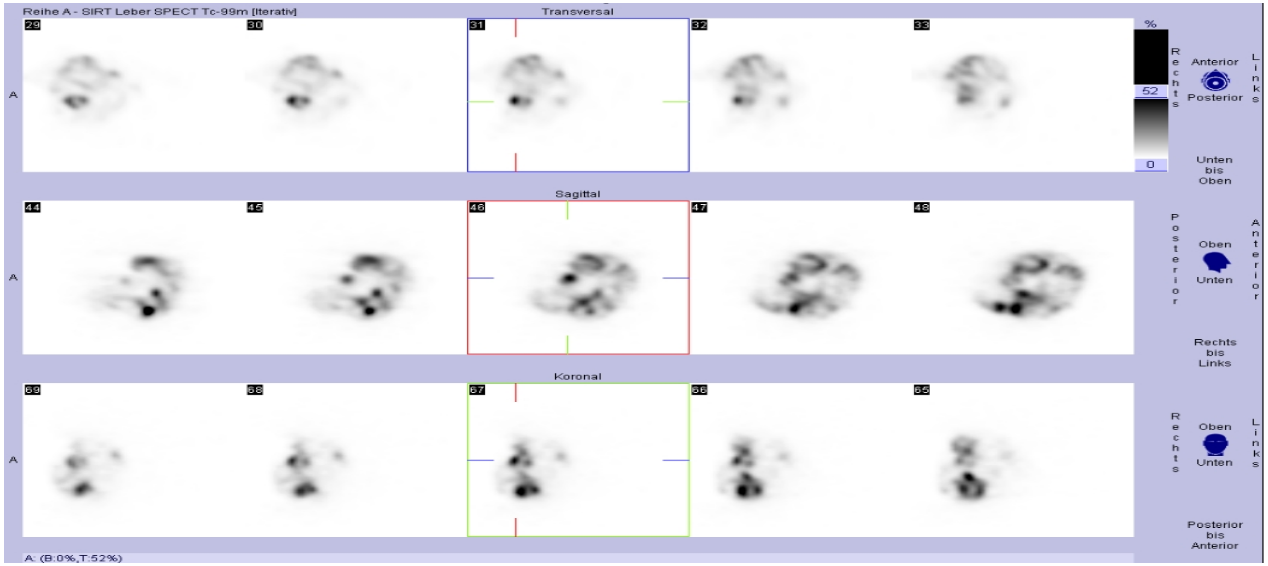
Tc-99m

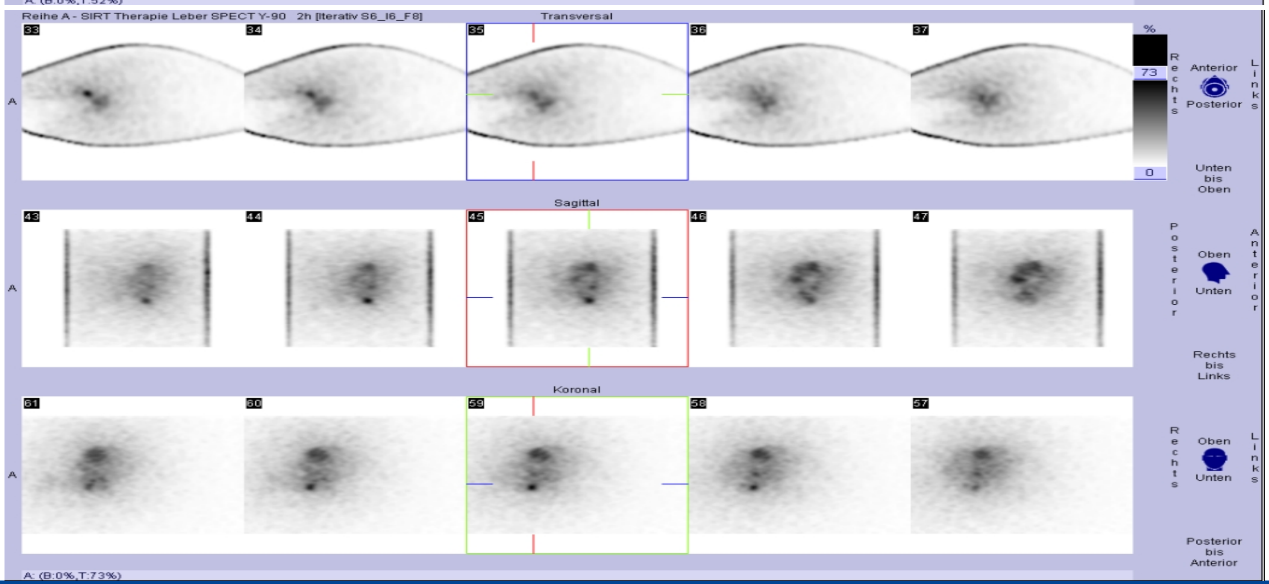


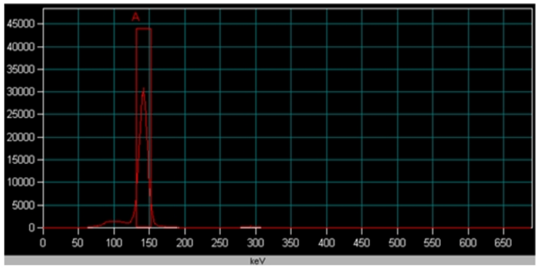


Y-90

The Apparent Complexity & Limited Accuracy : Images of Tc-99m and Y-90







Tc-99m

Y-90

Objectives

- To investigate the quality of Y-90 Bremsstrahlung SPECT/CT imaging and evaluate the possibility of quantifying the activity in differently shaped sources.

- To study the influence of various parameters on the reliability of the quantitative Bremsstrahlung SPECT/CT.

• Literature Survey:

Energy Windows (keV)	Collimator	Crystal Thickness (mm)	SPECT-CT	Phantom	Reconstruction Algorithm
105-195	HEGP	25.4	A SPECT/CT Discovery VH system (GE Healthcare) + Hawkeye CT	X	Lund Adose software, OSEM
105-195	HEGP	25.4	Hybrid SPECT/CT Discovery VH (General Electric Medical Systems, Milwaukee, USA)	4, 5	OSEM [with and without different attenuation, scatter and CDR compensations.]
76-84 136-204	MEGP	9.5	Hybrid SPECT-CT, Symbia-T2	1, 2, 3	OSEM 3D fast (e.soft®)
56-100	MEGP	X	Bright View XCT SPECT/CT Philips Healthcare,	X	3D OSEM
70–210	MEGP	X	Either General Electric Discovery VH (Milwaukee, WI, USA) SPECT/CT-capable system or e.cam	X	(P:60-64)
105-195	HEGP	9.5	Siemens Symbia T16	6, 7	2D OSEM and 2D OSEM+PSF
68-83	MEGP	9.5	e.cam	8	2D OSEM
88-113	ME-ph	X	Siemens	X	FBP
86-94 102-138 139-231	ME-ph	9.5	PRISM-2000XP, PICKER, with two rectangular crystals	9,10, 11,12	FBP and OSEM
120–250 50–250	MEGP HEGP	9.5	Philips FORTE dual-headed camera	13	FBP

X: no information ph: parallel hole

1-Cylindrical Plexiglas phantom

2-Torso-shaped phantom
3-A voxel-based phantom
4-The RSD thorax phantom
5-Elliptical water phantom
6-The NEMA 2007/IEC 2008 Torso phantom

7-Digital phantom
8-Cyclindrical phantom
9-SPECT phantom JSP type NEMA cylindrical phantom, bar phantom, and a cold block phantom

10-Line source phantom
11- Hot spot phantom

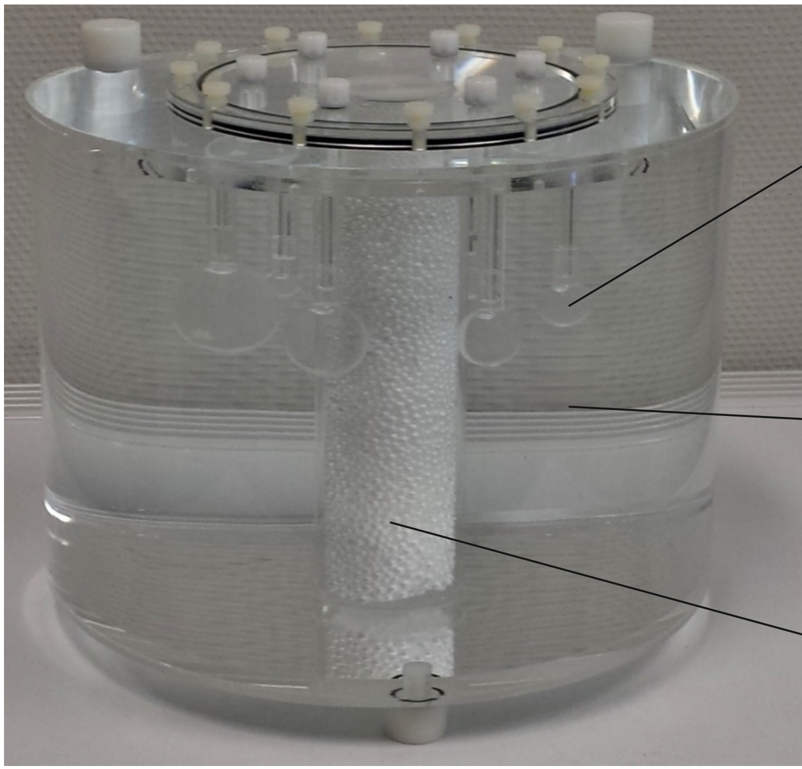
12- Heart–liver phantom

13-The NEMA torso-shaped phantom

Materials and Method

- **Investigated Parameters:**
  - Energy Window Settings
  - Influence of Collimator (HEGP& MEGP)
  - Reconstruction Algorithms (2D OSEM and 3D FLASH)
  - Image Noise
  - Image Contrast
  - The Contrast Recovery Coefficient
  - The Coefficient of Variation
  - Partial Volume Effect

Torso-shaped phantom containing 6 hot spheres of various sizes



6 fillable glass spheres
diameter: 10, 13, 17, 22, 28, and 37 mm
Y-90 activity: 42, 18, 9, 4, 2, and 1 MBq

fillable 9700 ml torso-shaped compartment (1911 MBq)
[Sphere to background activity ratio:1/7]

cylindrical lung insert

The NEMA NU2-2001 PET/SPECT-Phantom

Calibration in Gamma Camera

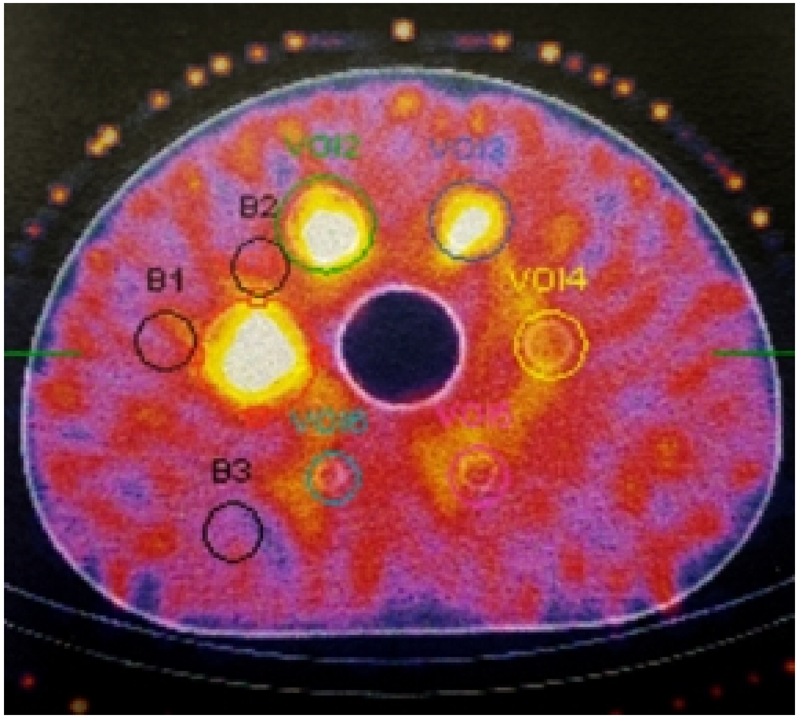
phantom

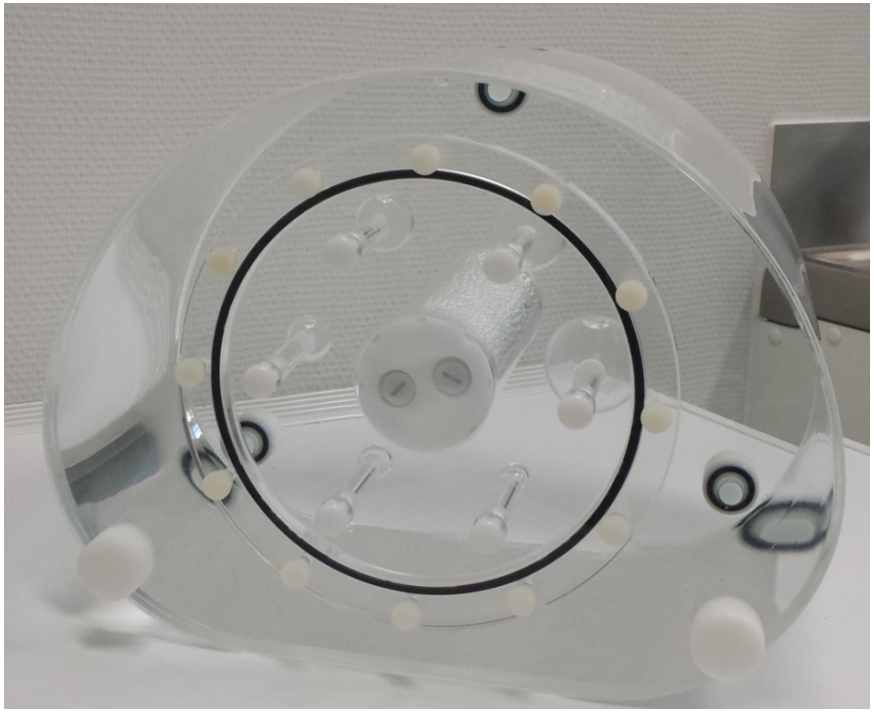
bottle

Phantom
+
Bottle (~79 MBq Y-90 & 50 ml)

For all scans, the same acquisition duration (30 min) were used.

Delineations of Volume of Interests (VOIs)





The results of the corresponding VOIs for each energy window and collimator are reported as:

- total (TC) and mean(CH) number of counts in VOIs
- total (BG) and mean(CB) number of counts
- the standard deviation of counts in the background (std.BG)

Calculations

By using the information from the drawn VOIs:

Signal to Noise Ratio
Image Contrast
Coefficient of Variation
Contrast Recovery Coefficient
Visibility

were calculated for each acquisition parameter, collimators and reconstruction algorithms.

- The ratios of the total number of counts to activity concentrations (CA-Ratio) in each sphere
- Total numbers of counts for each sphere and the bottle

were calculated.

Image Quality and Quantification

$$C\,[\%] = \frac{\frac{TC*Zz}{BG}-1}{R-1} \quad \text{Eq. (1)}$$

$$QH = \frac{\frac{CH}{CB}-1}{R-1} * 100\% \quad \text{Eq. (2)}$$

$$CV = \frac{\text{Std.BG}}{CB} * 100\% \quad \text{Eq. (3)}$$

$$VH = \frac{(CH)-CB}{\text{std.BG}} * \sqrt{\text{Nvoxels}} \quad \text{Eq. (4)}$$

$$SNR = \frac{((\text{TC}*\text{Zz})-\text{BG})}{\text{std.BG}} \quad \text{Eq. (5)}$$

$$Cc = \frac{TC}{A0*t} \quad \text{Eq. (6)}$$

$$Zz = \frac{\text{volume of background}}{\text{volume of sphere}} \quad \text{Eq. (7)}$$

Where:

C[%]: relative contrast

QH: contrast recovery coefficient

CV: coefficient of variation - (counts^{-1})

VH: visibility - (counts)

SNR: signal to noise ratio - (counts)

R: the true sphere-to-background activity concentration ratio (8.37)

t: acquisition duration - (30 sec)

A_0: amount of activity in the bottle – (MBq)

N voxels: the number of voxels in the VOIs

Cc: calibration constant - (counts·(MBq·s)$^{-1}$)

Results

- Optimal Energy Window:

  For SNR, C [%] , QH and VH → **[86-106 keV]**

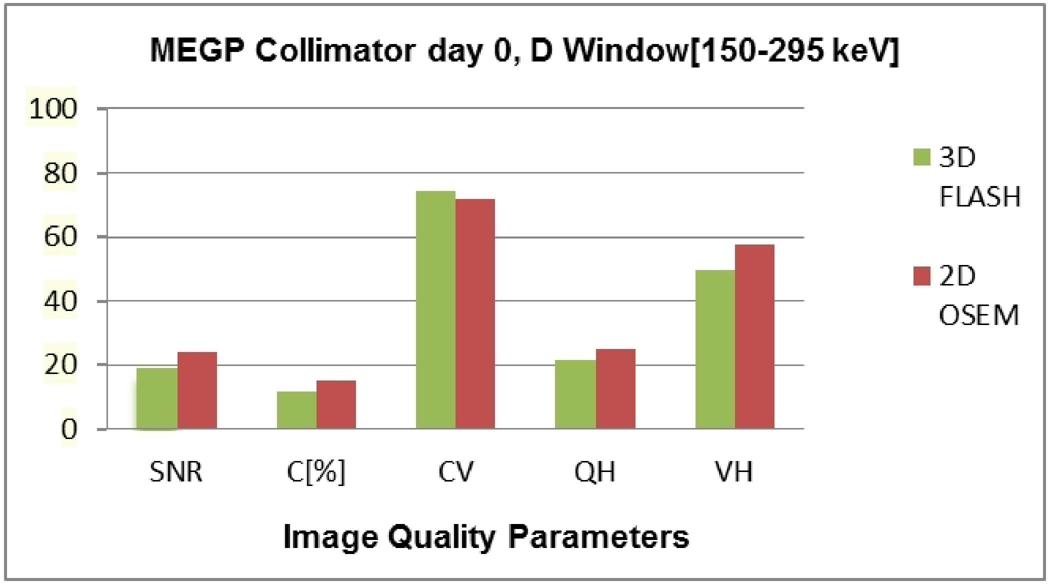
  For CV → [50-195 keV]

- The Best Collimator Choice: → **HEGP**

Results

- **The Best Reconstruction Algorithm:**

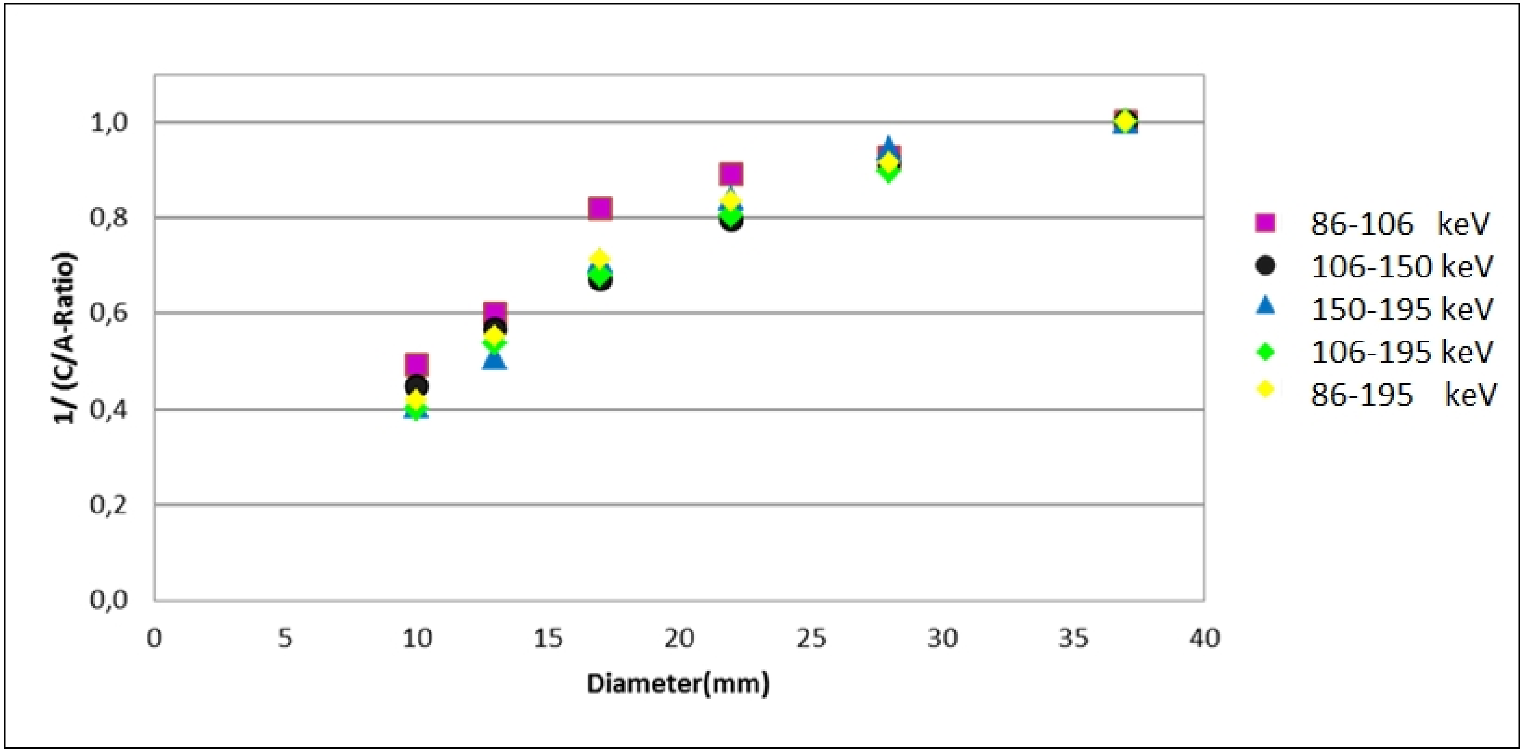
For SNR, C[%], CV, QH and VH → **2D-OSEM**



The quality parameters related to 2D-OSEM and 3D-FLASH

• **Results:** Partial Volume Effect (PVE)

The influence of the PVE described by the total number of counts-to-activity concentration ratios (CA-Ratio) for each of the spheres as a function of sphere diameter **[86-106 keV]**



MEGP collimator, selected energy window settings

• **Results:** Quantification

The unexpected result: total count and activity ratios of spheres and the bottle were not consistent.

SPHERE

True Volume of the largest sphere [ml]	Total Counts in VOIs [count]	Activity [MBq]
26.52	149697	42

BOTTLE

True Volume of the Bottle [ml]	Total counts in the bottle [count]	Activity [MBq]
50.00	126650	79

~ 1

~ 2

Same activity concentrations in bottle and spheres were used.

• Conclusion

- Best energy window setting = <u>86-106 keV</u>

  <u>(the lowest CV with the highest VH, C[%], QH and SNR)</u>

- The recommended energy window = 106-150 keV

- Best choice of collimator = High energy collimator [HEGP]
- Reconstruction Algorithm = 2D-OSEM and 3D-FLASH

- Phantoms with glass spheres may not be a perfect material for calibration and quantification purposes due to modification of the Bremsstrahlung yield most likely caused by the glass walls of the spheres.

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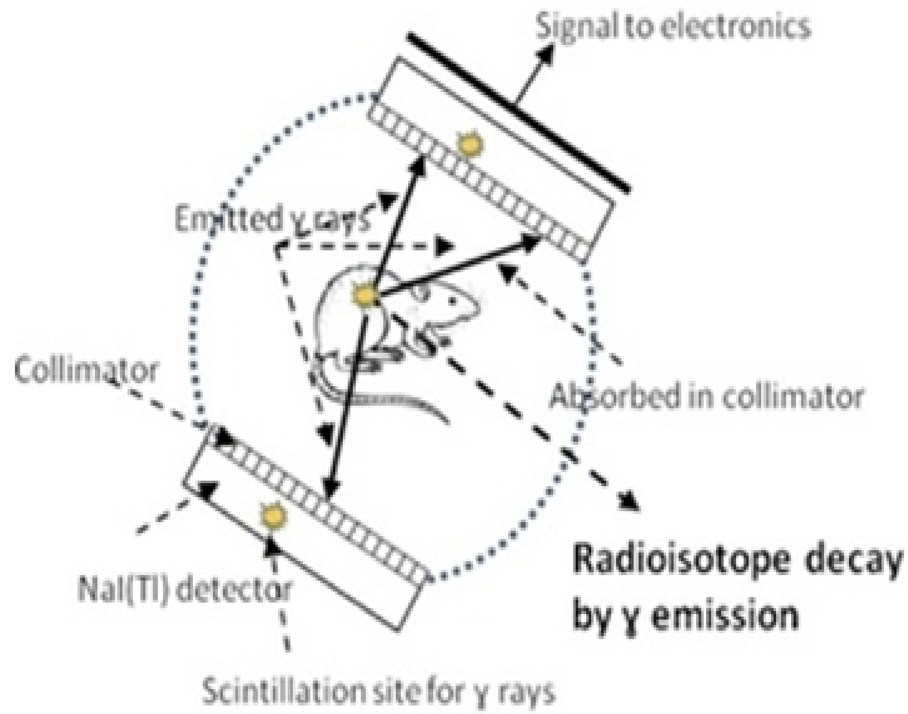
Thank you

Stempel Vielen Dank 63 x 17 mm

Vielen Dank

Teşekkürler

SPECT-CT(Single Photon Emission Computed Tomography)



Systematic principle of SPECT

SPECT

- Diagnostic Radionuclides

  Tc^{99m} In^{111} I^{123}

  6h 2.8d 13h

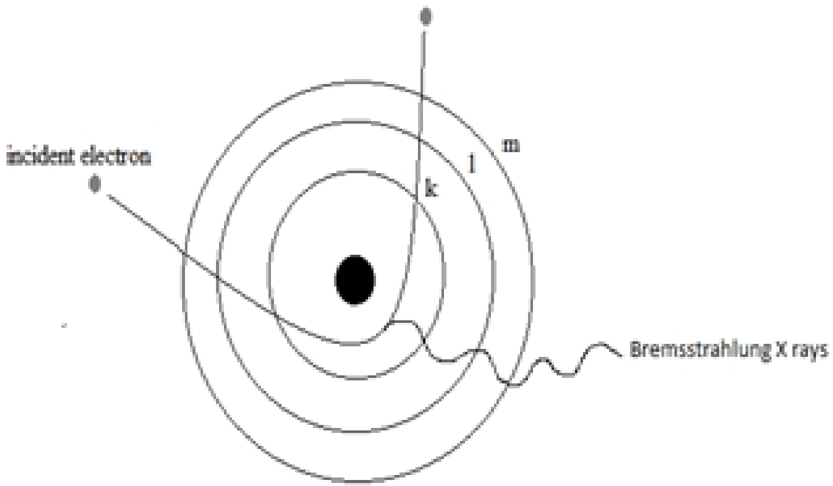
- Diagnostic Radionuclides

  I^{131} Y^{90} Re^{188}

  6h 2.8d 13h

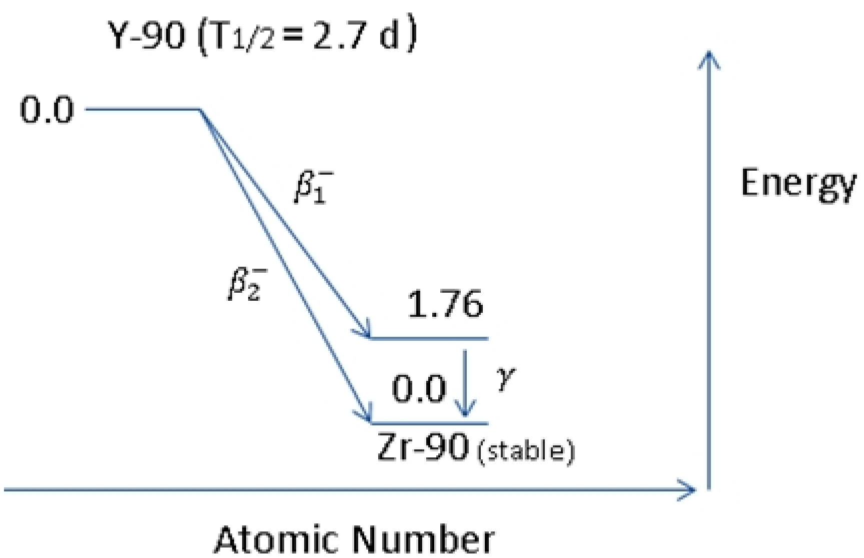
Bremsstrahlung X rays

- continuous x rays emitted through electron-nucleus interactions
- produced by accelerating electrons with high voltage in order to allow them to collide with a metal target X rays. When the electrons suddenly decelerated upon collision with the metal target and lose their energy, then Bremsstrahlung X rays are produced.
- the interaction of β^- particles emitted from Y-90 decay with atomic nuclei in the body produces bremsstrahlung photons.



Y-90

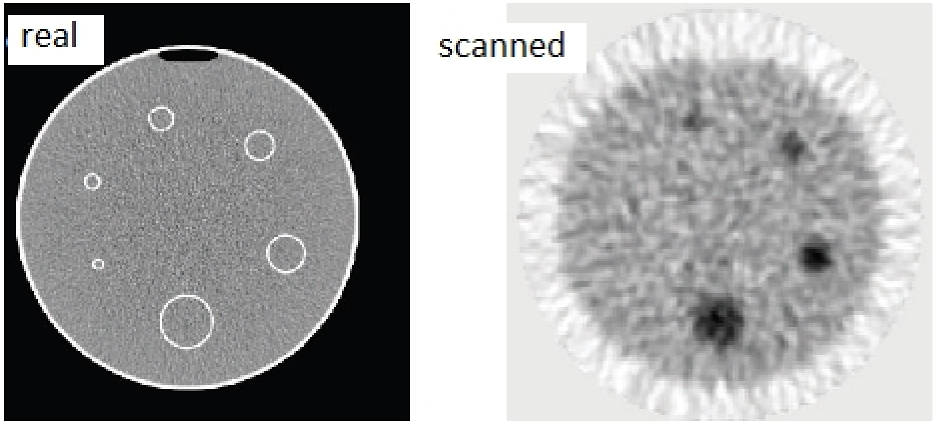
The interaction of β⁻ particles emitted from Y-90 decay with atomic nuclei in the body produces bremsstrahlung photons.

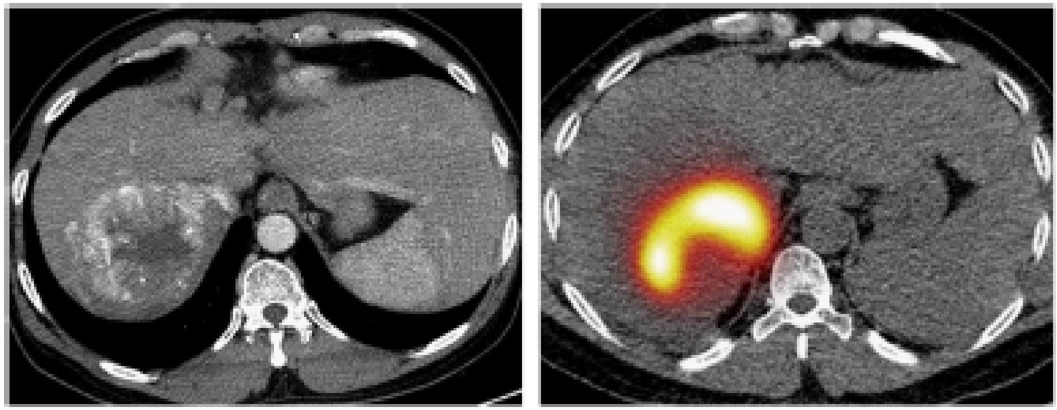


$$Y^{90} \rightarrow Zr^{90} + \beta^- + antineutrino + E$$

Partial Volume Effect (PVE)

Due to limited resolution and spatial resolution of the system





Collimator

- to define the direction of the detected γ rays
- to minimize the scattered photons that created artifacts results in poor image quality