



PET/CT

Bioimaging Master Medical Technology

Ferdinand Seith, MD

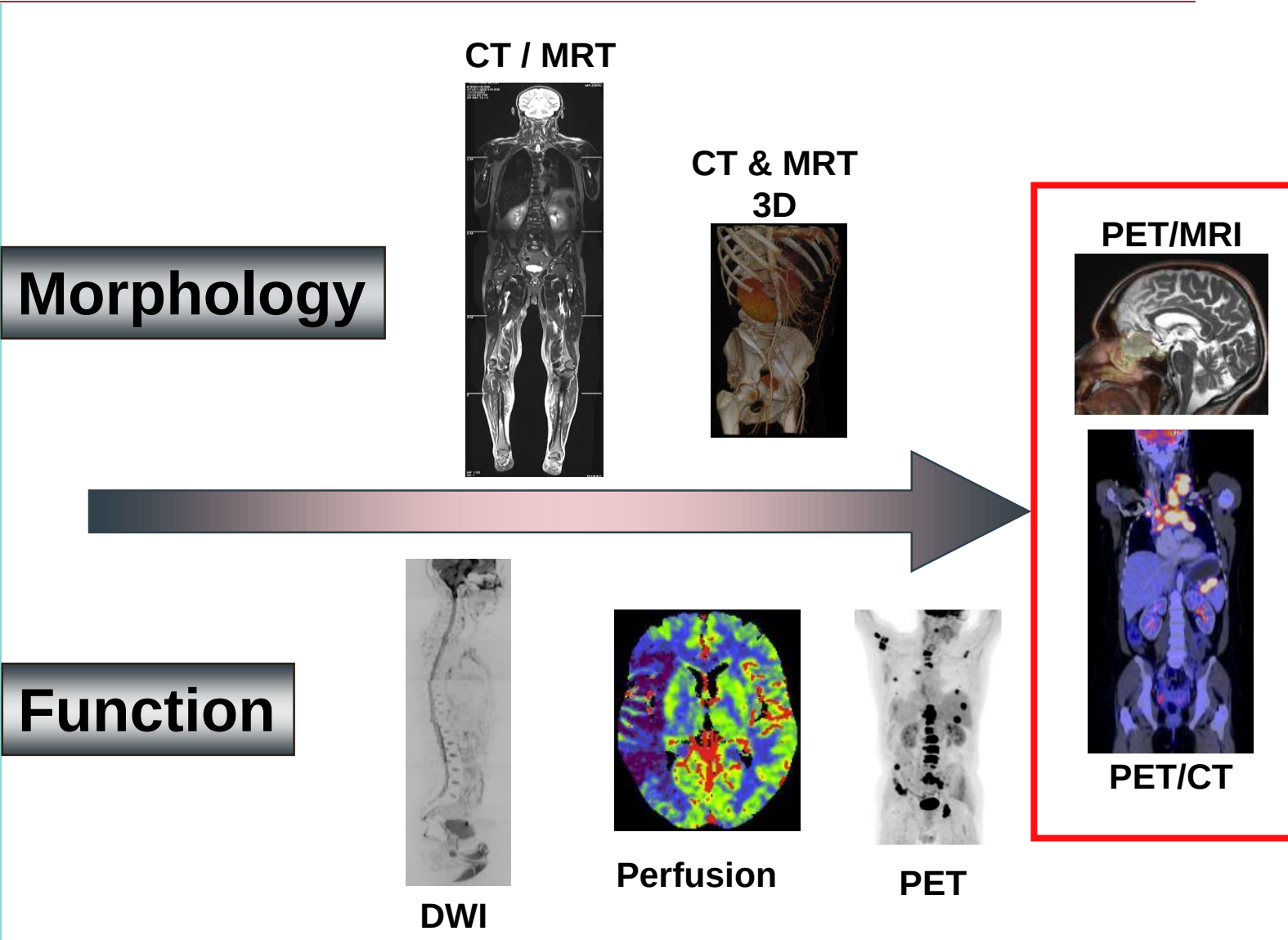
Department of Diagnostic and Interventional Radiology
Head: Prof. Dr. Konstantin Nikolaou



Agenda

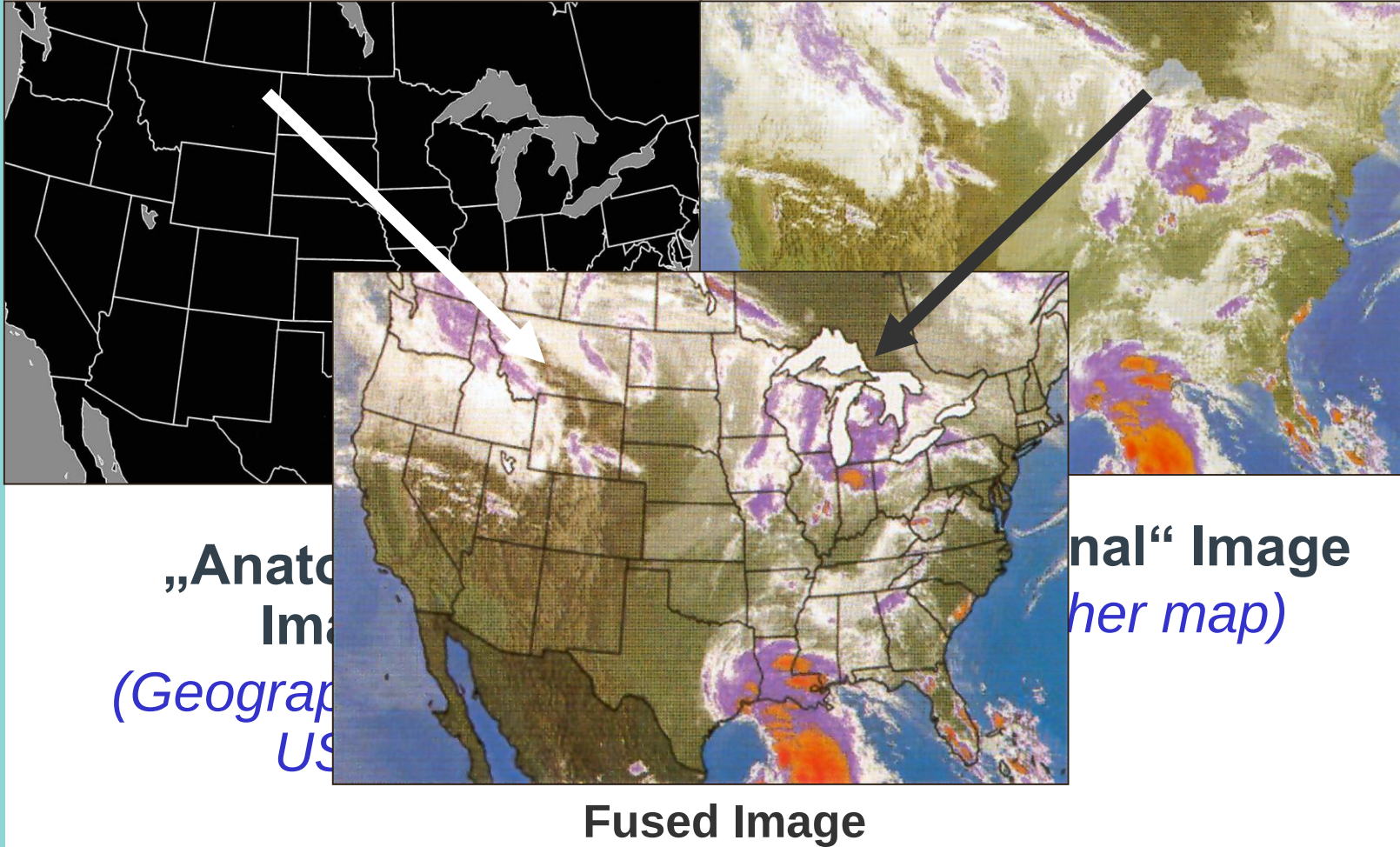
1. Hybrid imaging: Principles of image fusion
2. Positron Emission Tomography (PET)
3. Tracer: Definition, Quantification, Artifacts

1. Hybrid Imaging
2. PET
3. Tracer



1. Hybrid Imaging
2. PET
3. Tracer

Image Fusion: Principle





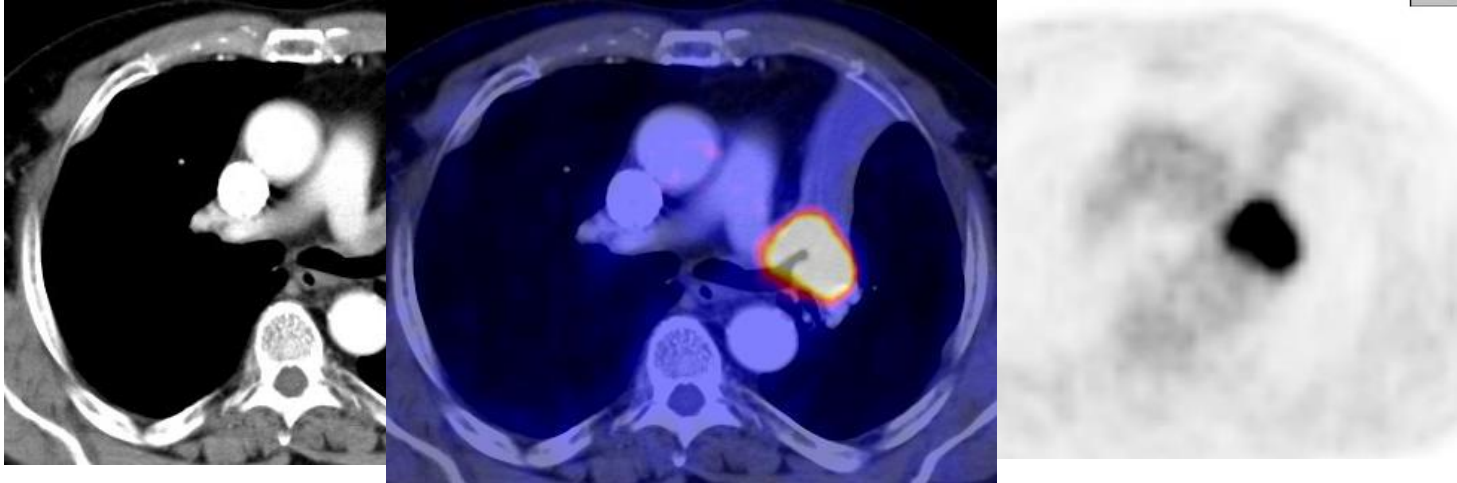
1. Hybrid Imaging
2. PET
3. Tracer

Image Fusion: PET/CT

→ To combine the **high sensitivity and specificity of functional imaging** parameters in molecular imaging with the **high resolution of cross-sectional** images

- 1. Hybrid Imaging
- 2. PET
- 3. Tracer

Image Fusion: PET/CT



PET/CT:

Function

+

High spatial resolution



- 1. Hybrid Imaging
- 2. PET
- 3. Tracer

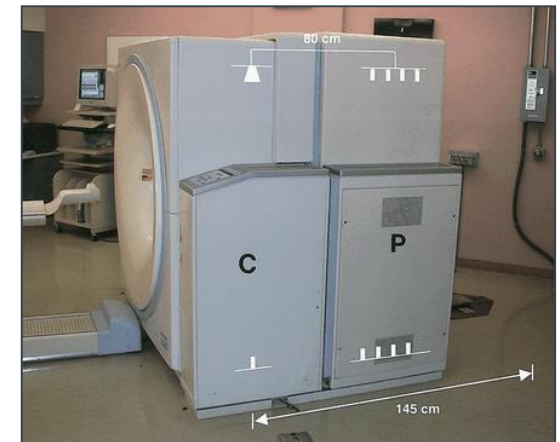
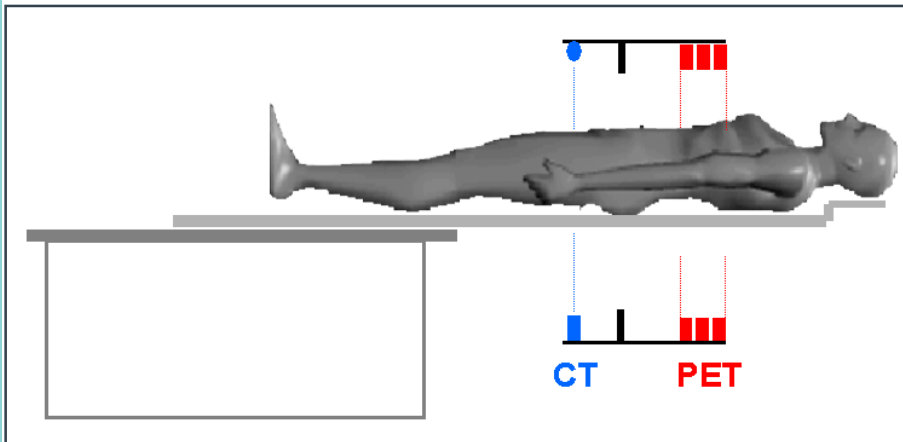
Image Fusion: Levels

- 1. Side-by-Side
- 2. Software fusion
- 3. Hardware fusion

1. Hybrid Imaging
2. PET
3. Tracer

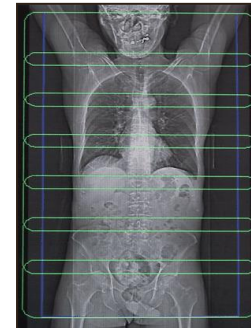
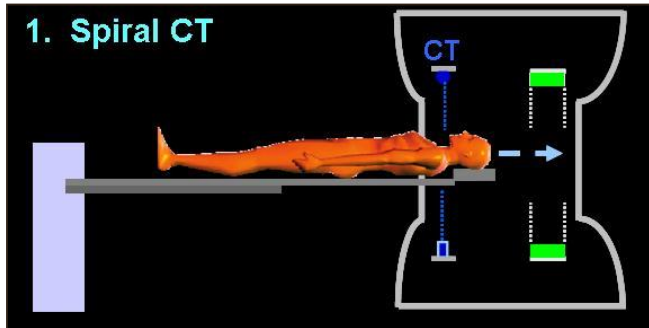
Image Fusion: Hardware Fusion (PET/CT)

PET/CT: One single scanner for the acquisition of PET and CT



1. Hybrid Imaging
2. PET
3. Tracer

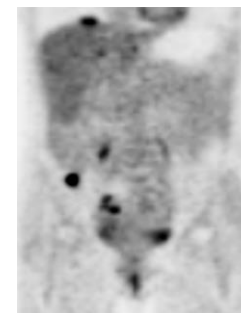
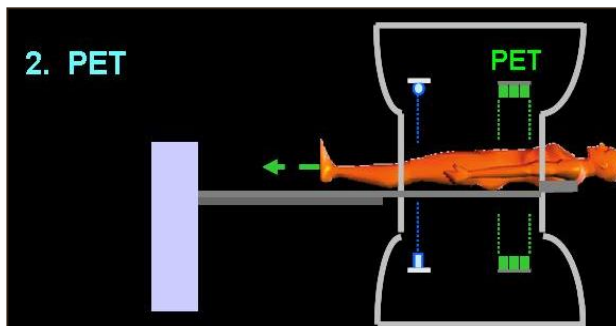
Protocol PET/CT



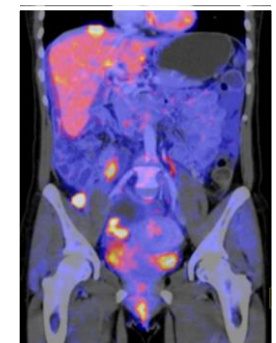
1. Scout



2. CT



3. PET



4. Fusion



- 1. Hybrid Imaging
- 2. PET
- 3. Tracer

Image Fusion: Hardware Fusion (PET/CT)

Advantages

- Only one examination for the patient
- No patient's movements between the two acquisitions
- (Nearly) perfect registration of PET and CT
- Improved attenuation correction compared to single PET-scanners

Challenges

- Technically demanding (software and hardware)
- Expensive (compared to single PET scanners)
- Interdisciplinary teamwork and know-how



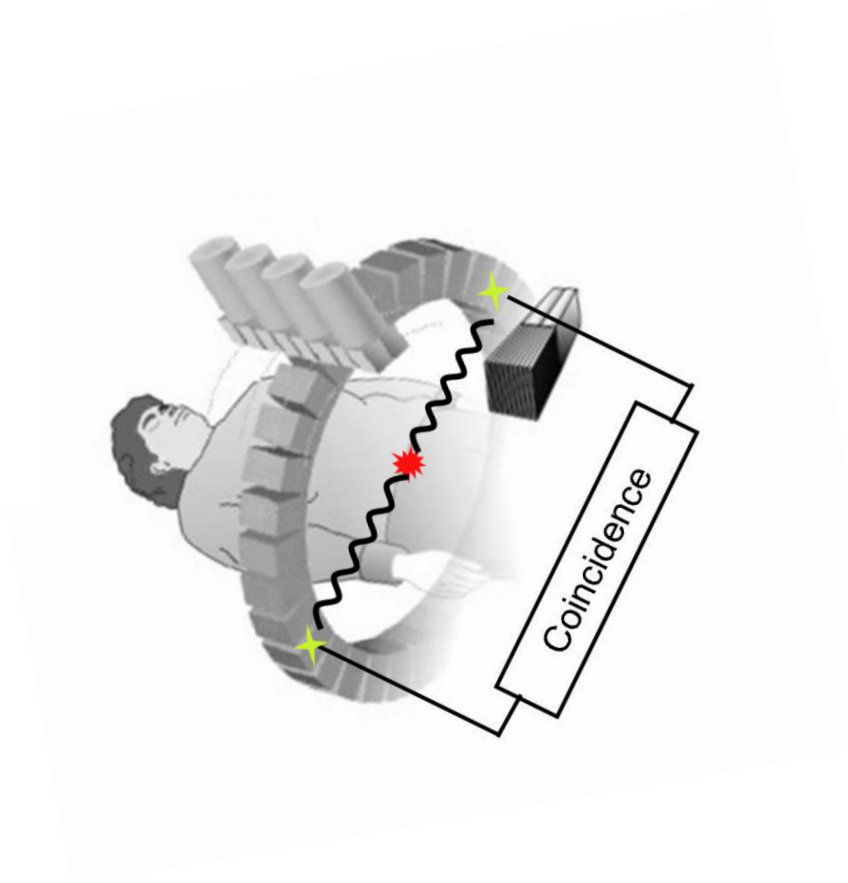
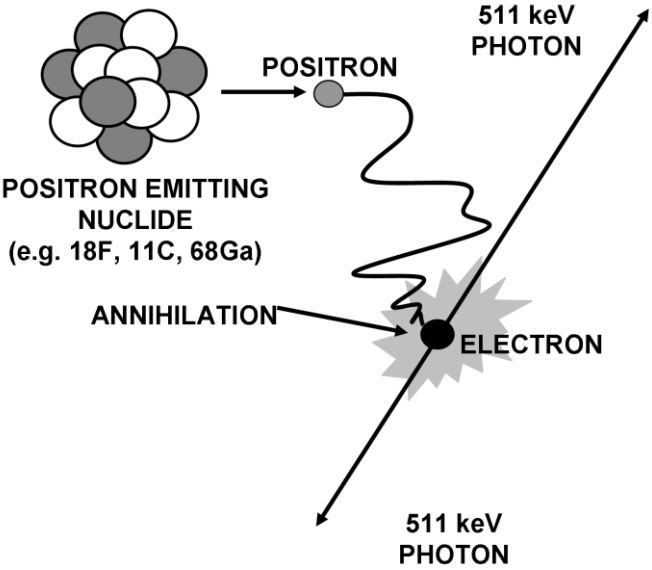
- 1. Hybrid Imaging
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Positron Emission Tomography (PET)

- Intravenous injection of a **radioactively labeled pharmaceutical (tracer)** which marks e.g. surface proteins or is taken up by the cells.
- Uptake time = Time between injection and scan.
Depending on radioactive decay, pharmacodynamics and pharmacokinetics of the tracer
- Imaging the distribution of radioactivity in the body

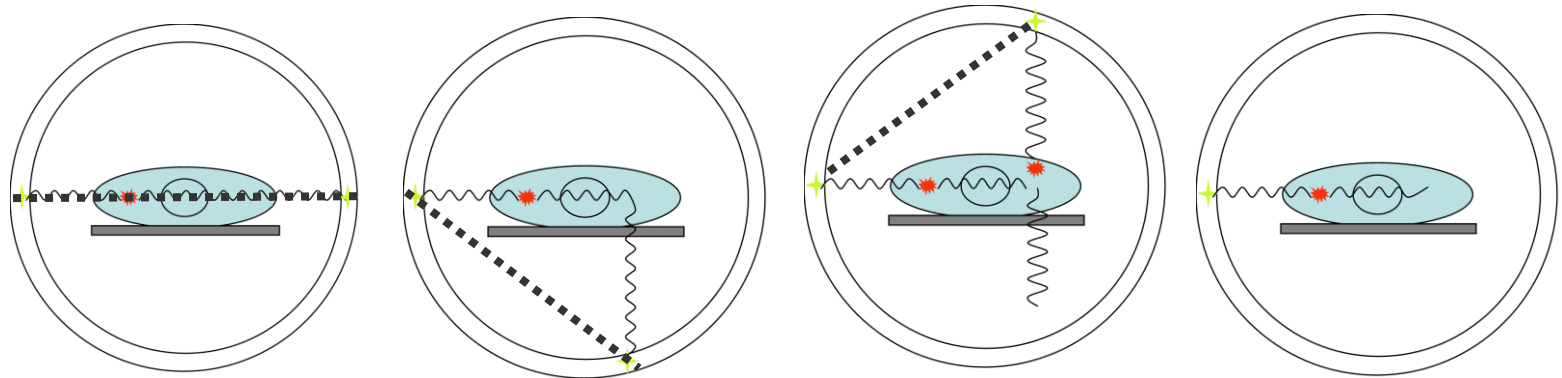
- 1. Hybrid Imaging
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Positronen-Emissions-Tomography (PET)



1. Hybrid Imaging
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Positron Emission Tomography (PET)



True
coincidence

Scattered
coincidence

Random
coincidence

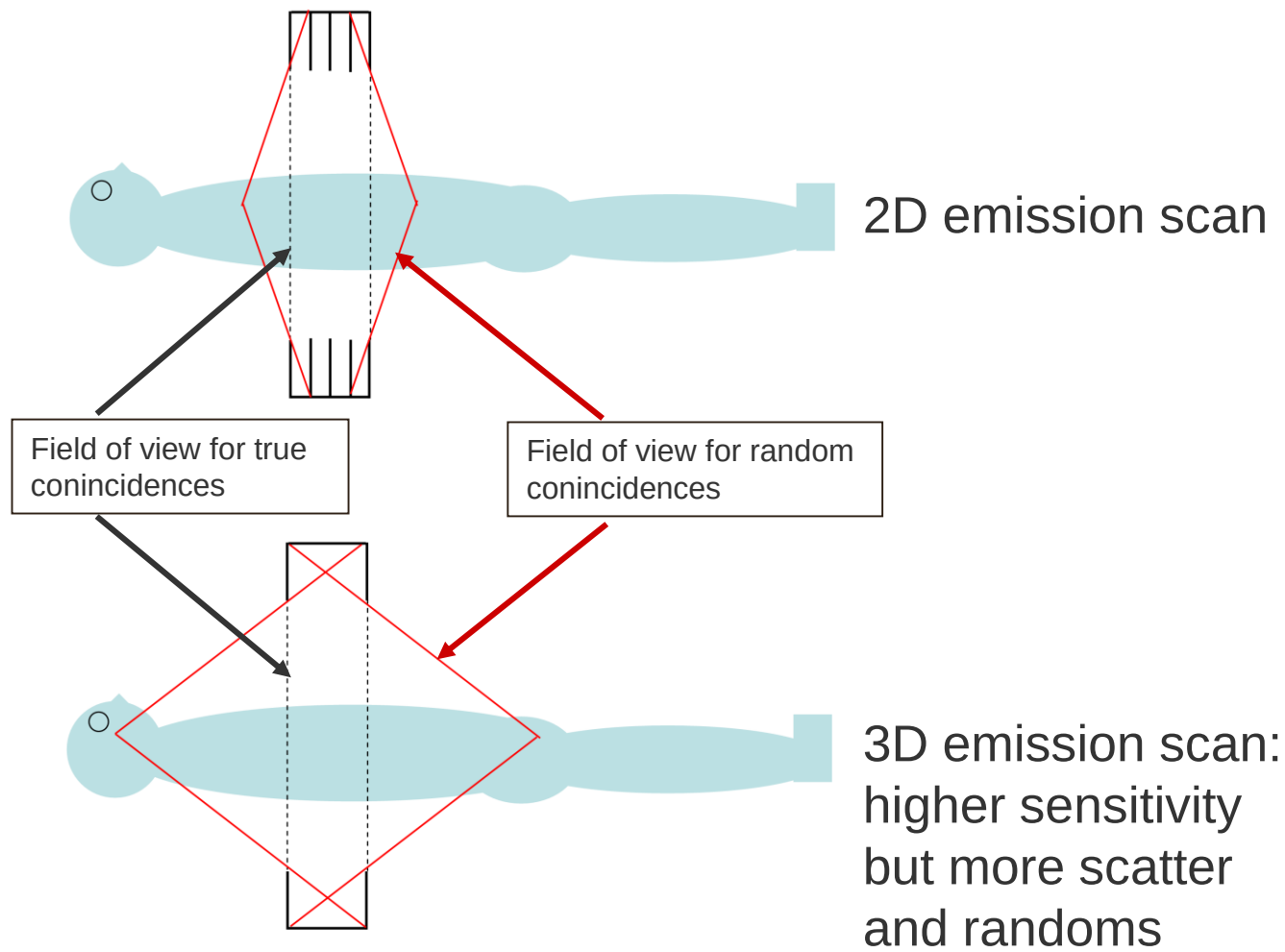
Attenuation

..... Line of response (LOR) ★ Annihilation event ~~~~~ Gamma ray

→ Energy resolution and time resolution of a scanner influence the image quality

1. Hybrid Imaging
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Positron Emission Tomography (PET)

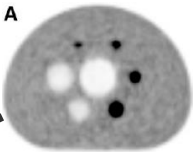


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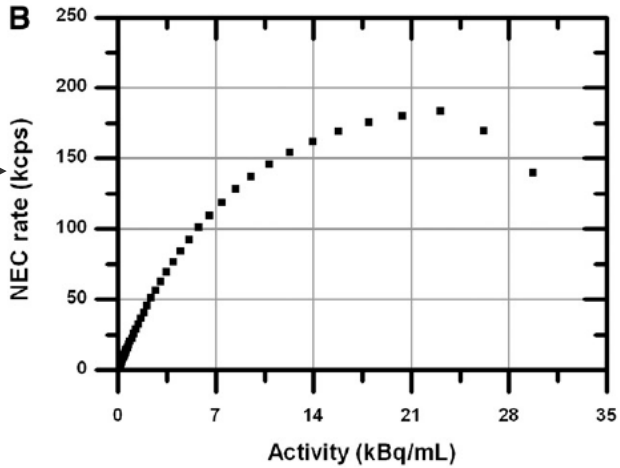
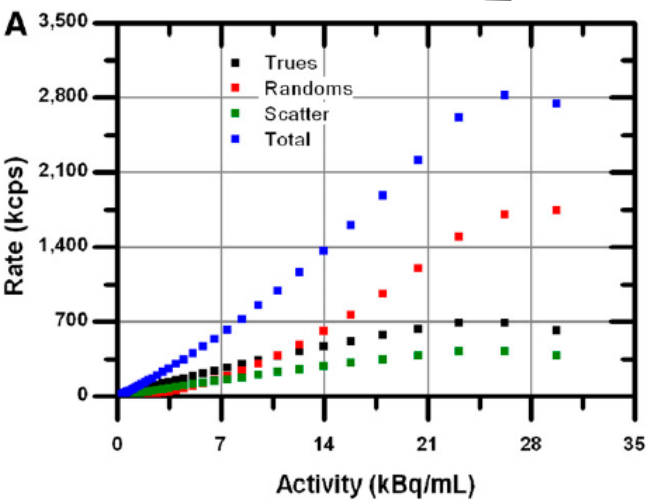
Positron Emission Tomography (PET)

Performance Measurements of the Siemens mMR Integrated Whole-Body PET/MR Scanner

Gaspar Delso^{*1}, Sebastian Fürst^{*1}, Björn Jakoby²⁻⁴, Ralf Ladebeck⁵, Carl Ganter⁶, Stephan G. Nekolla¹, Markus Schwaiger¹, and Sibylle I. Ziegler¹



Phantom study

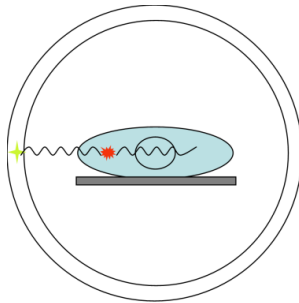


Noise equivalent count rate (NECR)

$$NECR = \frac{T^2}{T+S+2fR}$$

1. Hybrid Imaging
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Attenuation in PET



Attenuation

→ Significantly reduces the number of detected photons

→ Due to Compton scatter out of the detector ring or photoelectric absorption

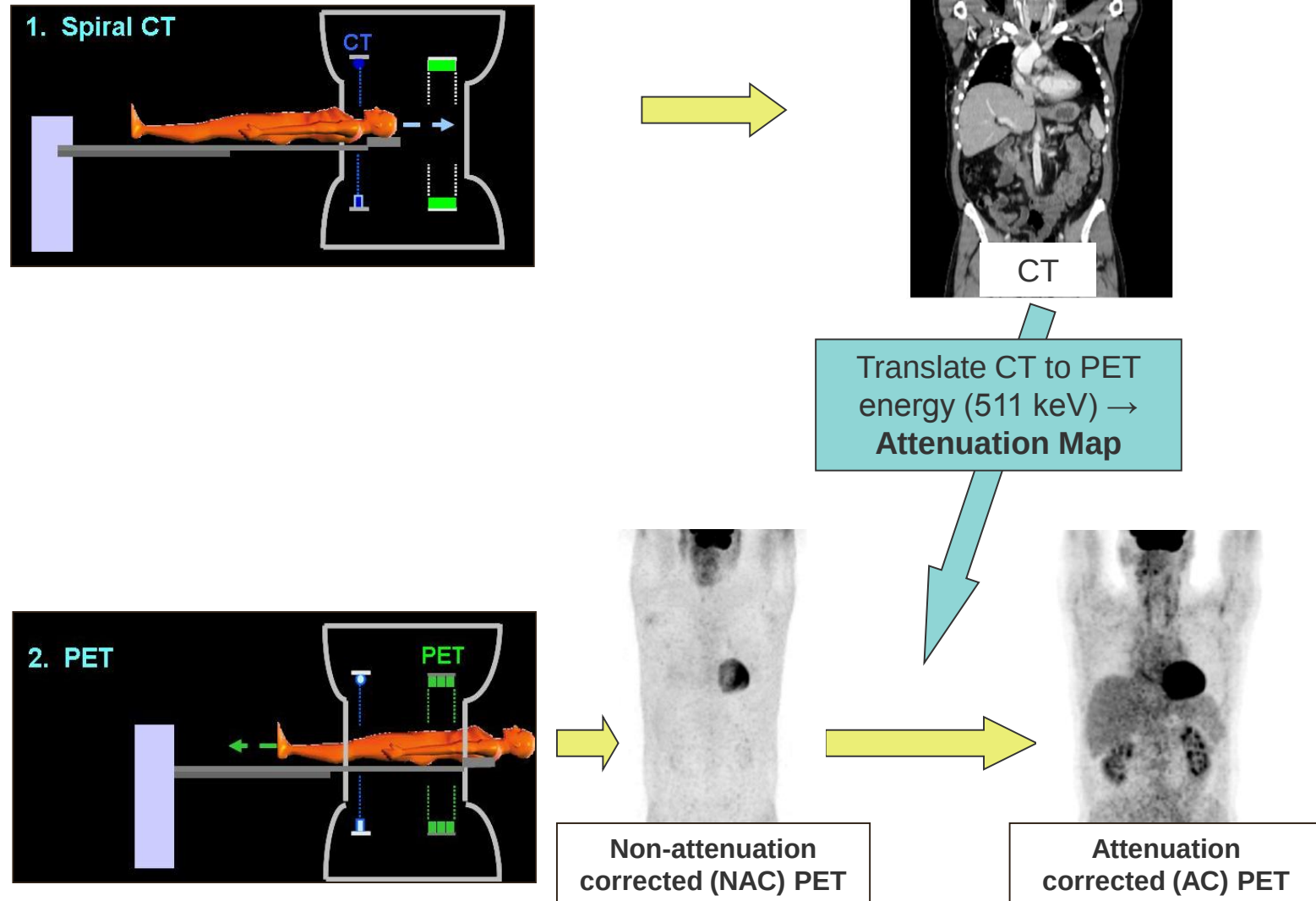
→ Depending on density and anatomic number of tissue / material which is passed by the photon



Attenuation correction

1. Hybrid Imaging
2. PET
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Attenuation correction in PET/CT



1. Hybrid Imaging
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Pitfalls and Artifacts in PET/CT: Positioning

! Artifacts in the CT image and differences in patients positioning between PET and CT might lead to incorrect attenuation correction of PET !

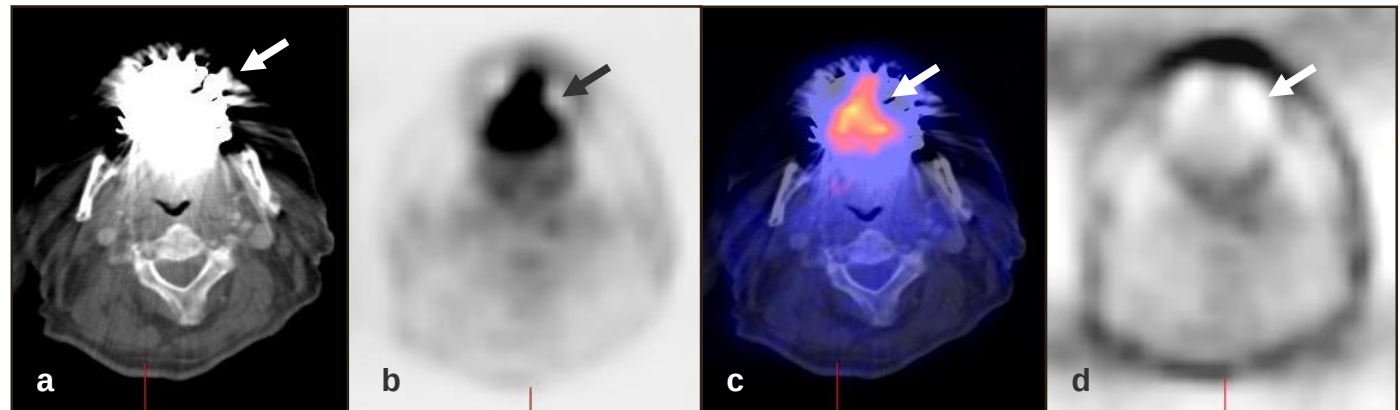
→ Arms positioned above the head

→ Patients positioned in a vacuum mattress



1. Hybrid Imaging
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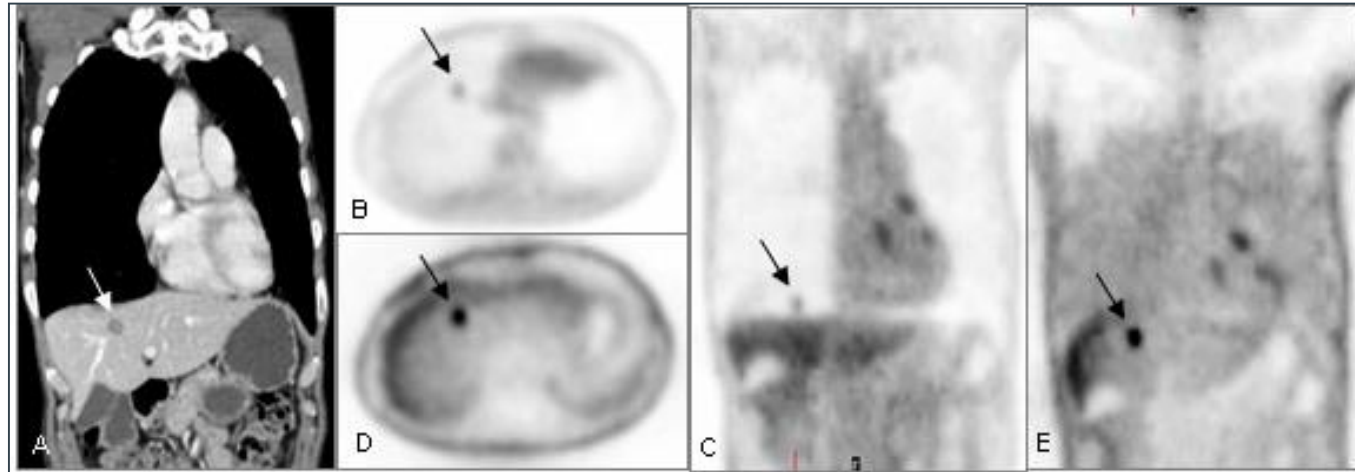
Pitfalls and Artifacts in PET/CT: Metal Implants



Regions with a high density in CT (e.g. high accumulation of contrast media or metal implants) lead to an incorrect quantification of tracer uptake

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Pitfalls and Artifacts in PET/CT: Breathing



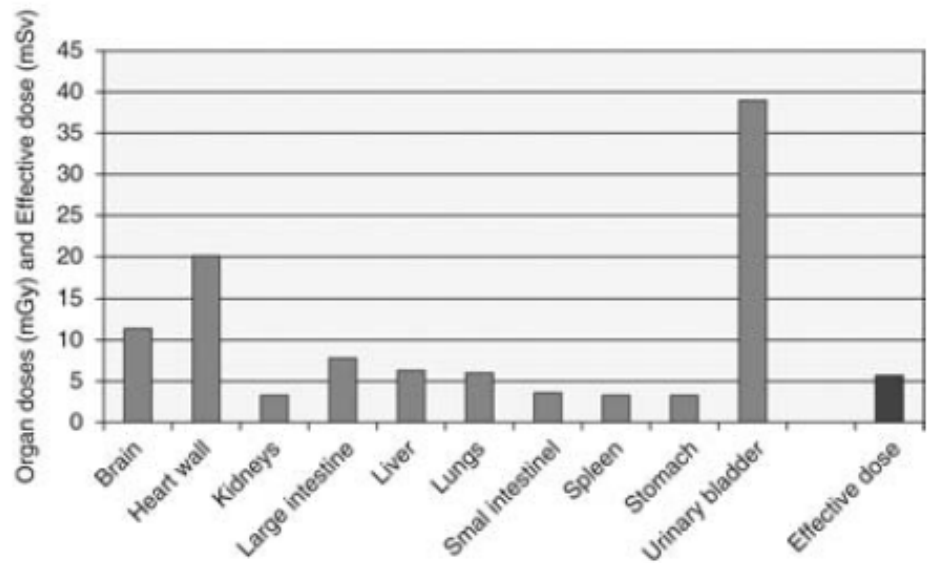
PET is acquired in free breathing. In free breathing, patients are most of the time in expiratory phase. Therefore, CT should be acquired in end-expiratory breath-hold. Artifacts in the upper abdomen can occur if CT is acquired in inspiration.

1. Hybrid Imaging
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Radiation exposure in PET

RADIATION EXPOSURE OF PATIENTS AND PERSONNEL FROM A PET/CT PROCEDURE WITH ¹⁸F-FDG

S. Leide-Svegborn*
Medical Radiation Physics, Department of Clinical Sciences Malmö, Lund University, Malmö, Sweden



Effective dose CT ~ 3x higher (Khamwan et al. 2010)

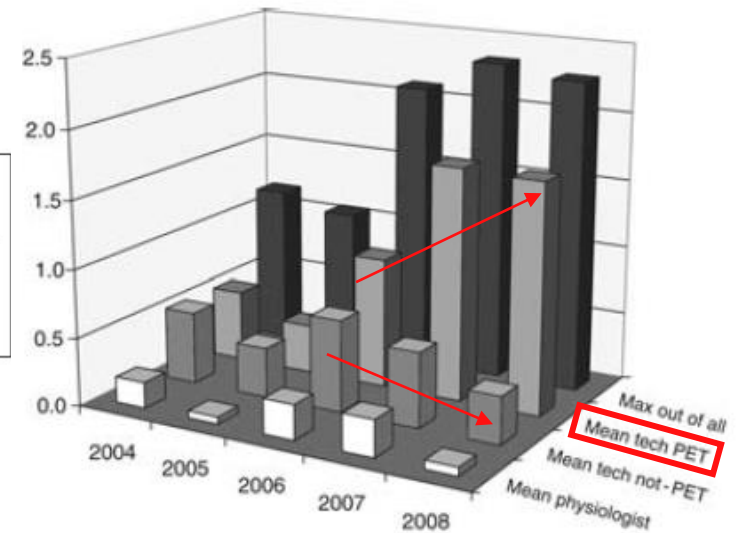
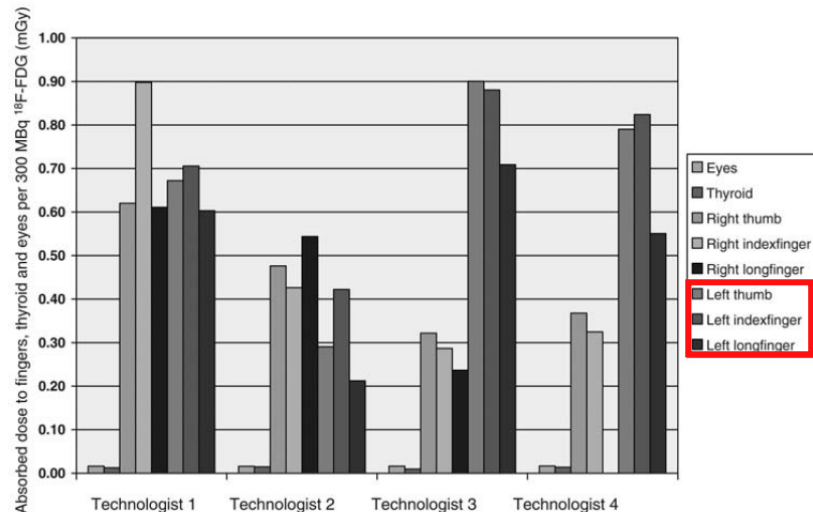
1. Hybrid Imaging
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Radiation exposure in PET

RADIATION EXPOSURE OF PATIENTS AND PERSONNEL FROM A PET/CT PROCEDURE WITH ^{18}F -FDG

S. Leide-Svegborn*

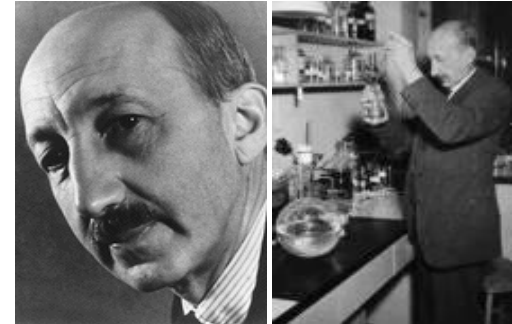
Medical Radiation Physics, Department of Clinical Sciences Malmö, Lund University, Malmö, Sweden



1. Hybrid Imaging
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Tracer: Definition

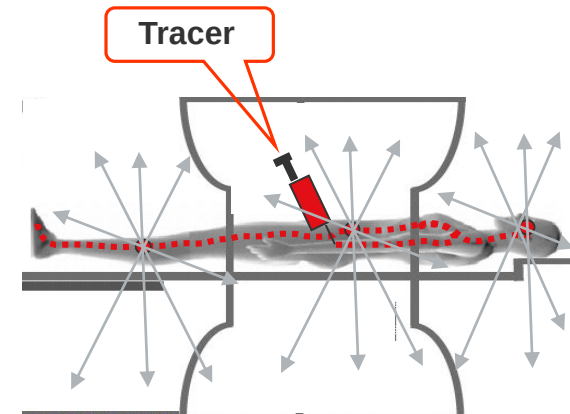
- Radioactively labeled pharmaceutical
- Containing small amounts of radionuclide
- Tracing the path of biochemical reactions
- Radioactive decay can be used for diagnostics



George de Hevesy

Nobelpreis 1943

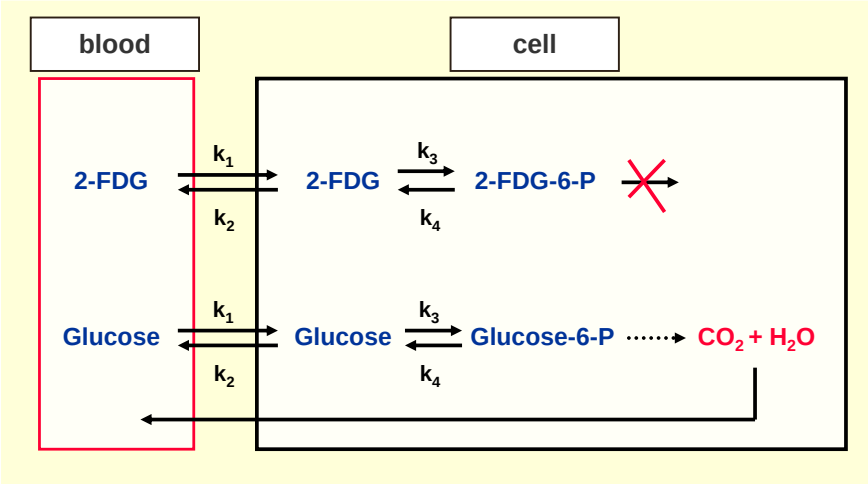
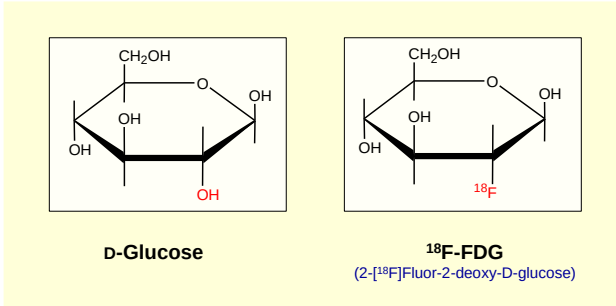
- Short half lives (low radiation exposure)
- non-toxic
- complete elimination
- not influencing natural metabolic processes



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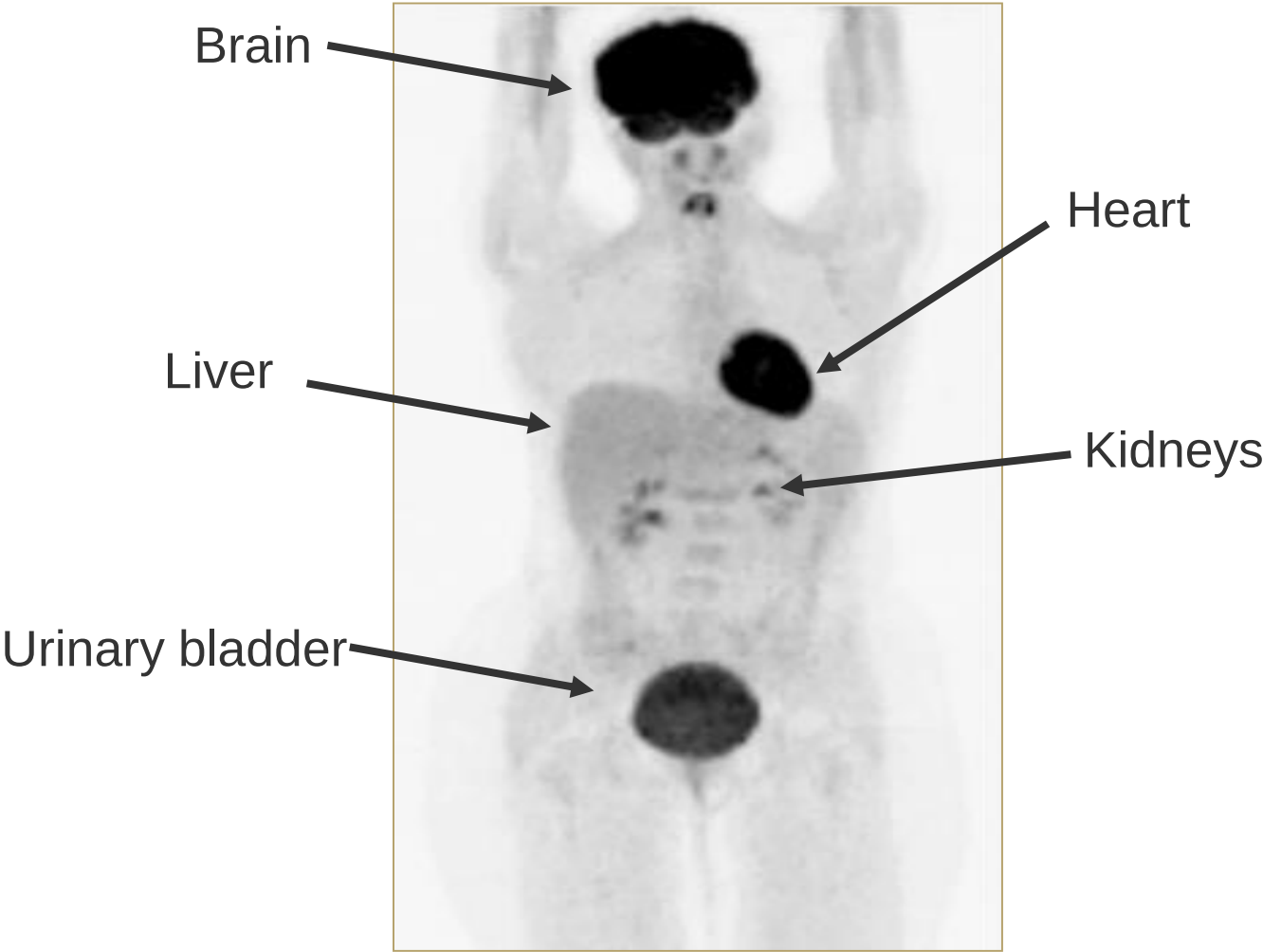
Example: 18F-FDG

- [18F]-labeled fluorodeoxyglucose
- Most widely used tracer in PET
- Taken up by the cell and trapped
- Represents the glucose consumption
- Increased uptake in most tumor types but also in healthy highly proliferating tissue → Not specific



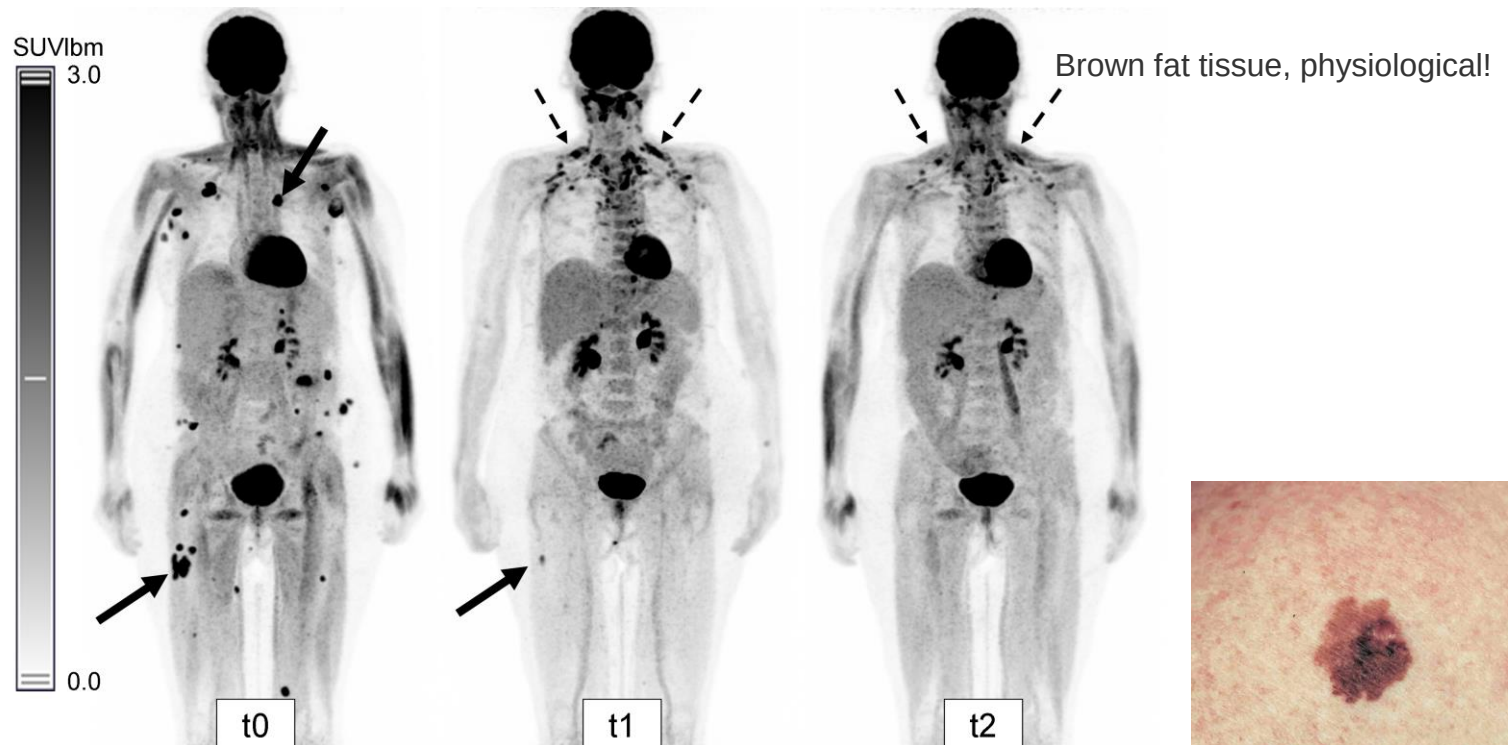
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18F-FDG: Physiological uptake



1. Hybrid Imaging
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3. Tracer

Example: ^{18}F -FDG, Melanoma under therapy



Quelle: Erkrankungen in der Schwangerschaft > Tumoren
Autoren: Claudia Schröder,
Hans F. Merk

1. Hybrid Imaging
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Example: 68Ga-DOMITATE / DOTATATE / DOTATOC

- Radiolabeled peptide
- Somatostatin receptor (SSR) specific radiotracer
- Well differentiated neuroendocrine tumors (NET) express SSR
- Information from PET can be used for therapy planning: peptide receptor radionuclide therapy (PRRT)

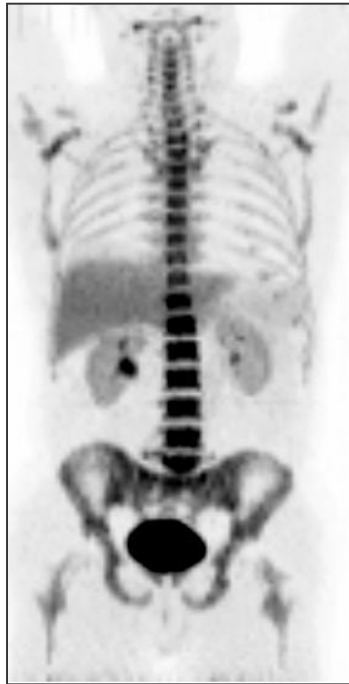


metastases

Physiological uptake

1. Hybrid Imaging
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... and further tracers to detect e.g.



cellular
proliferation

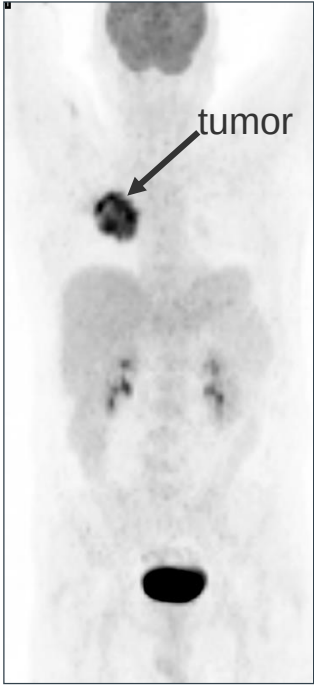


membrane
synthesis

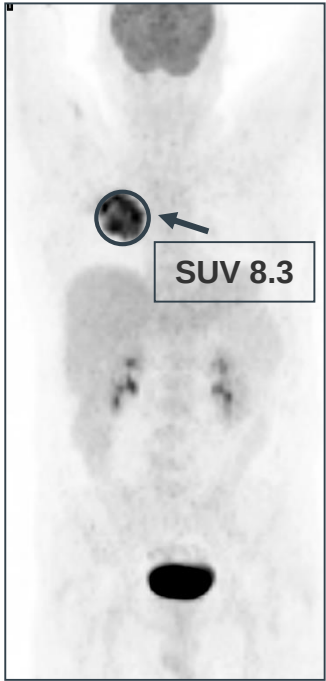
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Evaluation of PET

Visual interpretation



(Semi) Quantitative evaluation



Quantification of tracer uptake: **Standardized Uptake Value (SUV)** =
A ratio of measured radioactivity in the investigated volume and the injected radioactivity, corrected with the uptake time, the half life of the radionuclide and the body weight / lean body mass / body surface of the patient.



Thank you