

First clinical experience with a long axial FOV PET/CT

The NM physician perspective

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groningen

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University Medical Center Groningen

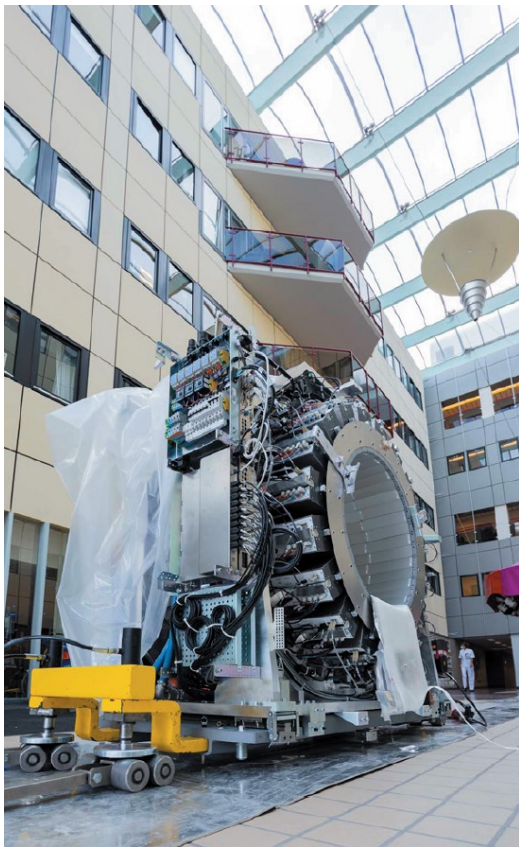
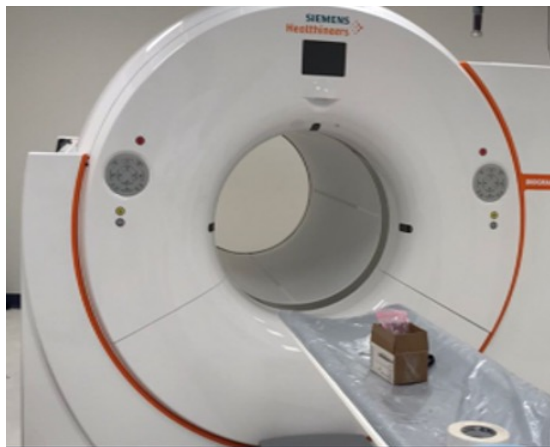
Disclosures

- Siemens Healthineers: independent research grants
- Pfizer: independent research grants

Total Body/LAFOV PET-CT Groningen, NL

2 September 2021





Introduction

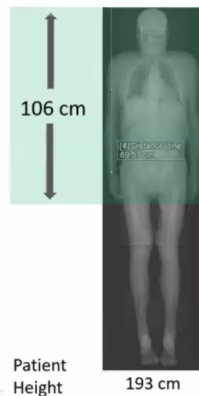
- Biograph Vision Quadra PET/CT
 - 4 interconnected Biograph Vision systems
 - 32 rings of 38 detector blocks per ring
 - 243,200 crystals coupled to 155,648 SiPM detector elements
 - Long axial field of view (LAFOV) of 106 cm



QUADRA PET/CT

Long axial field of view (LAFOV)

- LSO scintillator
- 106 cm axial PET FOV
- 78 cm bore
- 3.2 mm LSO pixel elements
- 223 psec TOF
- Water cooled
- Cantilever bed design
- SOMATOM® Definition Edge 128-slice CT
- CT low-dose tin filter
- Fits in a standard PET/CT room size



Clinical and research feature development¹

- HD•Chest to OncoFreeze™ AI
- Step-and-shoot to FlowMotion™ AI
- Single bed FoV dynamic imaging to whole-body dynamic imaging
- Manual multiparametric PET to automated Multiparametric PET AI

Before installing: Clinical and board support

- Questionnaire hospital
- Support letters of involved departments
- List of new possibilities for both clinic and medical research
- Approval hospital management

Business & financial plan

- Purchase: high costs
- Clinical and research applications
 - Dose/time reduction
 - Personnel
 - Contract research
- Rebuilding costs



 **Financial PLAN**

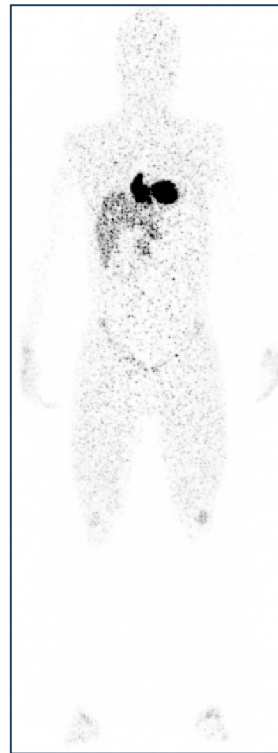
Infrastructure LAFOV/TBPET

- Required information infrastructure for any PET/CT scanner or a clinical PET centre: the International Atomic Energy Agency (IAEA) Human Health Series Applications
- Care should be taken to ensure that the additional weight, length, electricity supply, shielding of the wall
- Data storage (dynamic imaging, terabytes per hour of scan time)
- Access radial artery for blood sampling limited

Better Images

- > 10-fold improvement in SNR
 - Reconstruct at higher spatial resolution
 - Significantly improved image quality
 - Detect smaller lesions
 - Detect low-grade disease
 - Better statistics for kinetic modeling

$$\begin{array}{ccccc} 106 \text{ cm} & & \leq 228 \text{ ps} & & 10\text{x} \\ \text{larger axial PET} & + & \text{timing} & = & \text{effective} \\ \text{field of view} & & \text{resolution}^1 & & \text{sensitivity} \\ & & & & \text{gain}^2 \end{array}$$

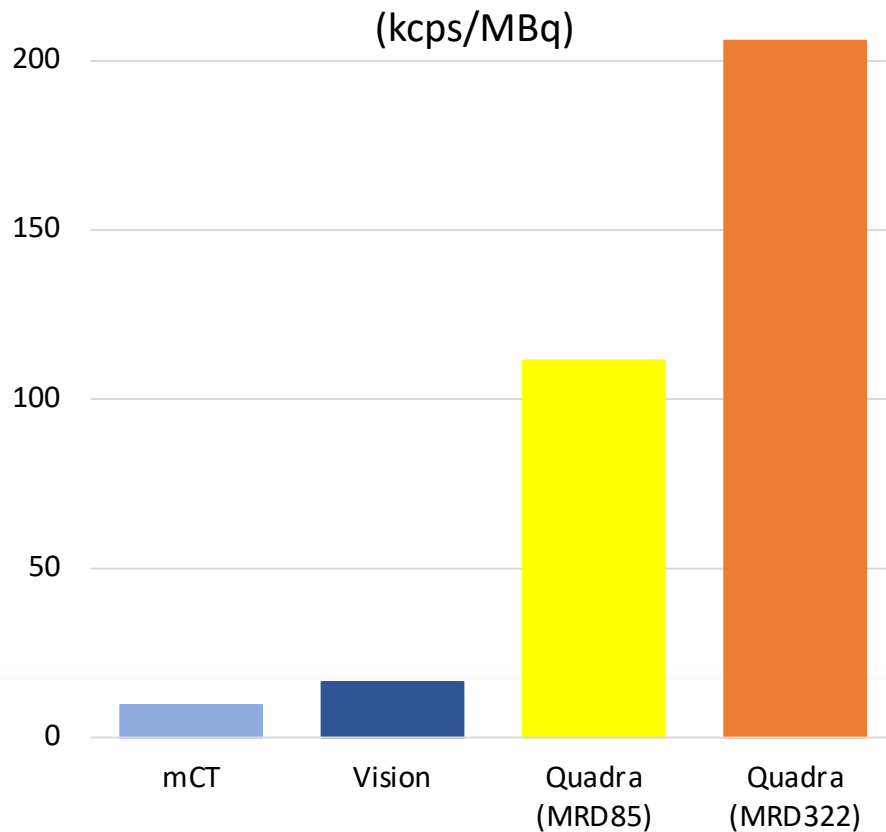
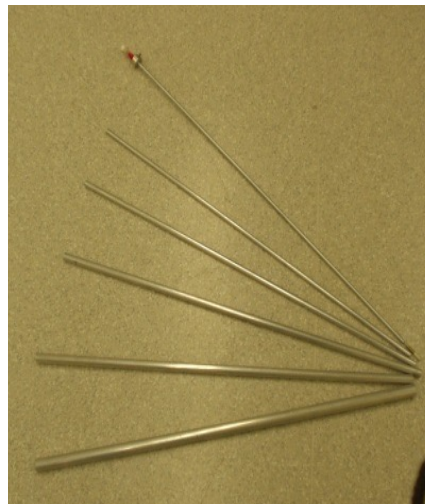


Conventional PET



TBPET

Performance: sensitivity

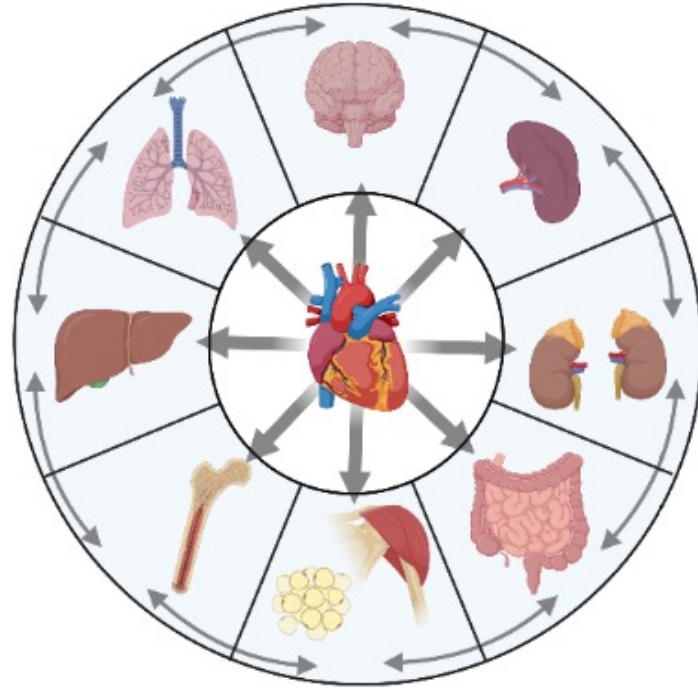


More and new clinical applications

- High patients' throughput / radiation reduction & costs
- Guided-therapy: monitoring therapy effect
- Pediatrics
- Intensive care
- High-risk population screening
- Long-living isotopes in oncology & other

New TBPET research applications

- Drug development/dynamic imaging
 - Drug monitoring
- Guided-therapy: paramapping
- Organ axes: systemic interaction
- Minimal risk new populations:
 - Pediatric, young patients
 - Normal controls
 - Long-living isotopes



QUADRA UMCG

- QUADRA: ~10-15 scans/day
 - Mainly clinical
 - Includes also dynamic imaging
 - Running research projects



Opportunities & Challenges



Long axial field of view PET scanners: a road map to implementation and new possibilities

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Abstract

In this contribution, several opportunities and challenges for long axial field of view (LAFOV) PET are described. It is an anthology in which the main issues have been highlighted. A consolidated overview of the camera system implementation, business and financial plan, opportunities and challenges is provided. What the nuclear medicine and molecular imaging community can expect from these new PET/CT scanners is the delivery of more comprehensive information to the clinicians for advancing diagnosis, therapy evaluation and clinical research.

Table 1 Opportunities and challenges of long axial field of view PET scanners

New opportunities	Challenges
Improved image quality and high signal to noise • Decrease population sampling size which will lead to faster translation of new/existing radiotracers • No need for post-filtering • Reconstruct images at smaller voxel size • Measure/correct motion using PET data • Increase specificity/sensitivity • Increase reproducibility • Detect low-grade uptake • Detect disease at earlier stages	• Amend standardisation values/harmonisation • Substantially non-uniform sensitivity along the axial field of view
Short imaging protocols • High patient throughput • Avoid anaesthesia in children • Scan ICU patients • Reduce motion artefacts • Reduce patient inconvenience and consequently increase compliance • Increase screening high-risk but otherwise healthy individuals	• More hot uptake rooms needed
Imaging with lower doses (as many more otherwise lost counts can be measured) • Imaging radiosensitive populations (paediatrics, pregnant women) • Imaging larger populations which will lead to faster translation of new/existing radiotracers and better understanding of health/disease • Less affected by radiophobia, which will help replace other diagnostic procedures • Use radiotracers with poor labelling efficiency or low positron emission branching ratio • Wider acceptance for use in clinical trials • Imaging the same patient more sessions, which will lead to frequent/accurate therapy evaluation	• Still requires CT for attenuation correction, which poses a significant limit to dose reduction (unless CT scan is avoided.) • Intrinsic ^{176}Lu radiation adds background noise
Imaging kinetics with greater temporal range • Imaging slower biological processes (e.g. radionuclide therapy and immunotherapy) • Imaging faster biological process due to higher temporal sampling • Imaging biological processes for much longer half-lives of the radiotracer • Derive accurate input function from short frames • Extract more relevant/valuable information from one scan • Increase specificity/sensitivity • Increase reproducibility • Identify input function delay in different organs • Enabling imaging more than one tracer simultaneously	• Require accurate motion correction • Require input function • Require metabolites • Require appropriate kinetic model due to kinetic heterogeneity • Slow computational times for reconstruction, data corrections and kinetic modelling
Imaging longer axial FOV • Imaging multiple regions at the body and investigate potential correlations • Biodistribution of newly developed (potentially radiolabelled) drugs • Improve accuracy of dose estimation for radionuclide or other radiomolecular therapies • Measure input function from aortas	• Requires checks of structural limits of the floor • Expensive (when compared to conventional PET) • May require bigger space • Makes difficult to withdraw blood samples or other interventions during the scan • Claustrophobic patients will be harder to scan • Increases environmental footprint • Adaptation of current QA procedures with longer phantoms which can be more difficult and time-consuming to handle • Data storage and networking infrastructure • If it replaces several conventional scanners or breaks, no other scanners available

Image Gently (Low Dose)

- 10-fold reduction in dose
 - Whole-body PET at ~ 0.5 mSv
 - Annual natural background: 2.4 mSv
 - PET can be used with minimal risk – new populations



Conventional PET



TBPET

Delayed Imaging

- 10-fold greater dynamic range
- Can image for 5 more half lives
- $^{11}\text{C} > 3$ hours
- $^{18}\text{F} > 18$ hours
- $^{89}\text{Zr} > 30$ days



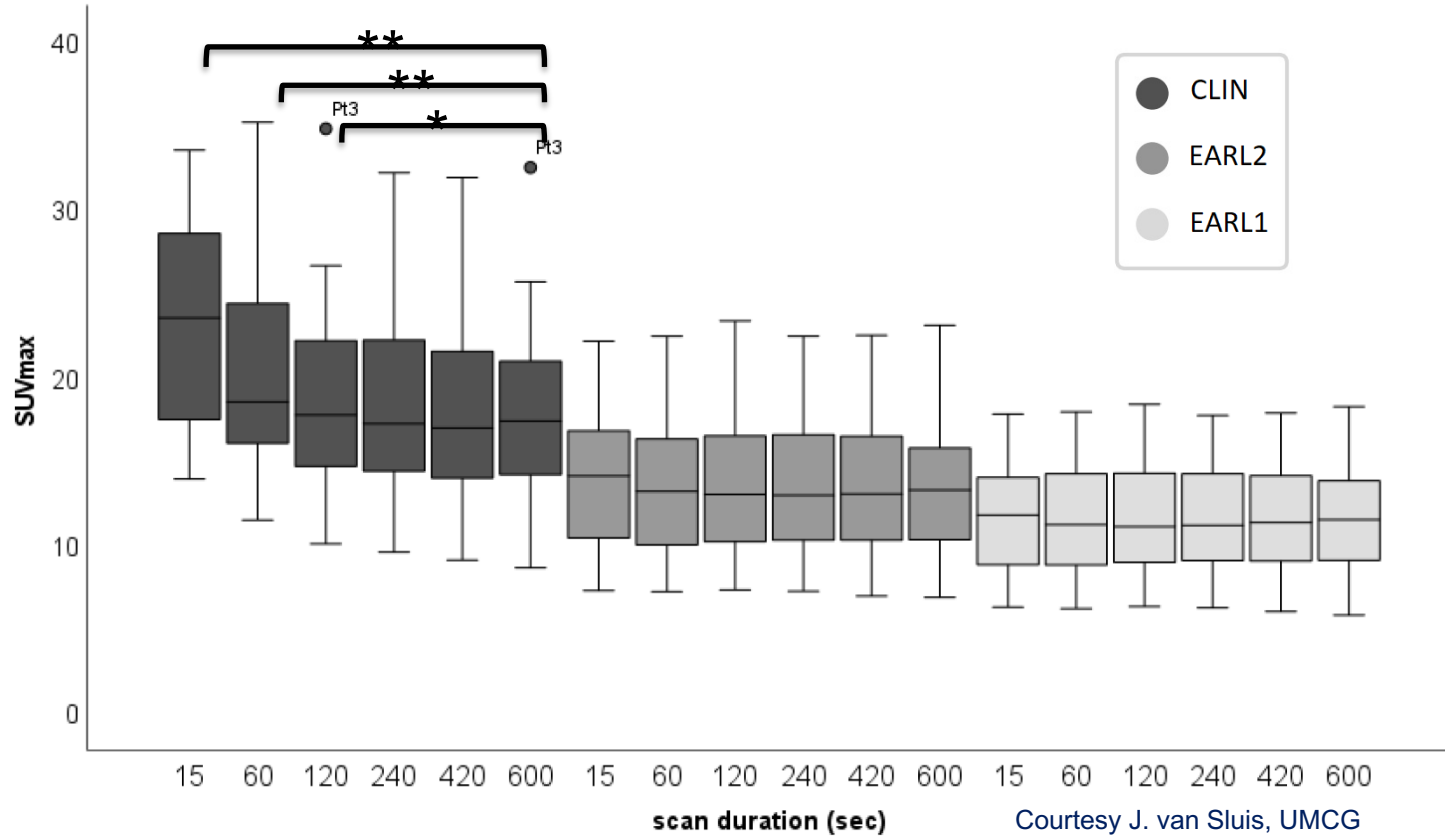
Conventional PET



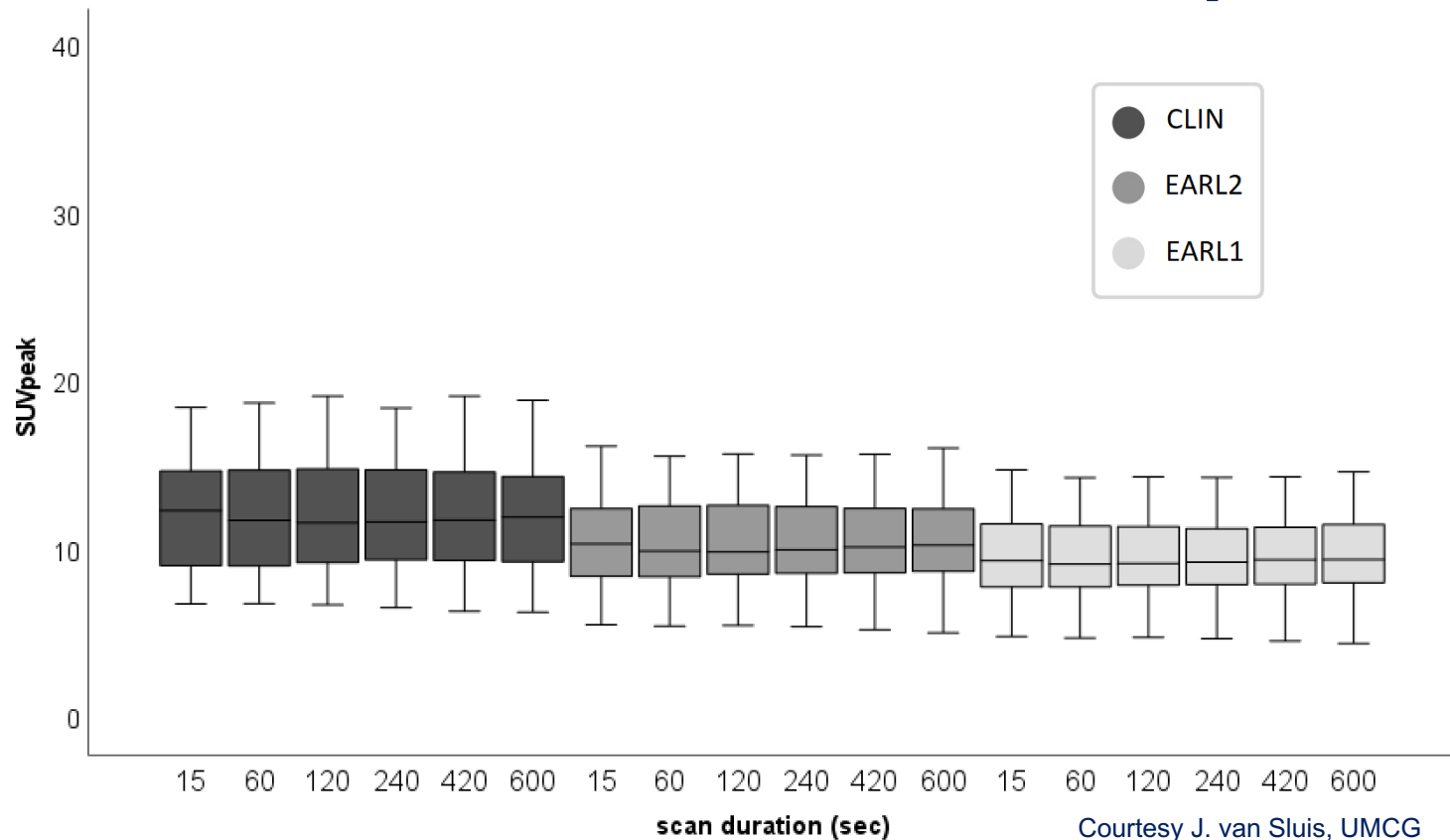
TBPET

Quantification & Kinetic Modeling

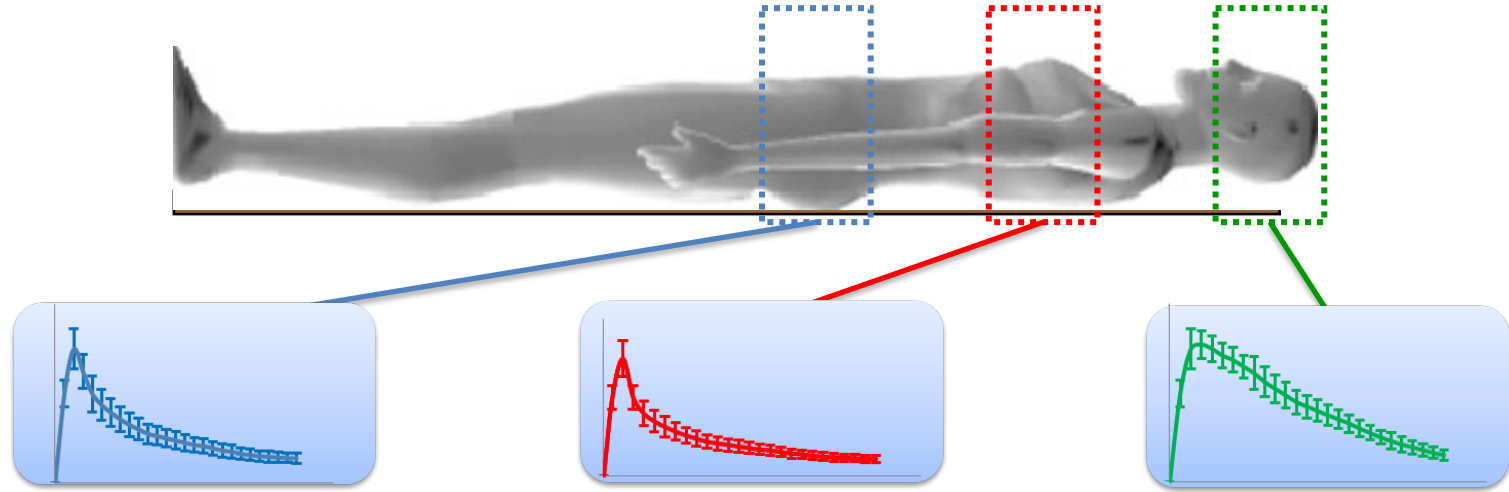
Various scantimes: lesion SUVmax



Various scantimes: lesion SUVpeak

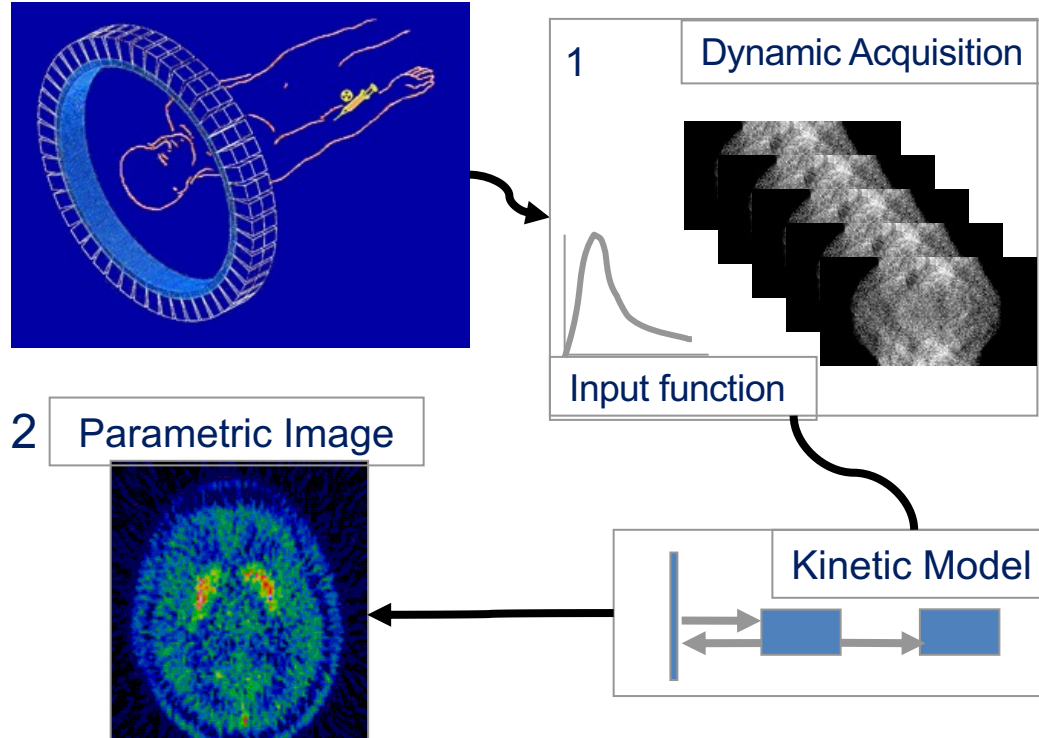


This could promote routine dynamic PET scanning as a quantitative tool for the clinical and scientific field

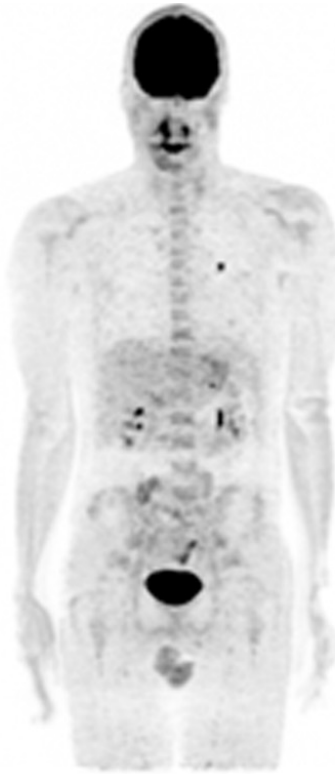


“Tracer evaluation for the whole body”

Dynamic studies for quantification/reconstruction



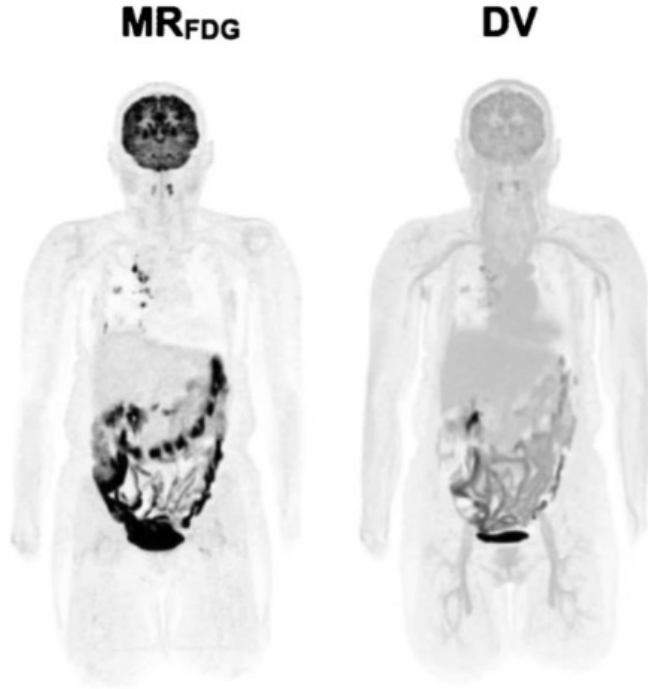
Dynamic ^{18}F -FDG PET



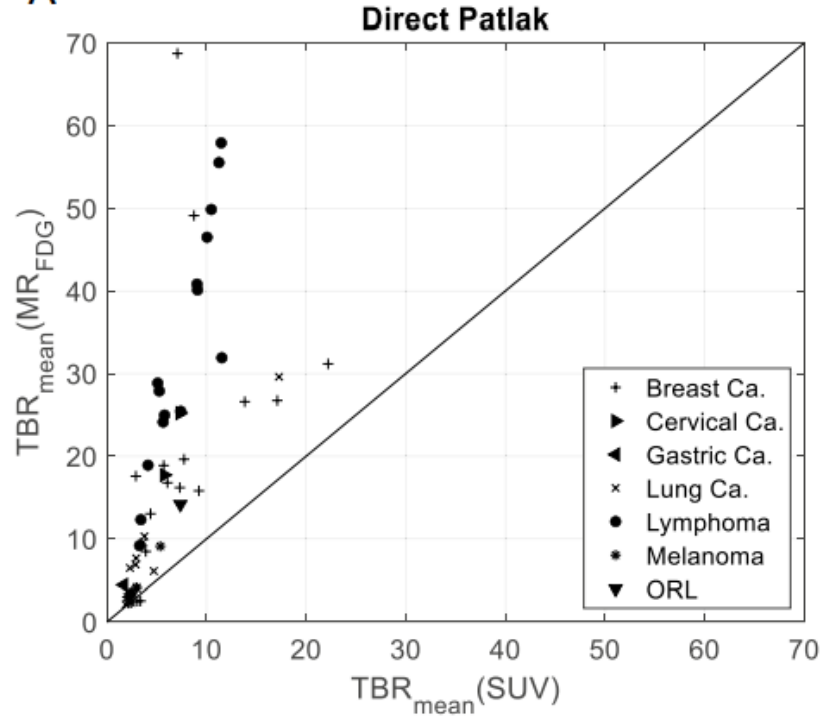
Activity concentration (SUV) Metabolic rate (K_i) Distribution Volume (DV)

Highest TBR (3x) with Patlak

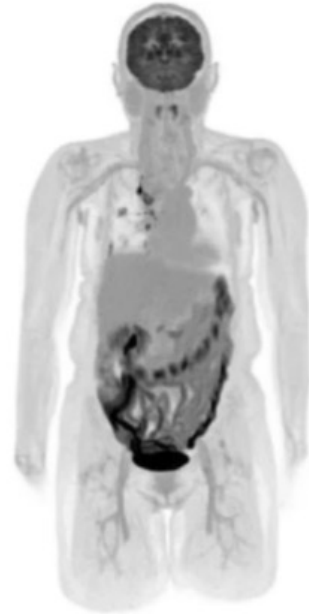
Direct Patlak



A



SUV



Dynamic [^{18}F]FDG PET – Patlak with PIF

[^{18}F]FDG PIF tested on Quadra data:

van Sluis *et al. EJNMMI Physics* (2022) 9:74
<https://doi.org/10.1186/s40658-022-00504-9>

EJNMMI Physics

ORIGINAL RESEARCH

Open Access

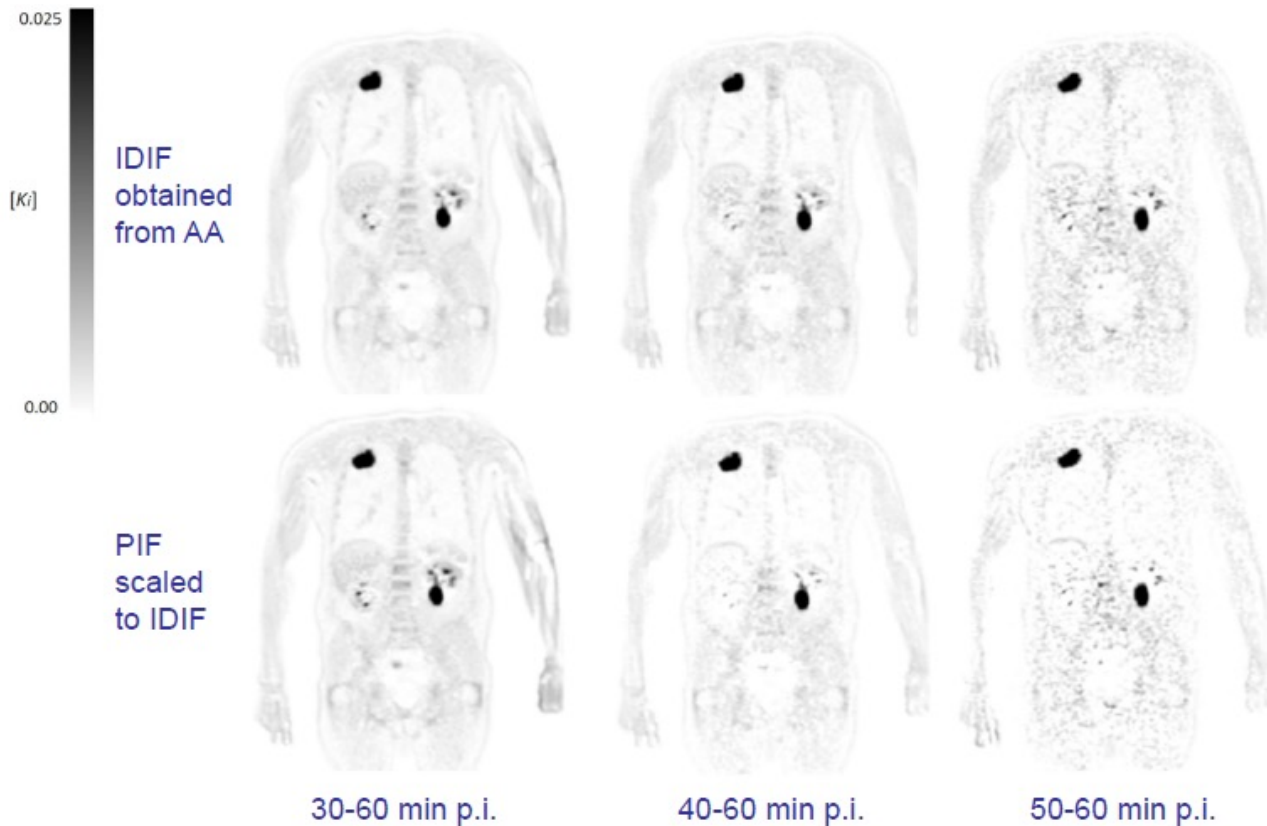
Shortened duration whole body ^{18}F -FDG PET Patlak imaging on the Biograph Vision Quadra PET/CT using a population-averaged input function



Joyce van Sluis^{1*} , Johannes H. van Snick¹, Adrienne H. Brouwers¹, Walter Noordzij¹, Rudi A. J. O. Dierckx¹, Ronald J. H. Borra¹, Adriaan A. Lammertsma¹, Andor W. J. M. Glaudemans¹, Riemer H. J. A. Slart, Maqsood Yaqub², Charalampos Tsoumpas¹ and Ronald Boellaard^{1,2}

Dynamic [^{18}F]FDG PET – Patlak with PIF

- no need to scan 65 min
- 20 min is sufficient
- More suitable for clinical practice



Clinical examples

First patient data: Quadra vs. Vision

65 y/o female

Metastatic breast cancer

Weight 83 kg

Injection 200 MBq ^{18}F -FDG

Time delay: 19 min



Conventional (digital)

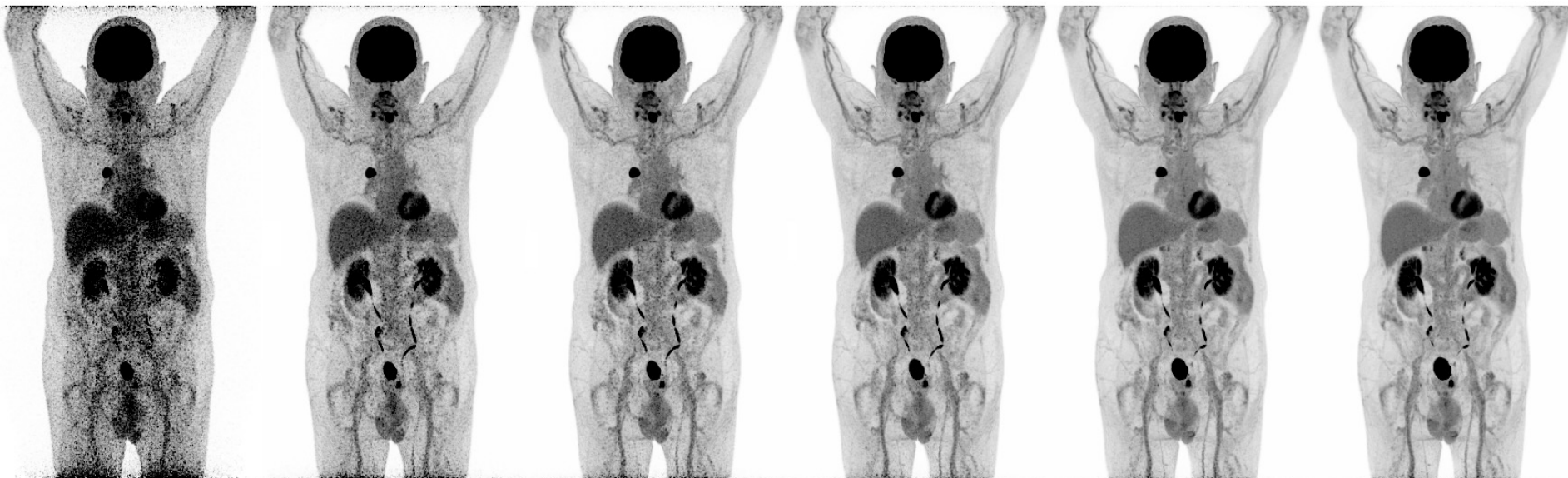
14 min



LAFOV

10 min

Various scantimes: CLIN



15 sec

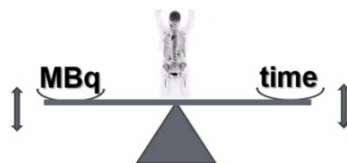
60 sec

120 sec

240 sec

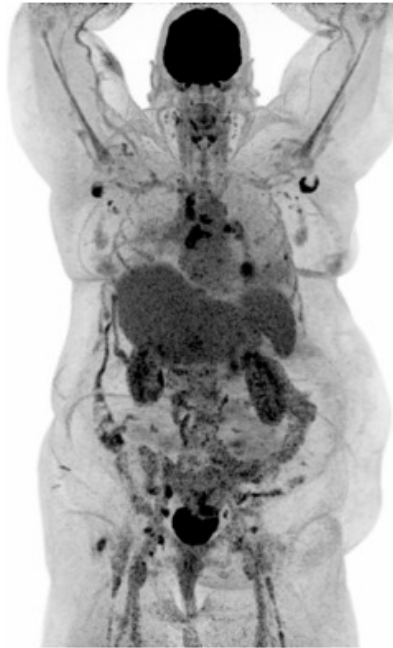
420 sec

600 sec

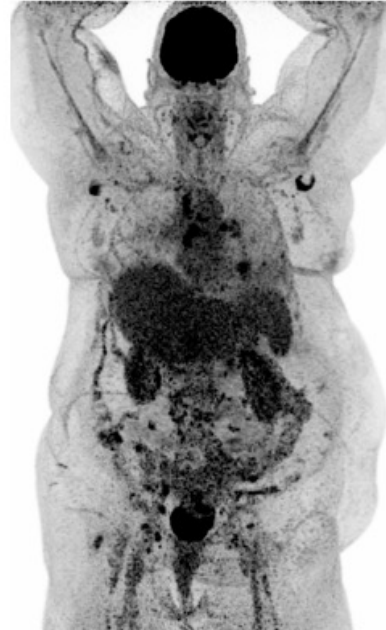


Extreme obese

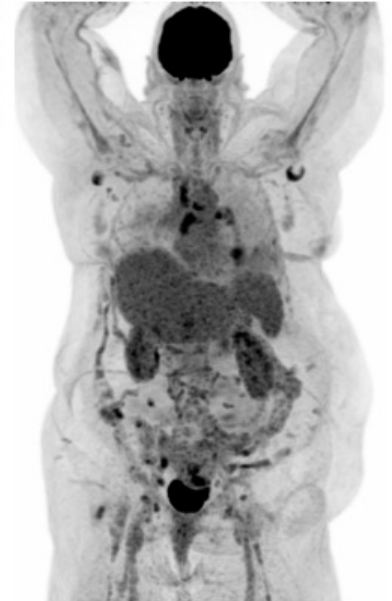
- S. Aureus in history
- Endocarditis?
- Abscesses?
- Septic embolics?
- 350 MBq [^{18}F]FDG
- Patiënt:
 - Male
 - 170 cm
 - 185 kg



10 min



3 min

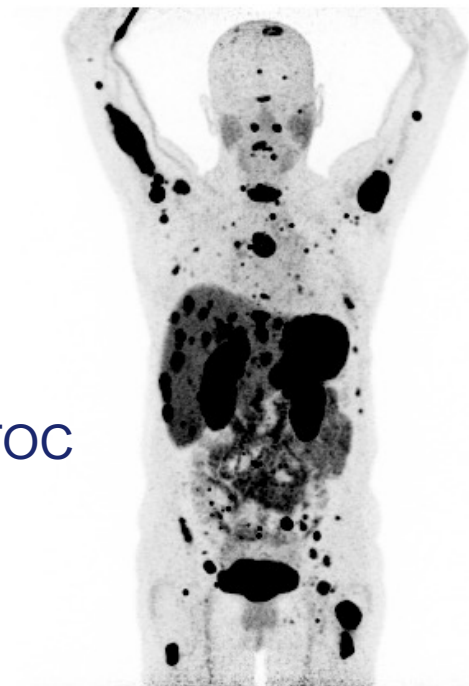


Earl 2 van 3 min

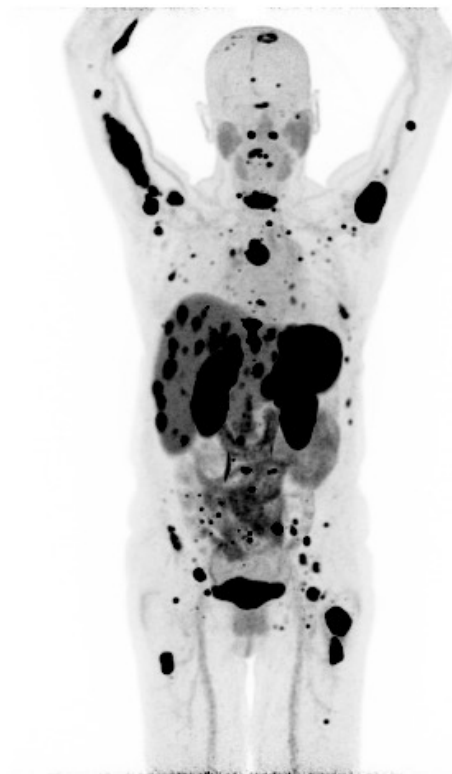
First patient data: Quadra vs. Vision

66 y/o female
Metastatic NET
Weight 62 kg
115 MBq [^{68}Ga]DOTATOC

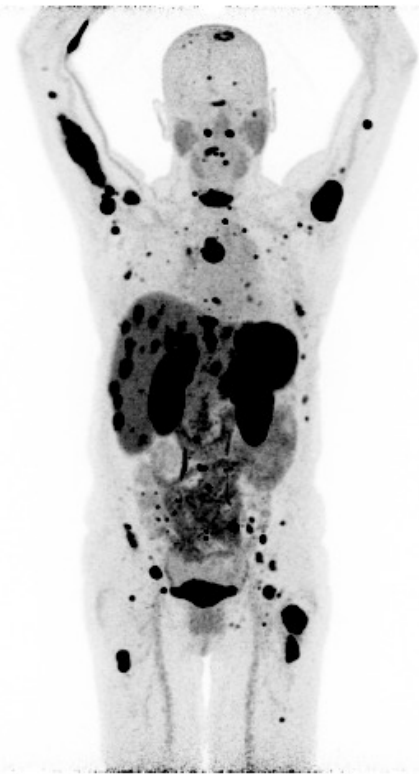
Time delay: 20 min



Conventional (digital)
14 min



LAFOV
10 min

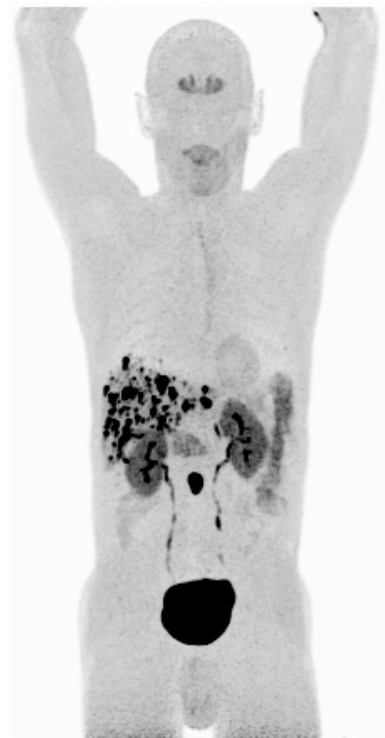


LAFOV
3 min

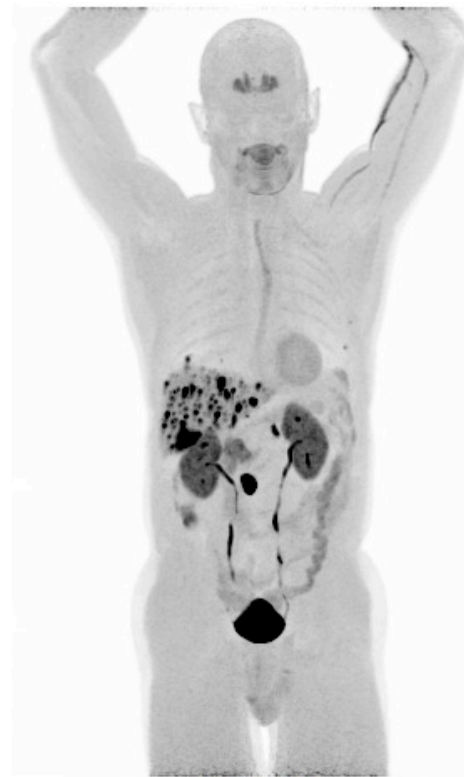
First patient data: Quadra vs. Vision

64 y/o male
Metastatic NET
Weight 74 kg
220 MBq [^{18}F]F-DOPA

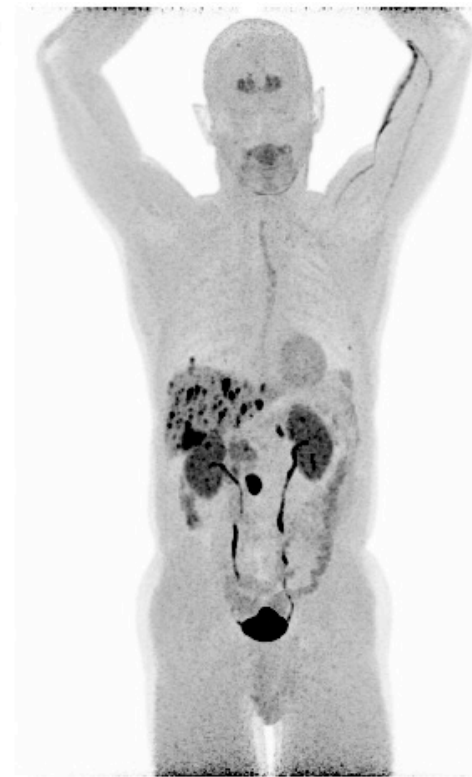
Time delay: 21 min



conventional (digital)
14 min



LAFOV
10 min



LAFOV
2 min

**^{11}C -choline QUADRA PET
Recurrence HCC
68 y.o male
3 minutes image**



^{89}Zr PET data: mCT vs. Quadra

Metastatic breast cancer

Injection 35 MBq ^{89}Zr -trastuzumab

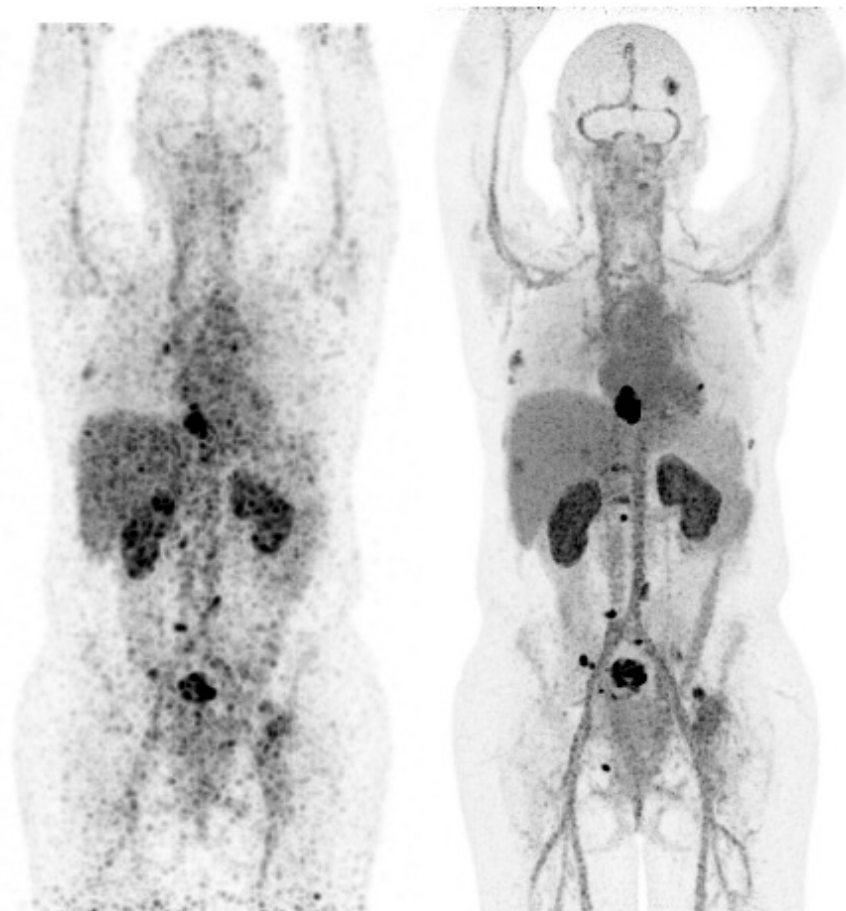
Scans at day 4 pi

Quadra

Total scantime **30 min**

mCT

Total scantime **45 min**



mCT

Quadra

^{89}Zr PET data: Vision vs. Quadra

Metastatic breast cancer
Injection 36 MBq ^{89}Zr -trastuzumab
Scans at day 4 pi

Vision

Total scantime 30 min

Quadra

Total scantime 30 min

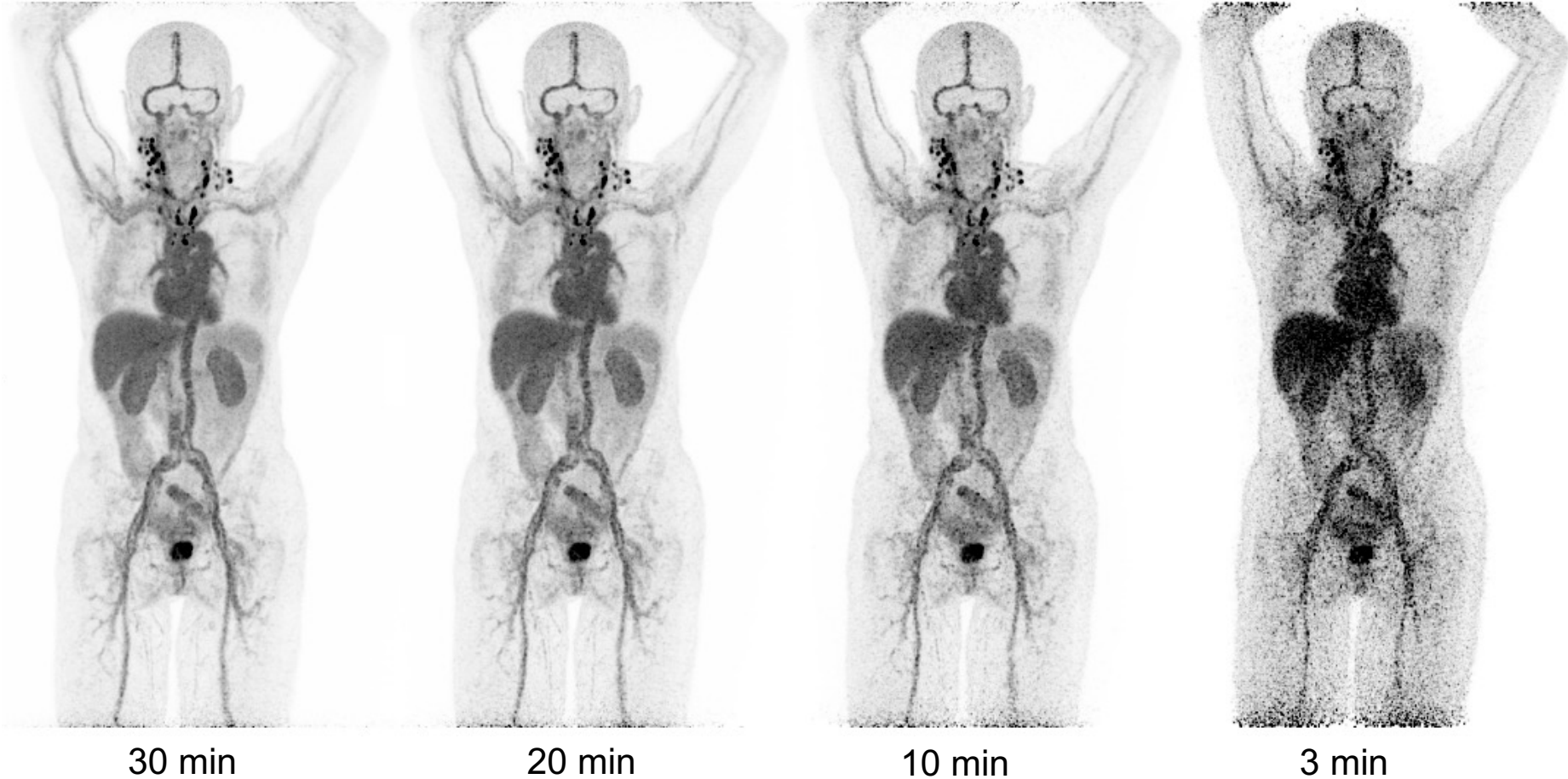


Vision



Quadra

Quadra: countless opportunities for the future



First patient data: Quadra only

5 y/o female
Endocarditis
Weight 17 kg
28 MBq [^{18}F]FDG
No sedation



7 min



3 min

Example

- Endocarditis, location
- 10-week-old newborn
- Tetralogy of Fallot/Eustachian valve
- *S. aureus* sepsis
- Infection & abscess right foot

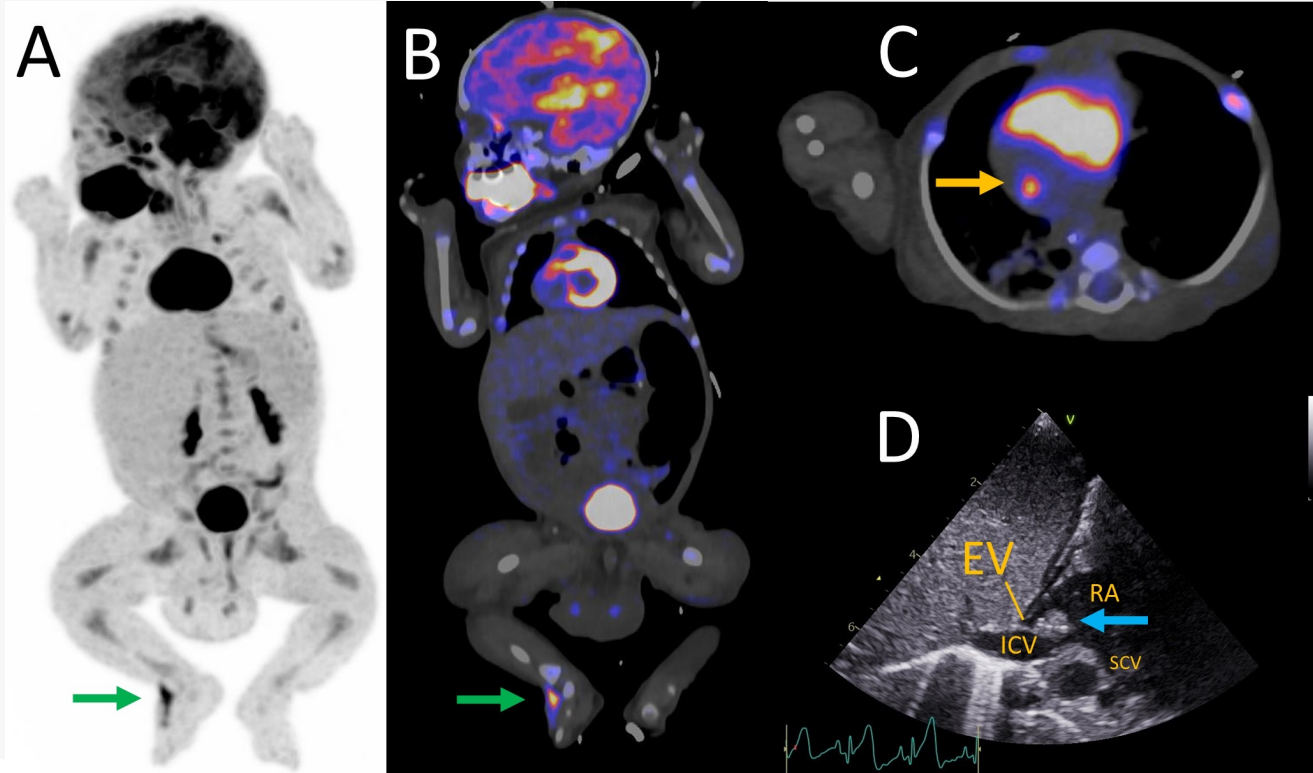
Quadra

12 MBq ^{18}F -FDG

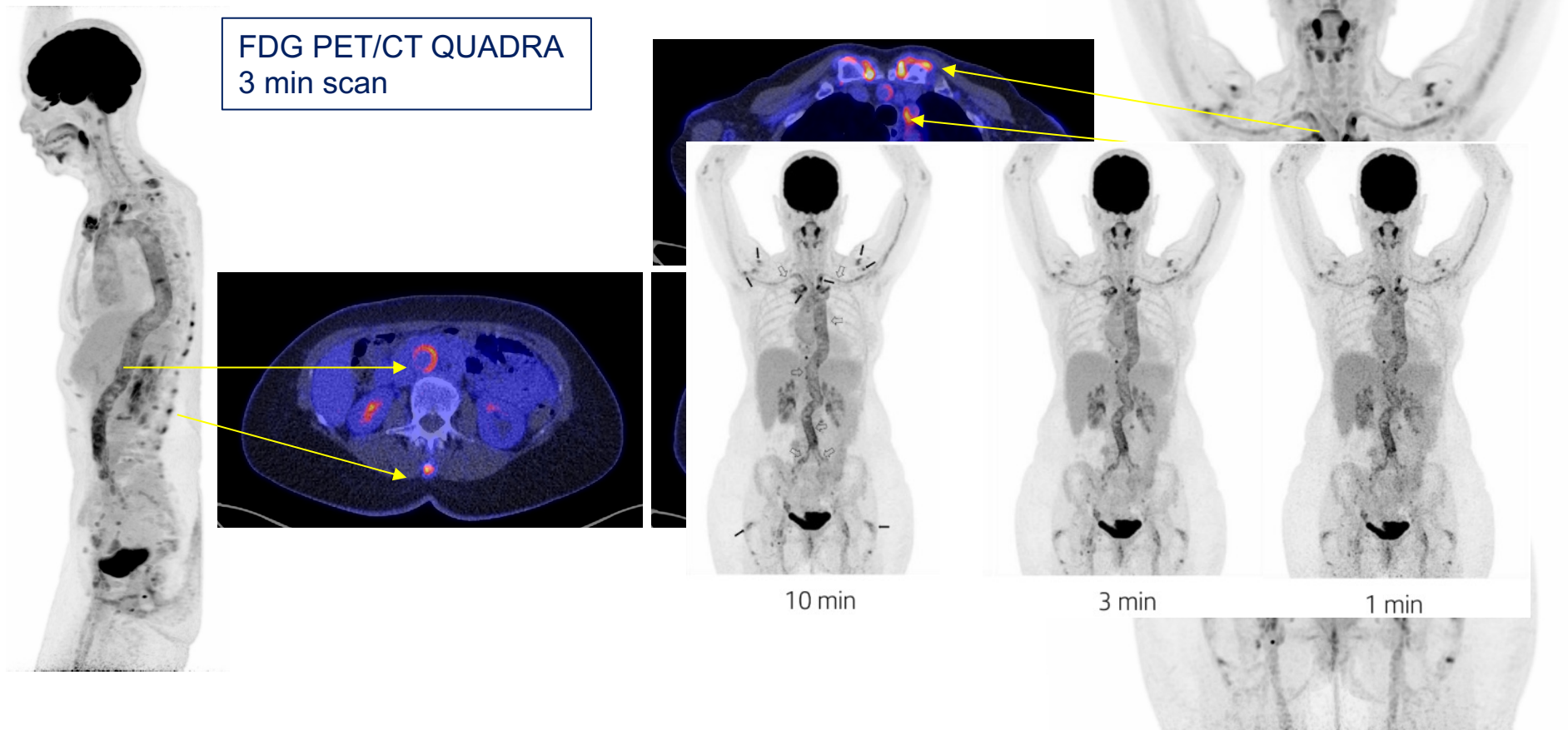
3 MINUTES SCANTIME

NO SEDATION

- Effective patient dose 1.3mSv
- <<< international recommendations



Large vessel vasculitis & PMR



Fracture-related infection (FRI)

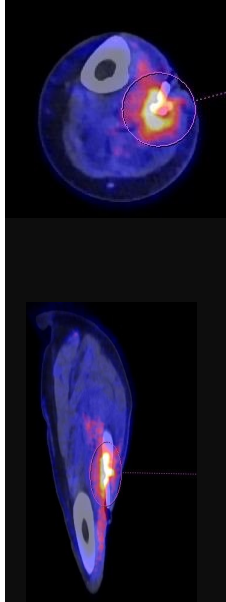
- 71 yrs male
- Many ulcers, ischemic limbs, CRP elevated
- Now fracture left fibula, due to osteomyelitis?
- FRI?
- Dynamic FDG PET QUADRA scan of 65 min
- Infection/inflammation?
- Localisation?
- Surgery & microbiology culture: Staph. Aureus



Clinical

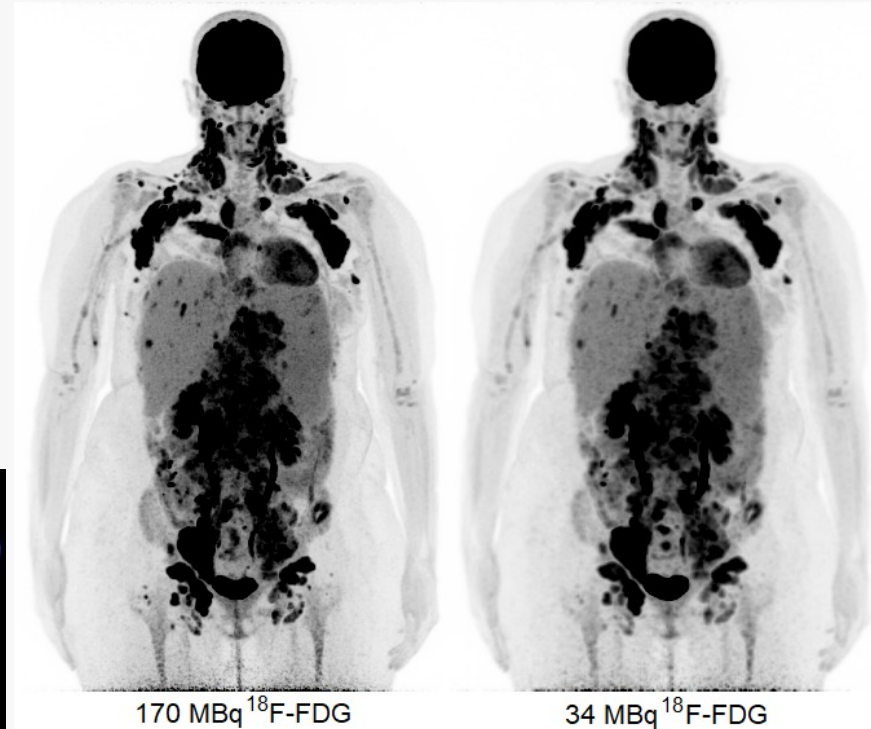
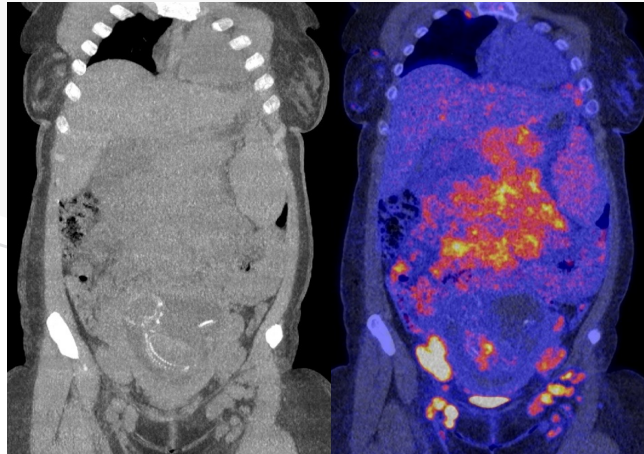


EARL2



Long Axial Field of View PET for ultra-low dose imaging of non-Hodgkin lymphoma during pregnancy

- 28 yrs old female
- 15 weeks pregnancy
- MRI: lymph nodes
- QUADRA PET/CT
- 1.5 MBq/kg FDG

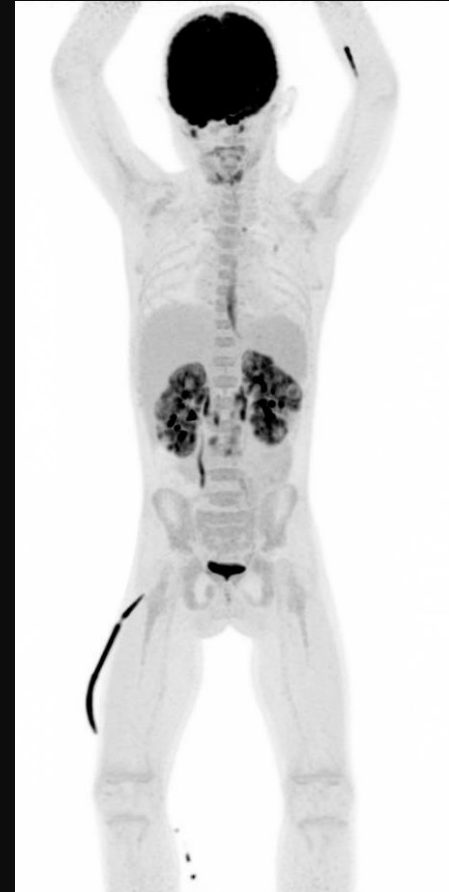


A 10-fold lower administered dose than according to EANM guidelines, a clear image can be obtained of more than adequate diagnostic quality, limiting the radiation exposure to the fetus substantially.

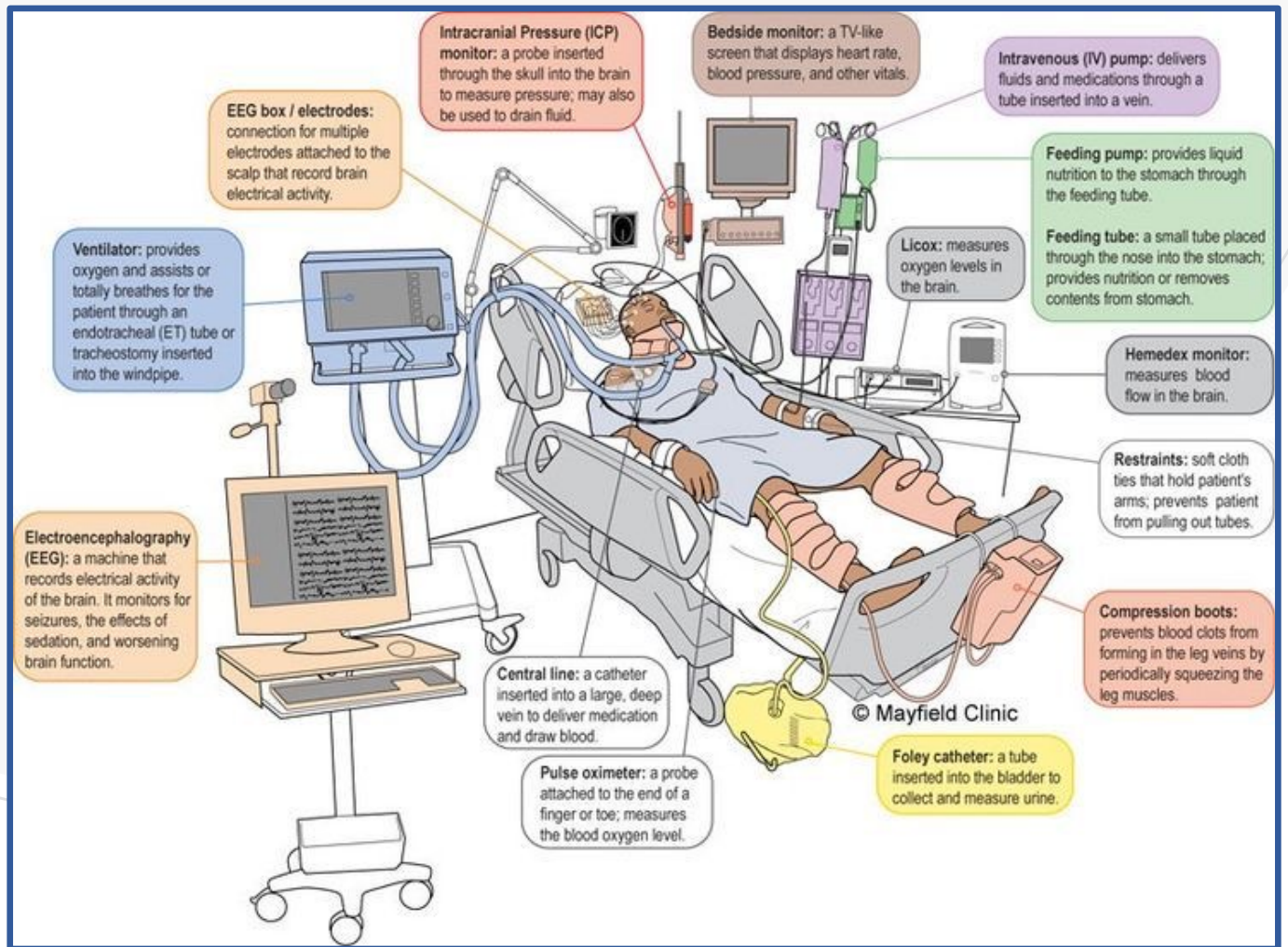
Child, 7 jaar

- Urosepsis and fever
 - CRP 100 during 10 days AB
 - Infection e.c.i.
 - 25 kg 40 MBq [^{18}F]FDG
 - No anesthesia or benzodiazepine use
 - Scan duration 5 min

 - Double-sided nephritis
-



The ICU patient



ICU patients



PET in ICU patients: how can we get a better match?

- SOP-protocols
- Fast imaging (Total-Body PET scanner)
- Helpful findings help to convince even the skeptic persons

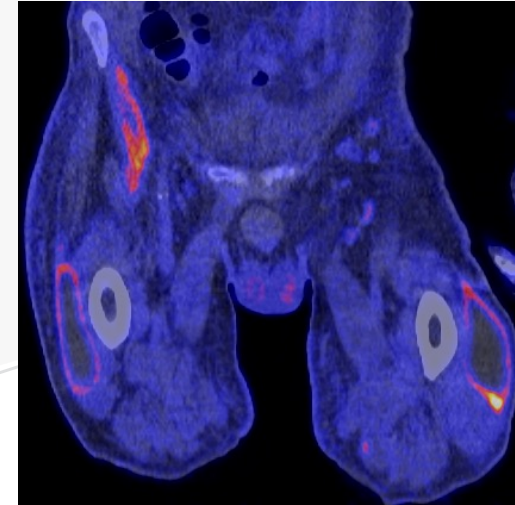
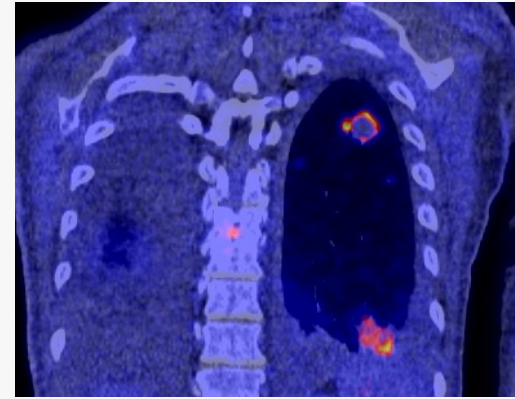
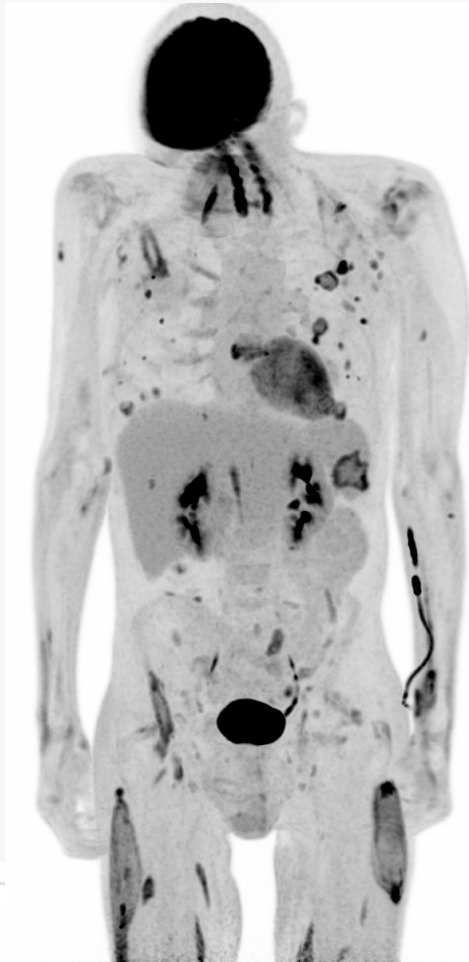
Example ICU

- Male, 46 years old
- MRSA bacteremia
- Port of entry unclear
- Probably pneumonia
- Other signs of infection?

Quadra

3 MINUTES SCANTIME

- → lung infections,
abscesses, spondylodiscitis



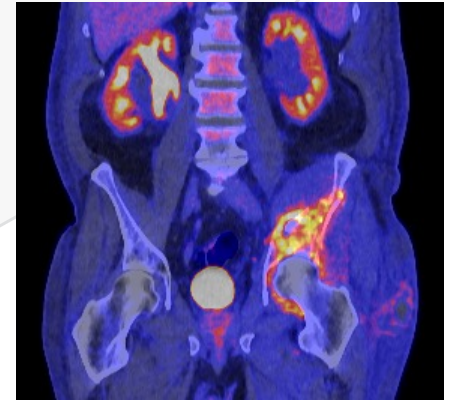
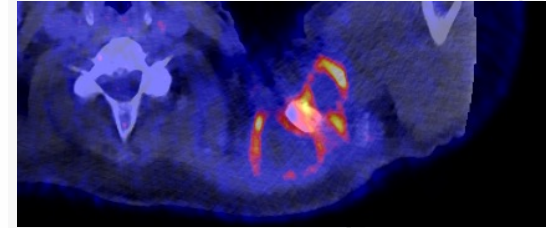
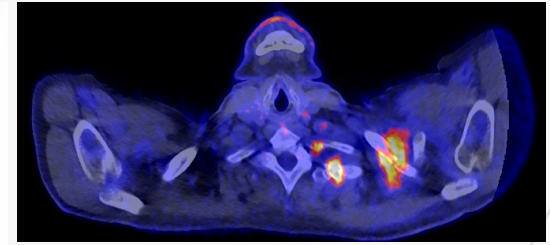
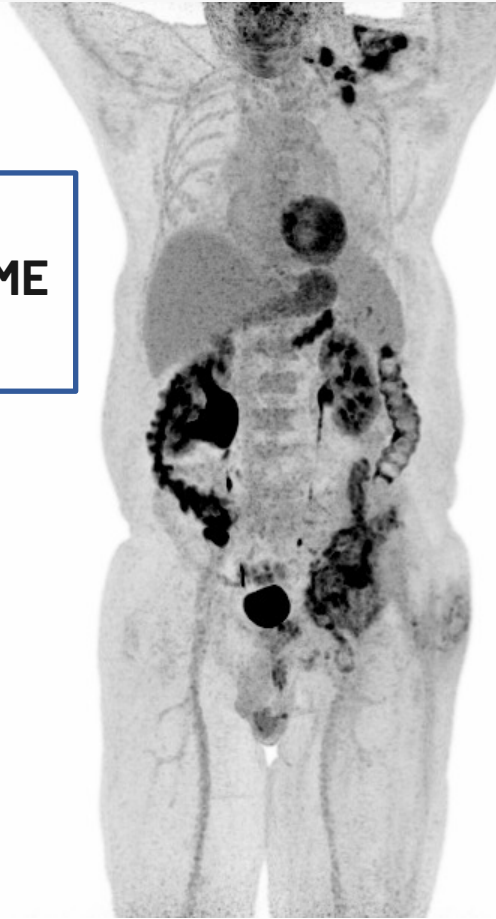
Example ICU

- Male, 69 years old
- Bike accident
- Several fractures, brain injury
- Surgeries pelvis/hips
- 4 weeks later *S. aureus* sepsis → ICU
- US, CT: hematoma obturator region left side
- → infected hematomas left clavicular region and nearby pelvic fracture

Quadra

3 MINUTES SCANTIME

FOV 106 cm....



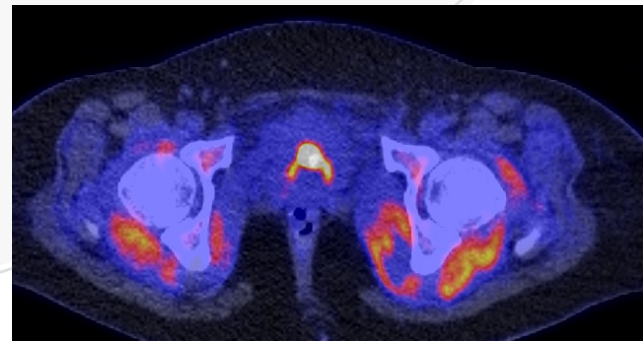
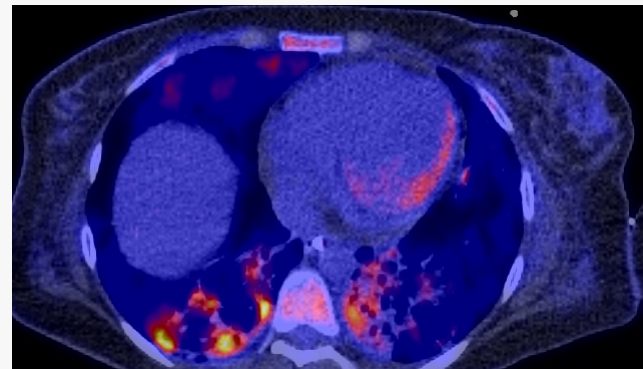
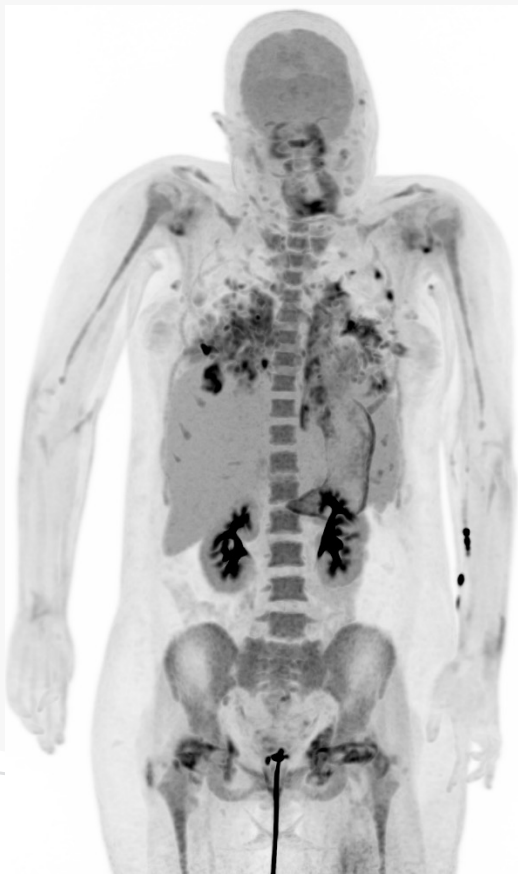
COVID-ICU-FDG

- Female, 26 years old
- 3 weeks ago: section caesaria
- 2 weeks ago: COVID
- Respiratory problems
- ICU, intubation
- Infection beside COVID?

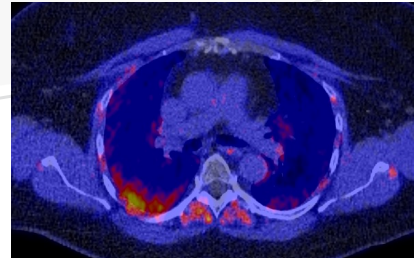
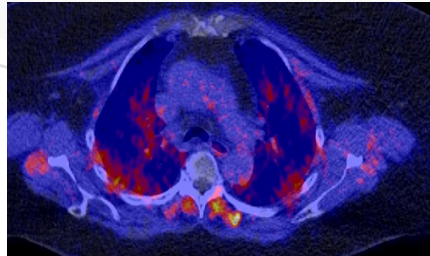
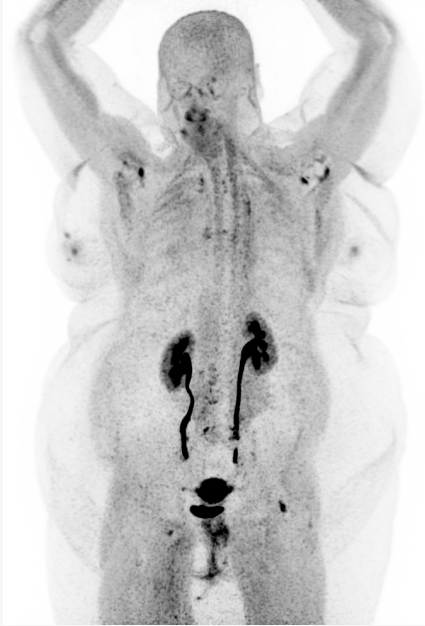
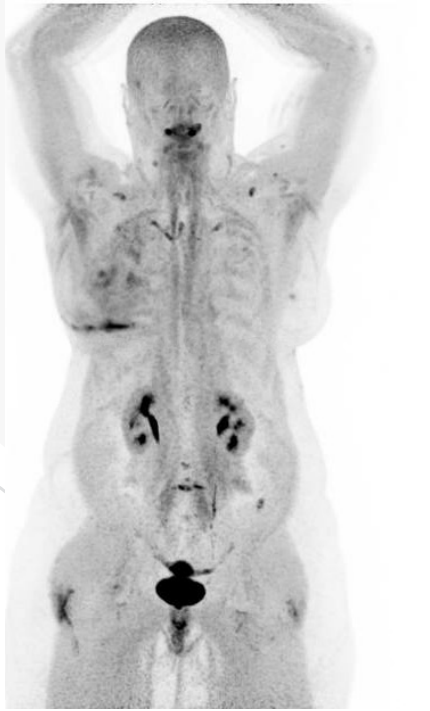
Quadra

3 MINUTES SCANTIME

- → COVID & superinfection (Aspergillus) & peri-articular ossification



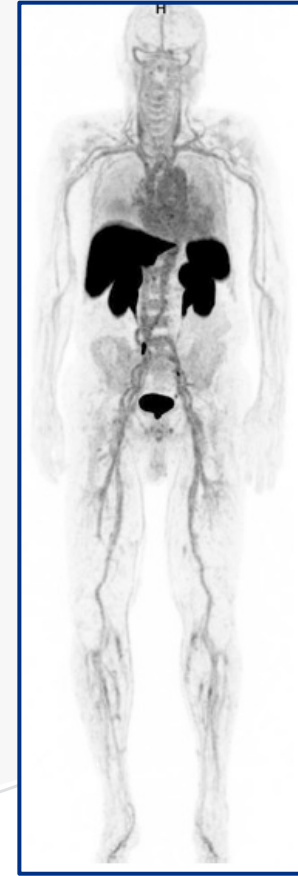
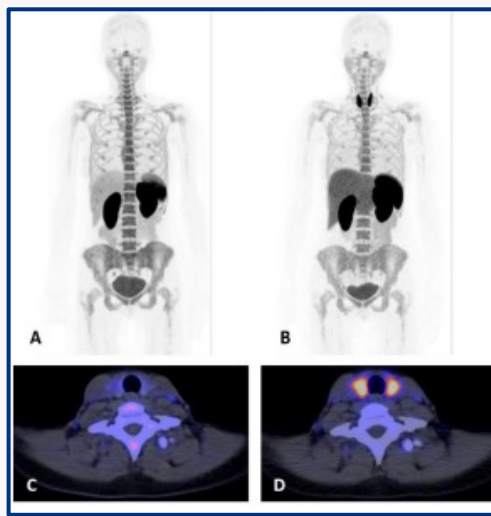
COVID-ICU-FAPI: fibroblast activity



- CLIMATE-COVID
- Dutch consortium
- ZonMw grant

New tracers

- Immune cells
 - ^{18}F -Interleukin-2
 - $^{18}\text{F}/^{89}\text{Zr}$ -PD-1/PDL-1
 - ^{89}Zr -CD8
 - Macrophage tracers
- Bacterial tracers:
 - ^{18}F -vancomycine
 - ^{18}F -sorbitol



Total body/LAFOV PET NM perspectives

High sensitivity

Fast acquisition: ICU/pediatrics

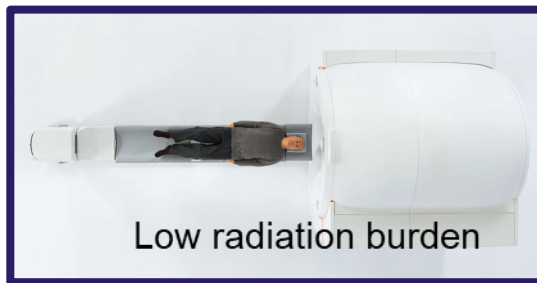
Late imaging
(r.l. antibodies)

Equivalent to 3-4 (dig.) PET scanners

Increased rate of patient through-put



High temporal resolution



Low radiation burden

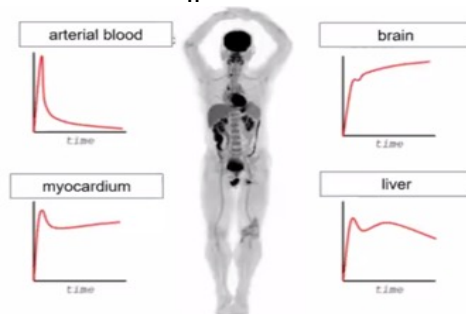
Med.drug response evaluation

Multitracer studies

Long-living isotopes

Organ interaction:

- Brain-heart,
- brain gut,
- heart-kidneys
- ..

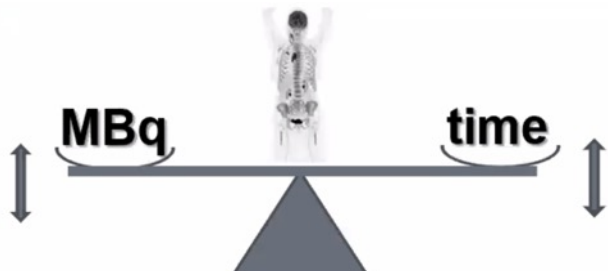
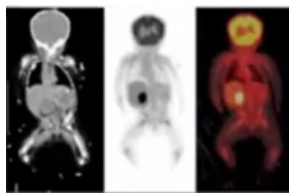


Quantification accuracy

Dynamic & whole-body parametric imaging

Low radiation burden

Waiting room



Focus QUADRA PET/CT UMCG

- ❑ Clinical imaging
- ❑ Quantitative imaging & motion correction
- ❑ Long-living isotopes ^{89}Zr , multi-tracer
- ❑ ^{15}O -water, ^{13}N -ammonia perfusion
- ❑ Many other special PET tracers
 - ❑ GMP lab & cyclotron
 - ❑ Cardiovascular, Infection & Inflammation
 - ❑ (and oncology 😊)

TBPET Conference
19-21 September 2024
Groningen



umcg

Thank you



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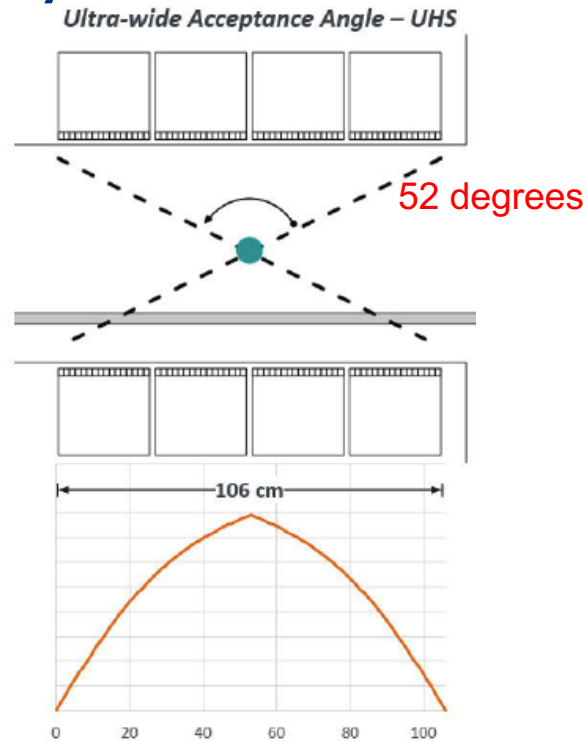
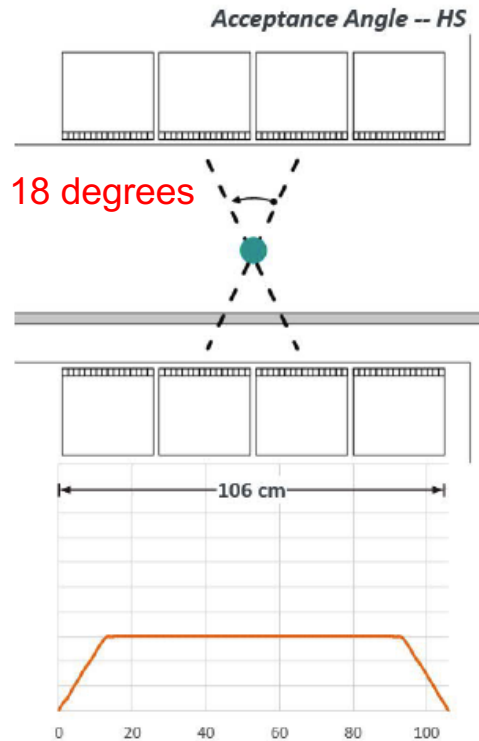


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Performance: sensitivity



Sensitivity Profile -- HS

Sensitivity Profile -- UHS