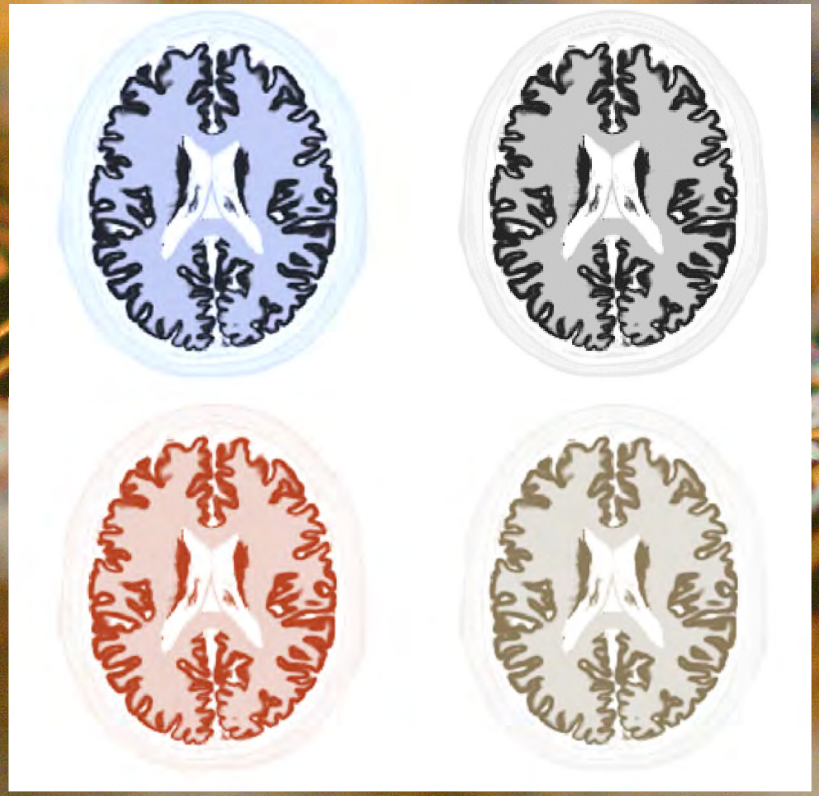


Prof. John O. Prior PhD MD
Nuclear Medicine and Molecular Imaging
Lausanne University Hospital

FATA 2019 (Acireale)

The 10-ps TOF-PET: Clinical applications

canton de vaud

UNIL | Université de Lausanne

CHUV

Plan

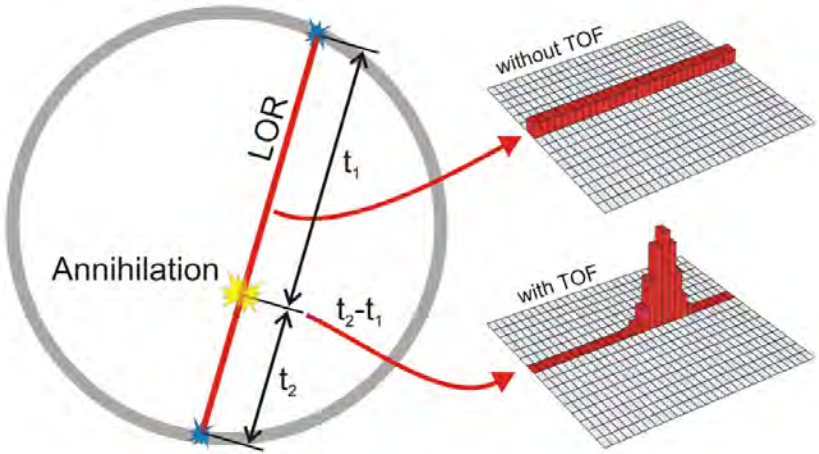
TOF advantage

State-of-the-art clinical PET (2018, 214 ps)

10-ps TOF PET:

- Non-tomographic reconstruction PET
- Medical benefits
- Are we there? The 10-ps TOF PET challenge

TOF PET: Principle and Advantages



P. Lecoq, C. Morel, J. Prior, 2018

Increase in signal-to-noise ratio as TOF resolution decreases

Year	TOF	S/N Gain
–	No TOF	1
2006	585 ps	
2011	500 ps	2.3
2017	375 ps	
2018	214 ps	3.3

Prof. Dr. Dr. John Prior
Lausanne University Hospital

First Clinical Results with Biograph Vision

12.10.2018

UNIL | Université de Lausanne

Biograph Vision: latest digital PET

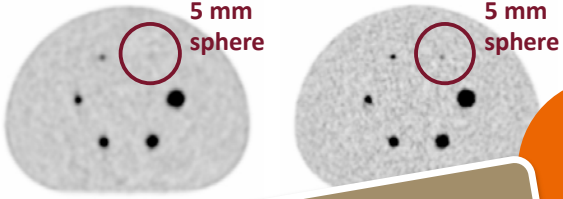
3.2 mm LSO crystals

214 ps[1] time of flight

100 cps/kBq[1] effective sensitivity

100% SiPM sensor coverage [1]

Biograph™ mCT **Biograph Vision™**



High-resolutio

56% higher contrast recovery[1]

Better Detectability

- [1] Based on internal measurements at time of publication. Data on file;
- Biograph Vision and its features and applications are not commercially available in all countries. Their future cannot be guaranteed. Please contact your local Siemens Healthineers organization for further details.

Clinical Applications

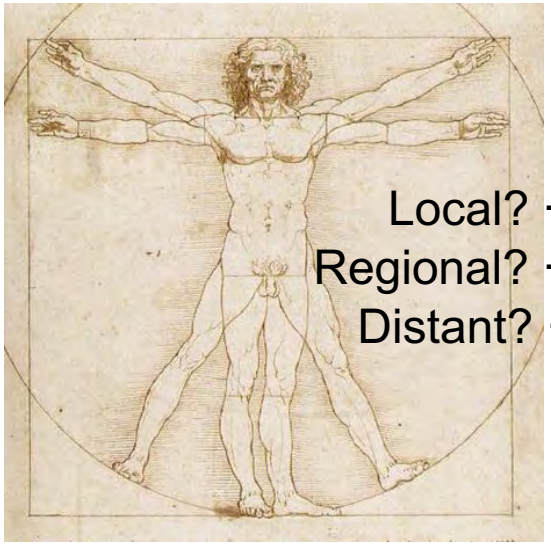
Low contrast lesions

Low activity situations

Sensitivity

Resolution

Today's Challenge in Oncologic Imaging



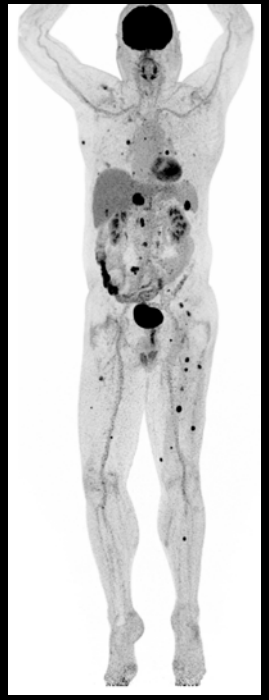
Local? → Surgery?
Regional? → Radiation?
Distant? → Chemo?

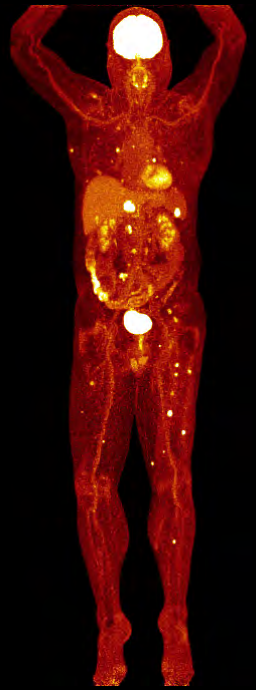
Identify all lesions is key to defining right therapy

- Local?
- Lymph nodes?
- Metastases?

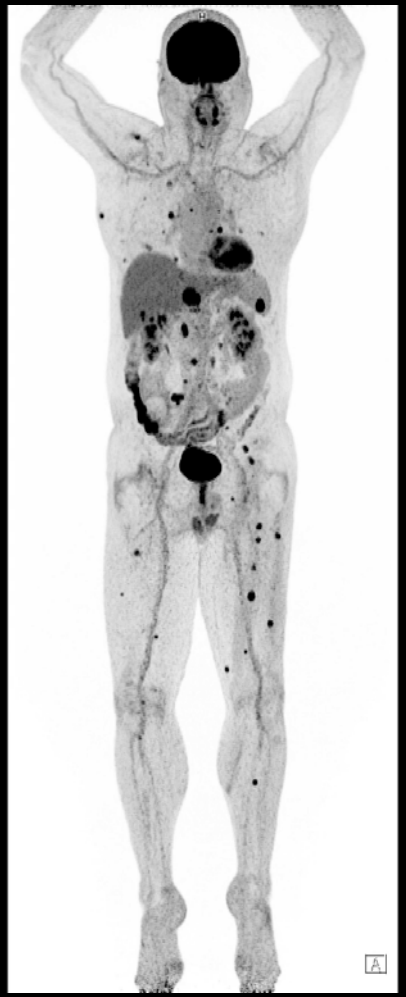
Poor spatial resolution and sensitivity negatively affects lesion detectability and staging

Delineation of multiple skeletal, lymph node soft tissue metastases





PET MIP



Data courtesy of Centre Hospitalier Universitaire Vaudois, Lausanne, Switzerland.
Biograph Vision is not commercially available in all countries. Due to regulatory reasons, its future availability cannot be guaranteed. Please contact your local Siemens organization for further details.

“I think it's very addictive and you get used to that high-quality image even after one patient.”

Prof. John Prior, MD, PhD

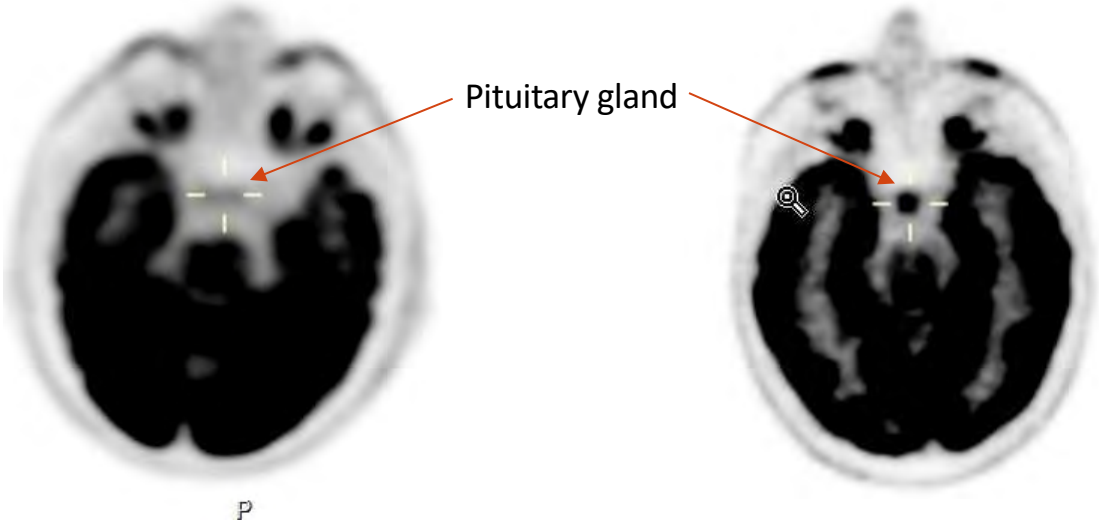
Head of Department, Nuclear Medicine

Centre Hospitalier Universitaire Vaudois CHUV, Lausanne, Switzerland

The statements by Siemens’ Healthineers customers described herein are based on results that were achieved in the customer's unique setting. Because there is no "typical" hospital or laboratory and many variables exist (e.g., hospital size, samples mix, case mix, level of IT and/or automation adoption) there can be no guarantee that other customers will achieve the same results.

Detectability of small structures in 18F FDG PET/CT examinations

Visual observations of the pituitary gland

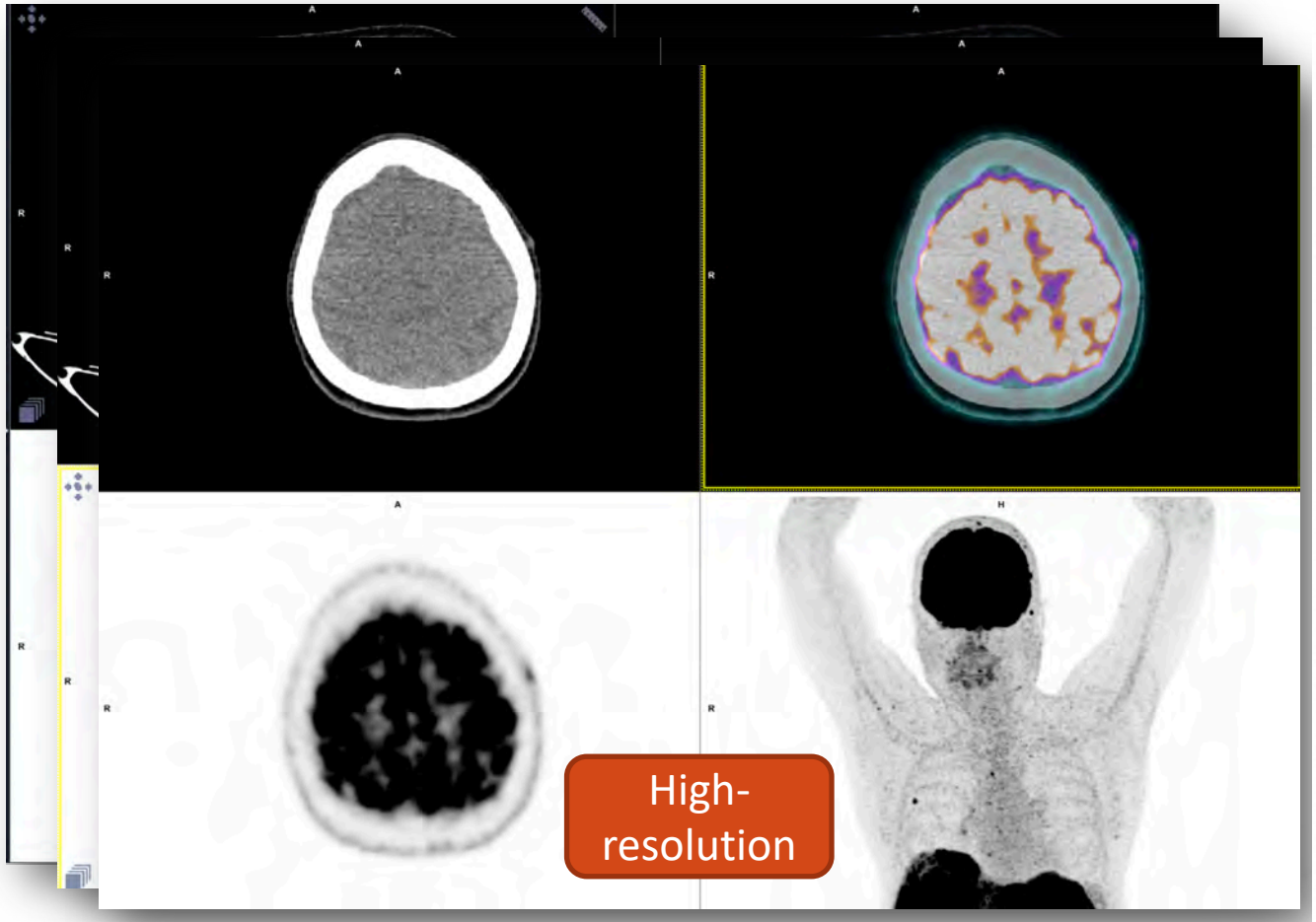


PET/CT Discovery 690
Gauss filter FWHM = 5mm
Voxel size : 2.74×2.74×3.27 mm

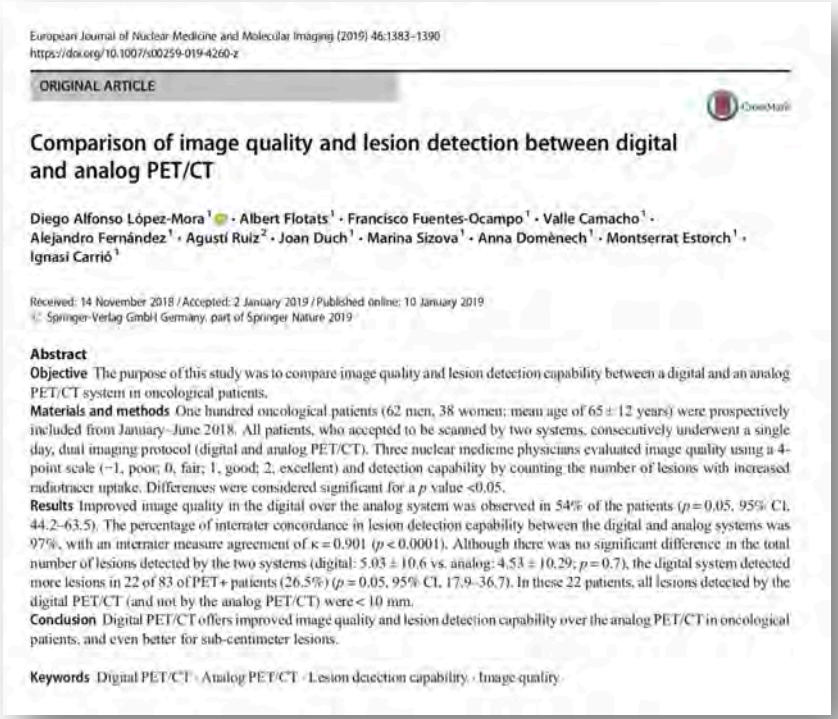
PET/CT Biograph Vision
No gaussian Filter
Voxel size: : 1.65×1.65×2mm

Reduced partial volume effects

55-y patient with uveal melanoma a



Lesion Detectability with Digital PET



European Journal of Nuclear Medicine and Molecular Imaging (2019) 46:1383–1390
https://doi.org/10.1007/s00259-019-4260-z

ORIGINAL ARTICLE

Comparison of image quality and lesion detection between digital and analog PET/CT

Diego Alfonso López-Mora[1] · Albert Flotats[1] · Francisco Fuentes-Ocampo[1] · Valle Camacho[1] · Alejandro Fernández[1] · Agustí Ruiz[2] · Joan Duch[1] · Marina Sizova[1] · Anna Domènech[1] · Montserrat Estorch[1] · Ignasi Carrió[1]

Received: 14 November 2018 / Accepted: 2 January 2019 / Published online: 10 January 2019

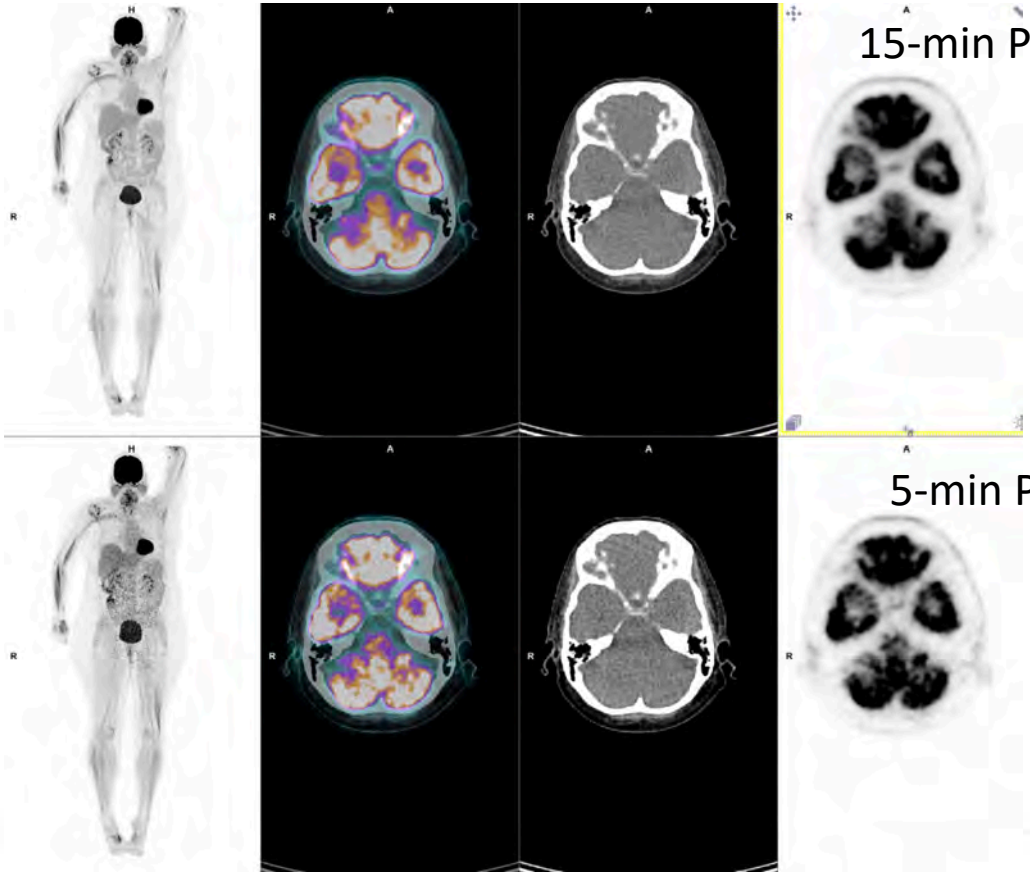
Abstract
Objective The purpose of this study was to compare image quality and lesion detection capability between a digital and an analog PET/CT system in oncological patients.
Materials and methods One hundred oncological patients (62 men, 38 women; mean age of 65 ± 12 years) were prospectively included from January–June 2018. All patients, who accepted to be scanned by two systems, consecutively underwent a single day, dual imaging protocol (digital and analog PET/CT). Three nuclear medicine physicians evaluated image quality using a 4-point scale (−1, poor; 0, fair; 1, good; 2, excellent) and detection capability by counting the number of lesions with increased radiotracer uptake. Differences were considered significant for a p value <0.05.
Results Improved image quality in the digital over the analog system was observed in 54% of the patients ($p = 0.05$, 95% CI, 44.2–63.5). The percentage of interrater concordance in lesion detection capability between the digital and analog systems was 97%, with an interrater measure agreement of $\kappa = 0.901$ ($p < 0.0001$). Although there was no significant difference in the total number of lesions detected by the two systems (digital: 5.03 ± 10.6 vs. analog: 4.53 ± 10.29; $p = 0.7$), the digital system detected more lesions in 22 of 83 of PET+ patients (26.5%) ($p = 0.05$, 95% CI, 17.9–36.7). In these 22 patients, all lesions detected by the digital PET/CT (and not by the analog PET/CT) were < 10 mm.
Conclusion Digital PET/CT offers improved image quality and lesion detection capability over the analog PET/CT in oncological patients, and even better for sub-centimeter lesions.

Keywords Digital PET/CT · Analog PET/CT · Lesion detection capability · Image quality

- N=100 oncological patients
- Comparison dPET vs. cPET
- Improved image quality in 54%
- dPET detected more lesions in 22 patients, all <10mm
- dPET changed staging in 32% of these 22 patients

Lopez-Mora et al, EJNMMI 2019

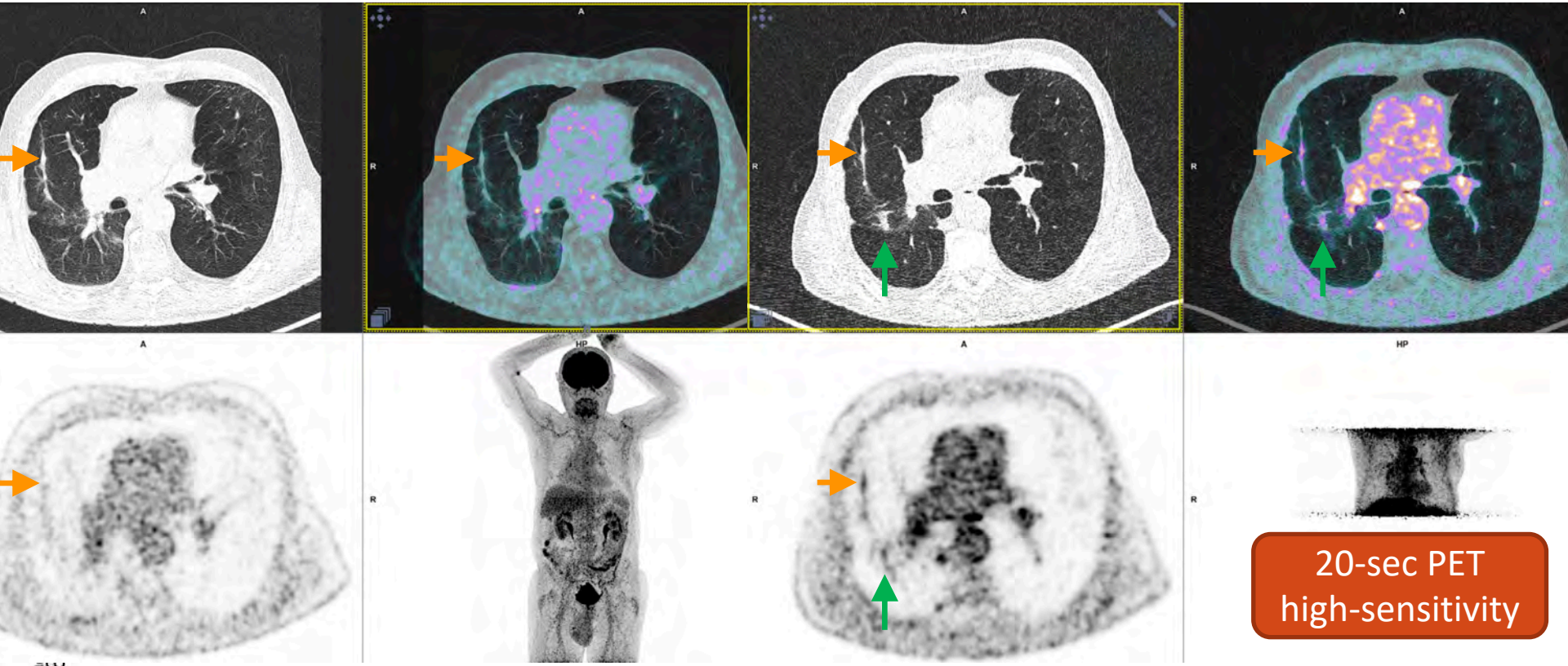
Ultrafast whole-body PET (<5-min)



15-min PET (CBM, 3-min/bed equivalent)

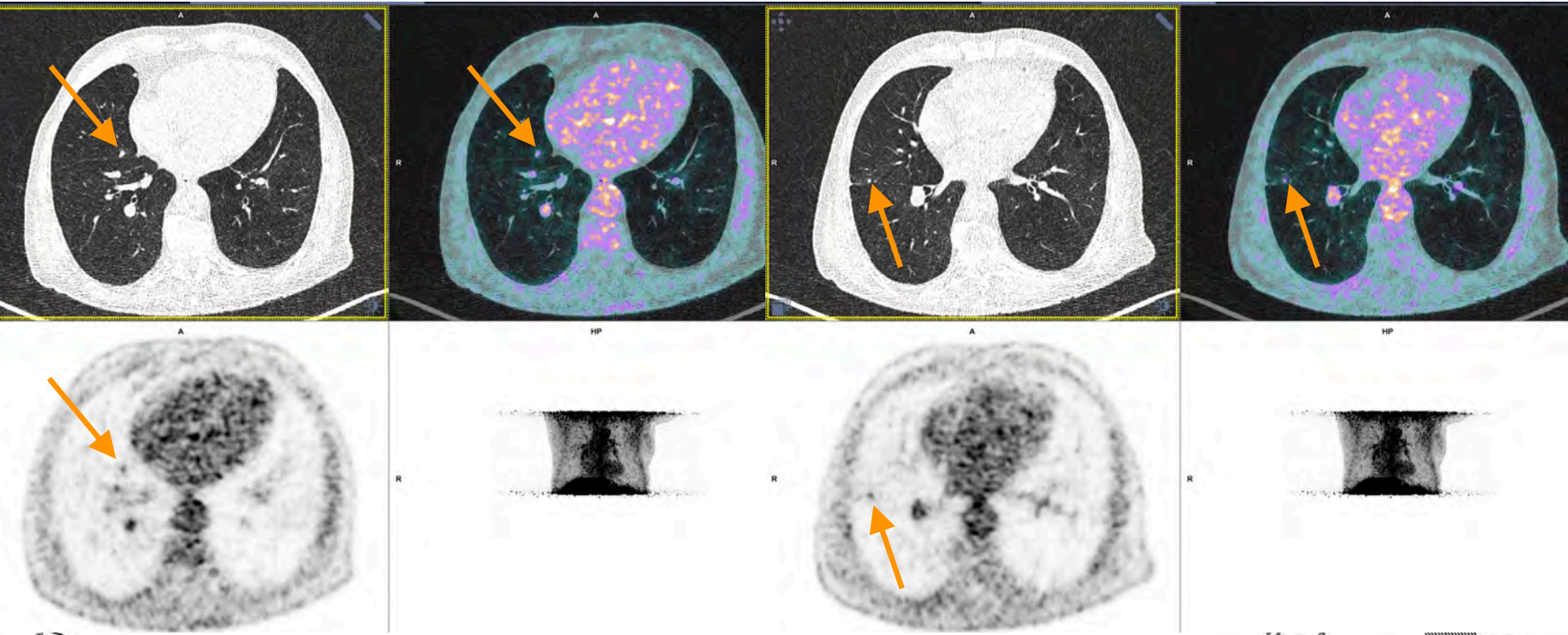
5-min PET

Free-breathing vs. “Breath-hold” PET

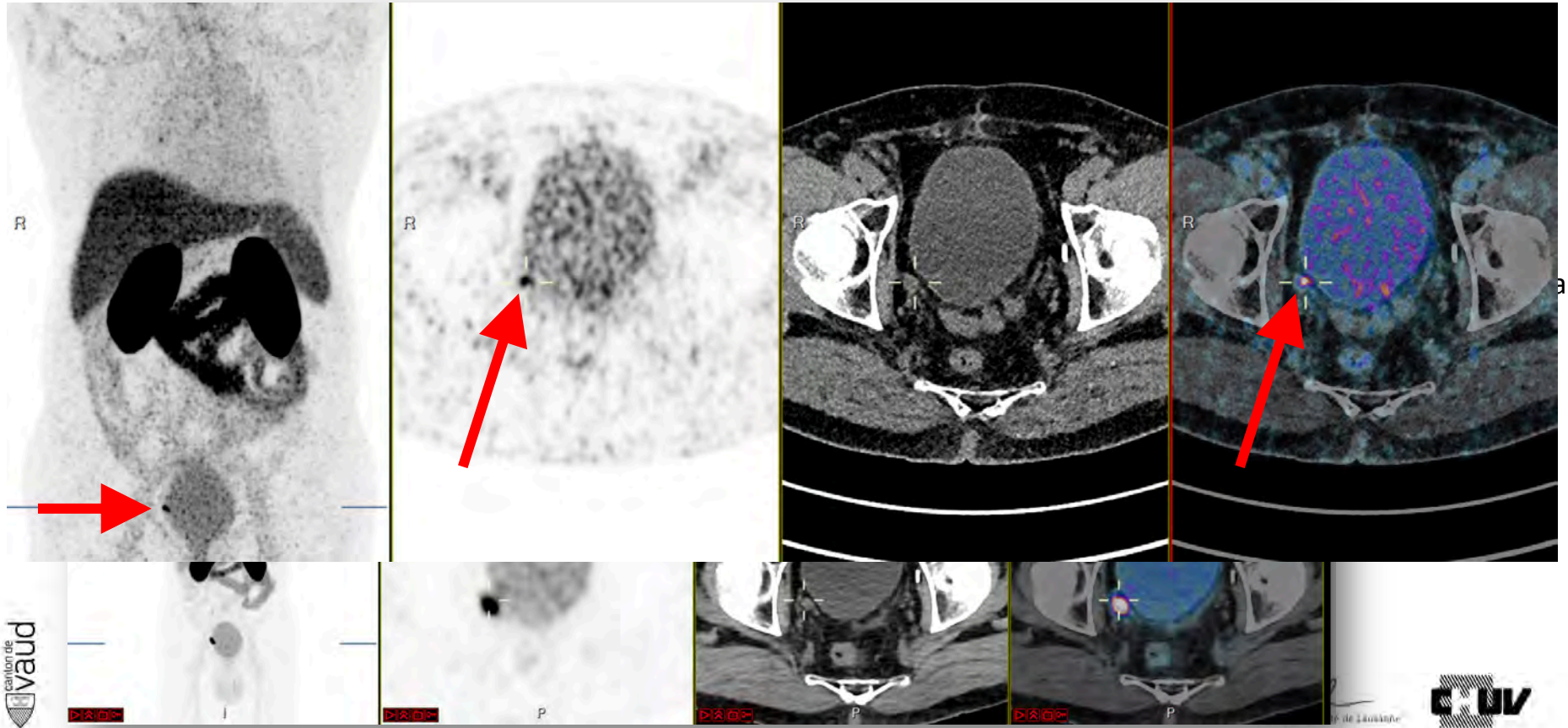


20-sec PET
high-sensitivity

“Breath-hold” PET: small lesions → big difference

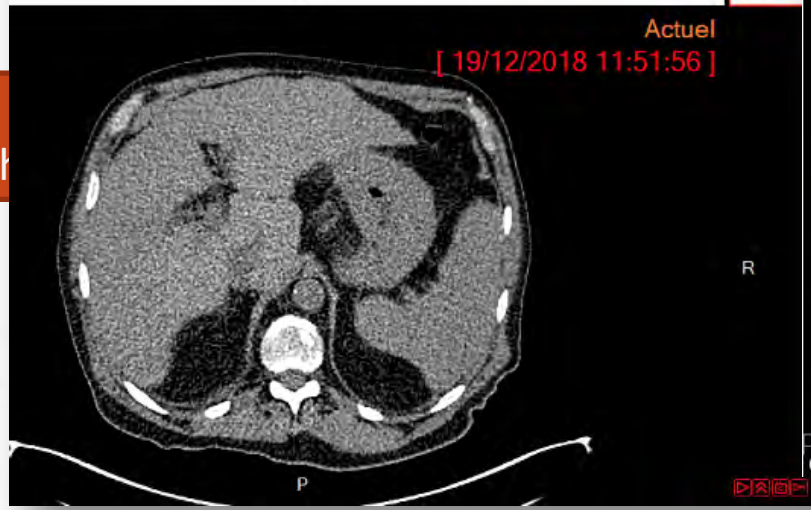


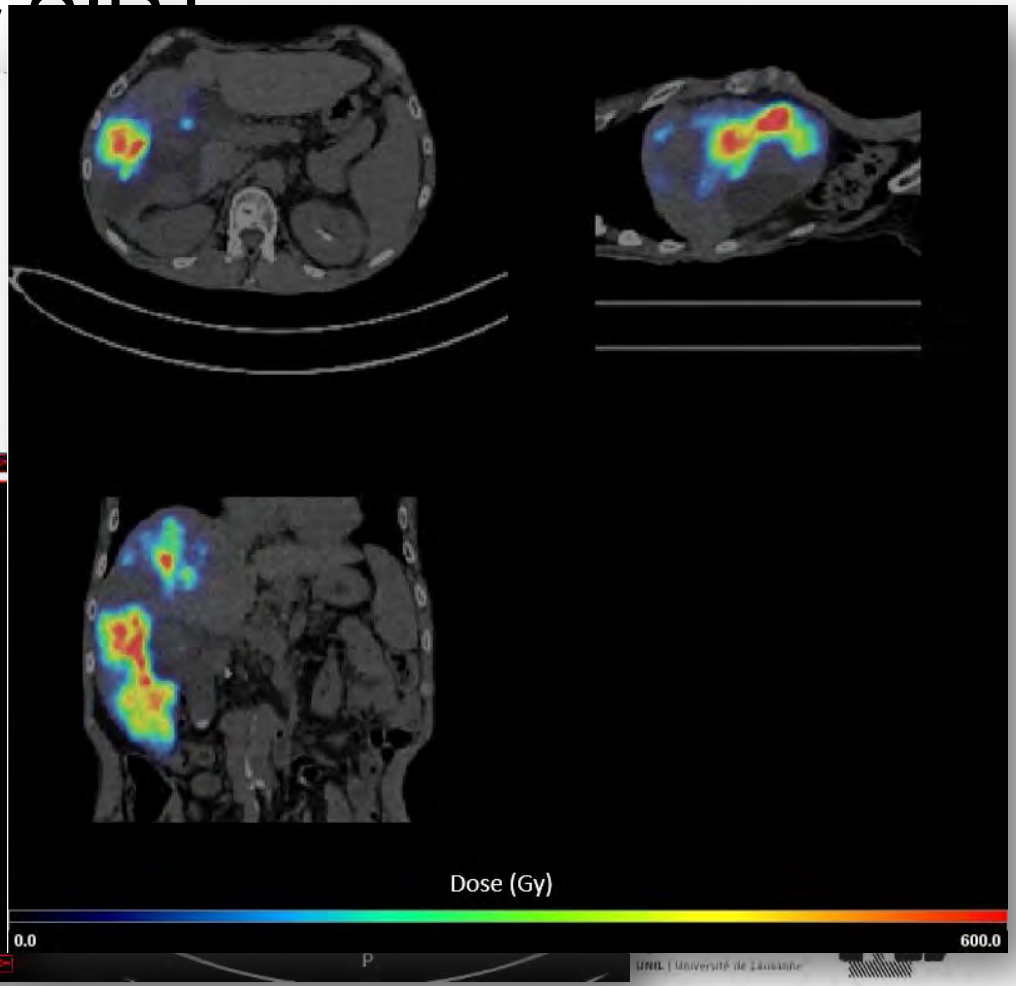
^{68}Ga-PSMA PET/CT Biochemical PCa Relapse



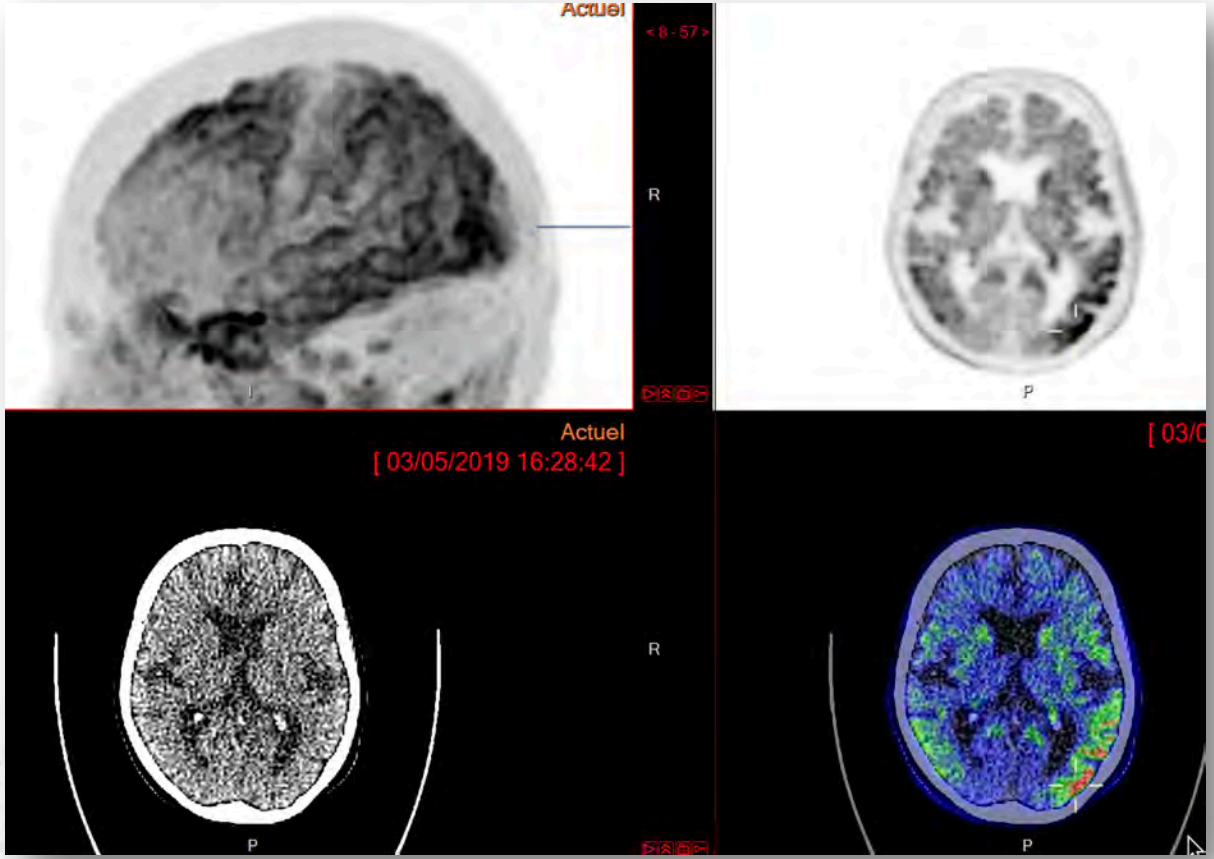
$32 \cdot 10^{-6}$ pair production

Y-90 TOF PET after SIRT



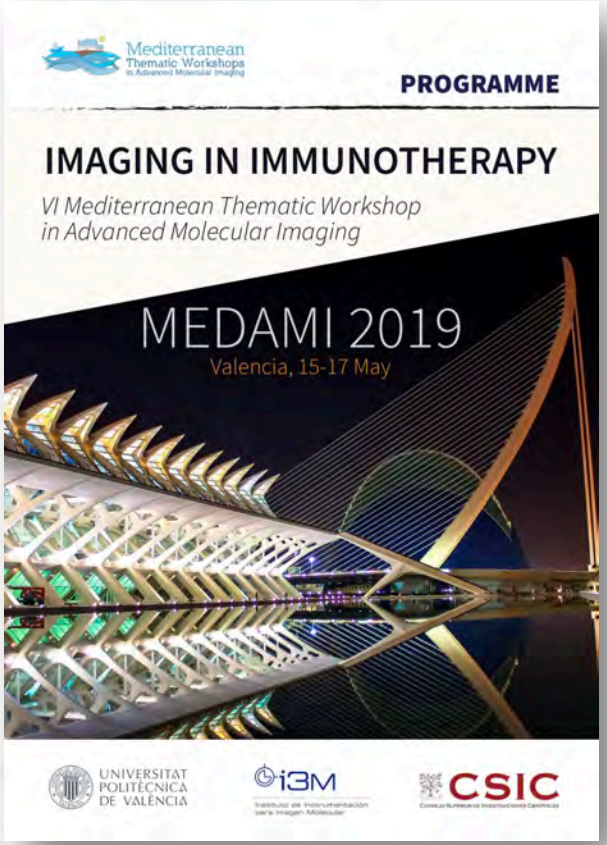


Tau-protein Imaging F-18-AV1451



30-min PET at 75 min 214 MBq

MEDAMI 2019: Imaging in Immunotherapy



WEDNESDAY 15TH MAY

14:30 - 16:30 **Session 3 - 10 ps Challenge** *Chair: S. Vandenberghe*

Setting up of the 10 ps Challenge: Rationale and Progress Status (15')
C. Morel, CERN, Switzerland

The 10 ps TOF PET: Clinical Applications and Immuno-Oncology Imaging (30')
J. Prior, Lausanne University Hospital, Switzerland

Disruptive Technologies (30')
P. Lecoq, CERN, Switzerland

Development of Innovative Detectors for PET (20')
V. Sharyy, IRFU, CEA, France

Heterostructure Radiation Detector Materials for Advanced Time of Flight Positron Emission Tomography (ToF-PET) Imaging (20')
G. Bizarri, Cranfield University, United Kingdom

16:30 - 17:00 **Coffee Break**

17:00 - 18:40 **Session 4 - 10 ps Challenge** *Chair: C. Morel*

Using Heterostructure and Photonic Crystal to Reach 10 ps Timing Resolution with a Scintillator-Based Detector (20')
M. Salomoni, CERN, University of Milano-Bicocca

Towards 10 ps Photon Timestamping with 3D Digital SiPM (20')
S. Charlesbois, Université de Sherbrooke, Canada

Combining a Meta-Material Approach to Depth of Interaction Correction: a Possible Road to 10 ps PET (20')
M. Pizzichemi, CERN, Switzerland

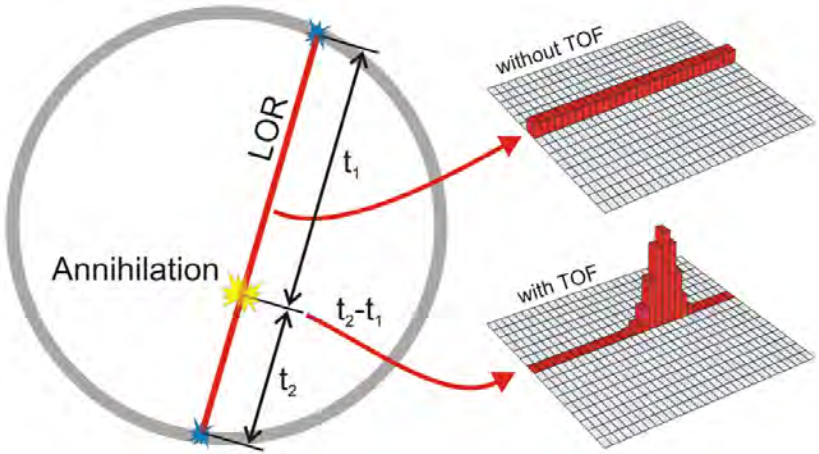
Total Body Molecular Imaging and Therapy with High Sensitivity and Spatial Resolution (20')
S. Vandenberghe, Ghent University, Belgium

New Sensor and FE Developments Towards 10 ps Timing Resolution (20')
D. Sánchez, Universitat de Barcelona, Spain

10-ps TOF PET Challenge ?

Valencia, Spain – May 15–17, 2019

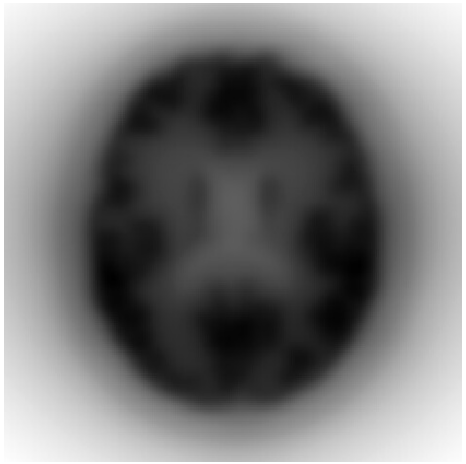
10-ps TOF PET



- 1.5-mm resolution along LOR
- Tomography-less reconstructions
- Increase PET sensitivity by a factor >16
- Reduction in activity/dose
- Reduce radiopharmaceutical price
- Novel clinical applications

P. Lecoq, C. Morel, J. Prior, 2018

10-ps TOF-PET improvement simulation



Non-TOF FBP

Non-TOF OSEM

10ps TOF FBP

10ps TOF OSEM

Clinical improvements

Direct 3-D resolution

- 1.5-mm resolution along LOR; →image accumulation (growing up)
- Limited angle tomography
- Reduce cost of radiotracer production per patient
- Less sensitive to incorrect attenuation
- Better quantification at low statistics (ultra low-dose for screening)
- Adapt scanning speed to clinical goal

Clinical improvements

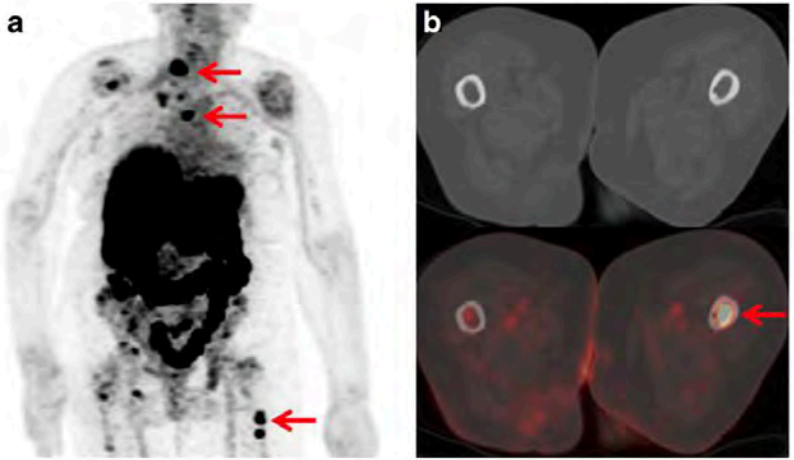
Better resolution (tumor microenvironment)

Better sensitivity

- Less activity
- Image longer (C-11 4h, F-18 20h, Zr-89 30d)
- Image faster (respiratory/cardiac/GI movements)
- High temporal resolution
- 200-fold reduction (0.03 mSv, 2.4 mSv)
- Image more often

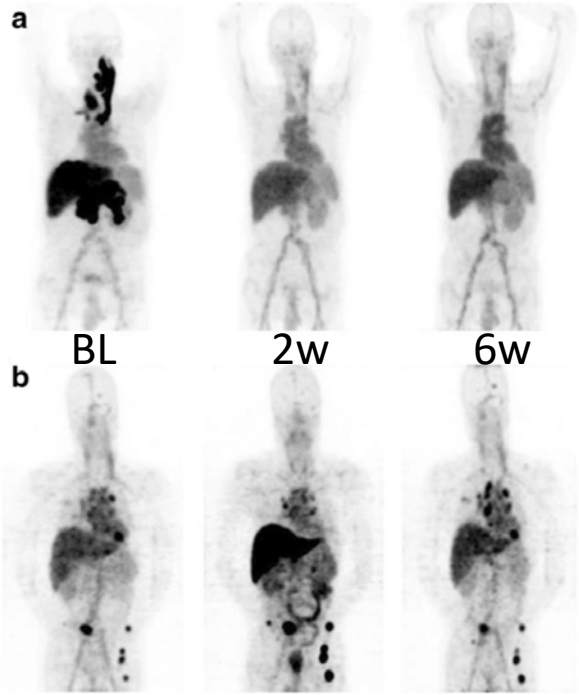
Long-lived imaging (Zr-89): Challenging

Zr-89-trastazumab



Breast cancer

Zr-89-bevacizumab



Renal Cell Cancer

La et al, Nucl Med Mol Imaging 2019

Novel clinical applications (1)

Precise quantification of low-activity metabolism, such as apoptosis (programmed cell death) in myocardial infarct, chronic heart failure, stroke or neurodegeneration (Alzheimer or Parkinson's disease)

→may help to develop new drugs or better follow and treat disease activity

Novel clinical applications (2)

Lung cancer screening (with CT: now 96% false positive rate) → better with ultra-low-dose PET

Non-fatal disease: tuberculosis (India, China, South Africa, $10 \cdot 10^6$ new cases/$1.8 \cdot 10^6$ death in 2015), HIV, also psychiatric diseases (schizophrenia, major depressive or bipolar disorders)

Novel clinical applications (3)

Radiation dose equivalent to a few weeks of natural radioactivity

Advantages for pediatric NM, but also for fetal growth and placental pathology (obstructive uropathy, brain development, hypoxic insult, abnormal fetal motor behavior and epilepsy) → benefit to percutaneous or fetal surgery, which has entered the clinical arena

Therefore…

Creation of the 10-ps TOF PET Challenge

http://the10ps-challenge.org

The 10ps challenge: a step toward reconstructionless TOF-PET

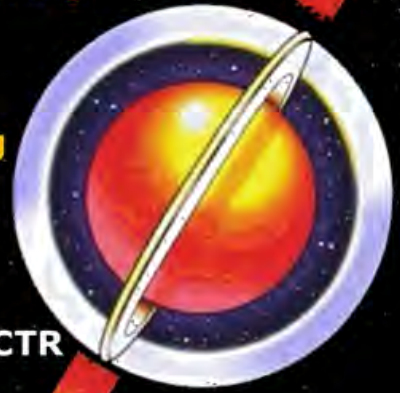
The 10ps challenge:

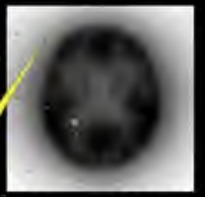
- a spur on the development of fast timing
- an opportunity to get together
- an incentive to raise funding
- a way to shed light on nuclear instrumentation for medical imaging

One unique challenge launched for 5 to 10 years and operated by an international organisation with rules issued by the community based on the measurement of CTR combined to sensitivity

Several milestones and prices:

- 3 years after the launch of the challenge: 1M€ expected for the Flash Gordon prices for the realisation of 3 important milestones
- until the end of the challenge: 1M€ expected for the Leonard McCoy price for the first team meeting successfully





Non-TOF FBP

Non-TOF OSEM

10ps TOF FBP

10ps TOF

http://the10ps-challenge.org

Endorsement

EANM European Association of Nuclear Medicine

EIBIR EUROPEAN INSTITUTE FOR BIOMEDICAL IMAGING RESEARCH

WMIS World Molecular Imaging Society Discover. Visualize. Learn. Cure.

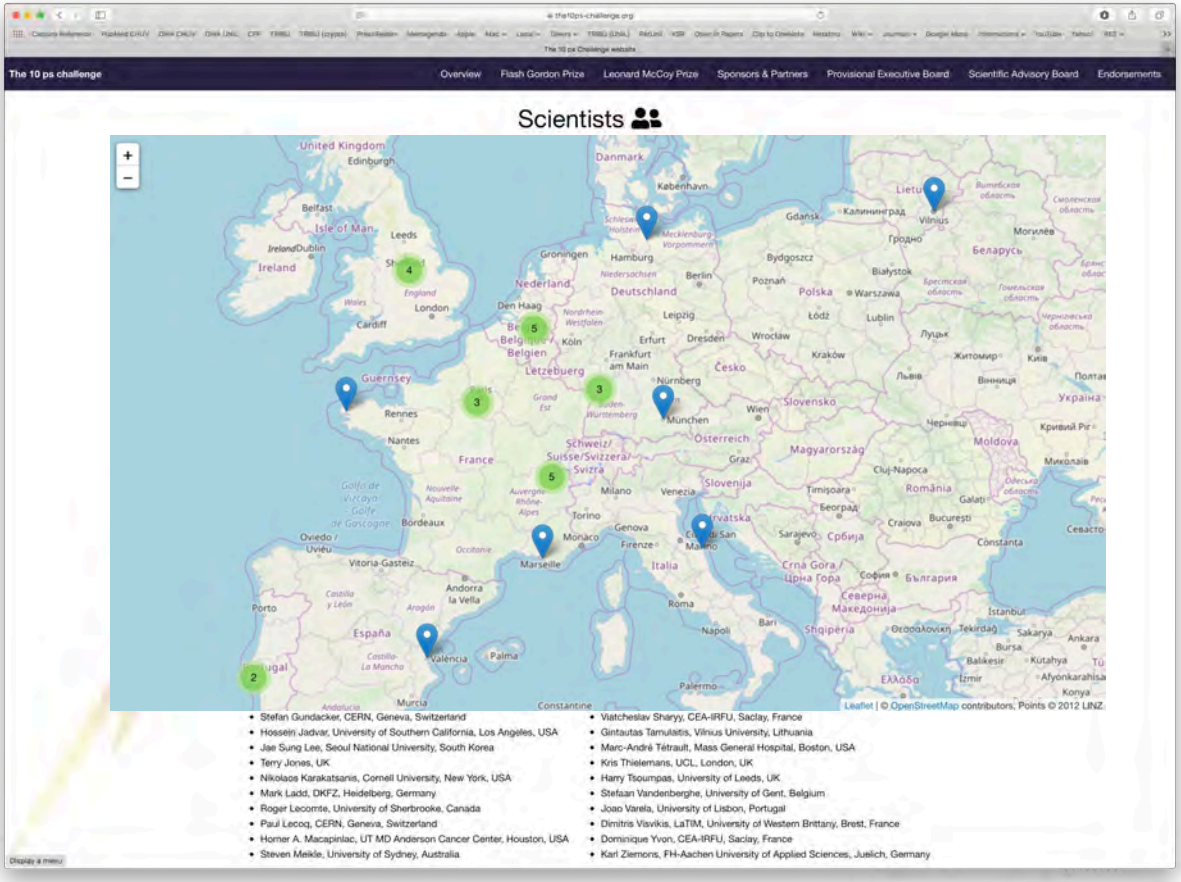
IEEE NPSS NUCLEAR & PLASMA SCIENCES SOCIETY

IEEE NPSS NMISC

PETsys Electronics

Crystal Photonics Inc.

Worldwide:
40 PET Scientists
and Physicians



canton de vaud

As of September 1, 2019

Conclusion

Shift of paradigm for molecular imaging

Impact societal challenges:

- Not only in oncological disease, also for screening (lung cancer)
- And neurodegenerative or psychiatric diseases, inflammatory or infectious diseases, and metabolic diseases, across all populational ages from prenatal to geriatric life period

Thank you for your attention!

http://the10ps-challenge.org