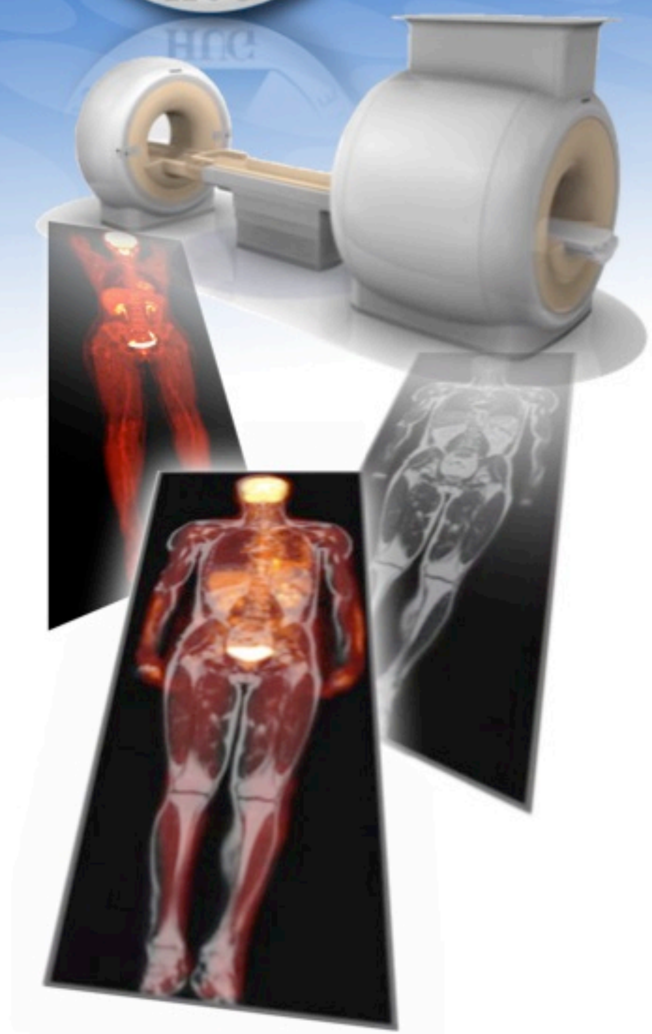


PET-MR

A (still) new hybrid imaging modality
Principles, Applications, Evolution...

Osman Ratib

Chef de département d'Imagerie et
Sciences de l'Information Médicale
Chef de Service de Médecine Nucléaire
et d'Imagerie Moléculaire, HUG, Switzerland

as tweaked and told by **Luc Bidaut**

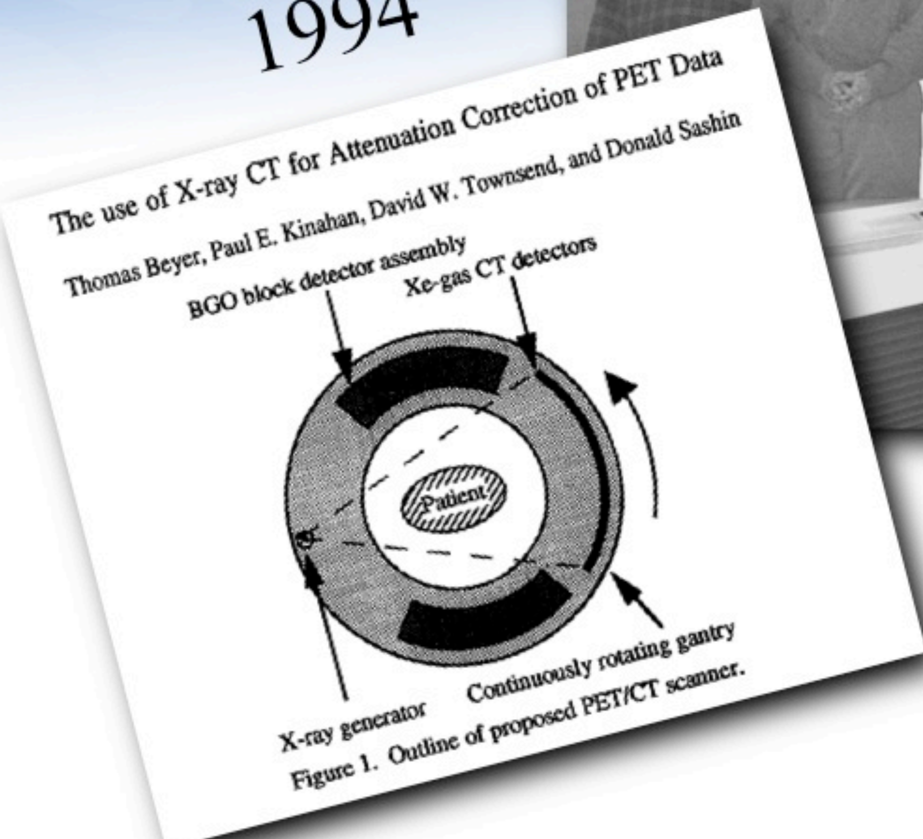
Translational Imaging & Technology
Fife-Tayside, Scotland-UK

Hôpitaux Universitaires de Genève

Hybrid imaging in Geneva

Origin of PET / CT

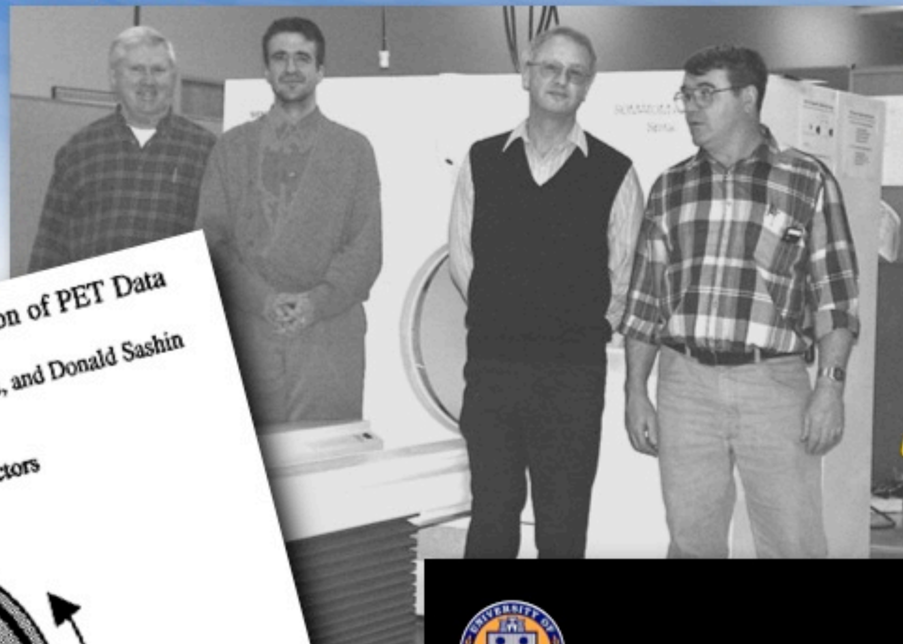
1994



The use of X-ray CT for Attenuation Correction of PET Data

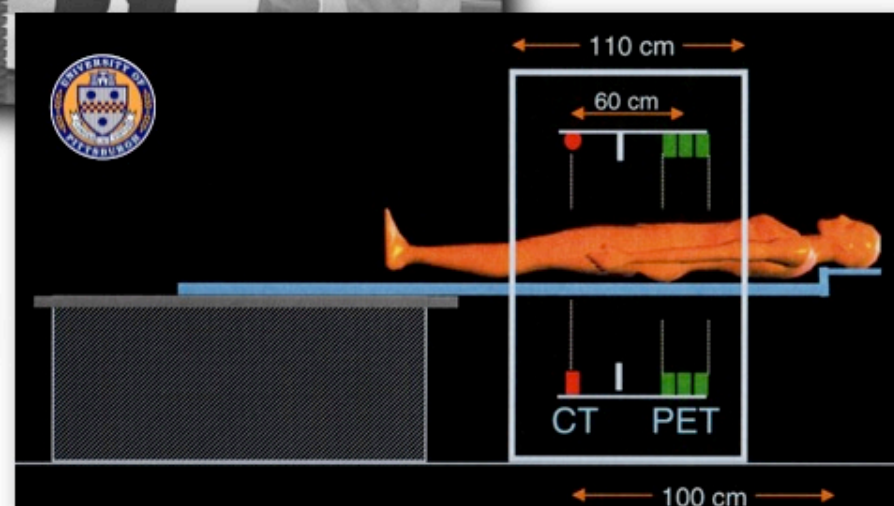
Thomas Beyer, Paul E. Kinahan, David W. Townsend, and Donald Sashin

Figure 1. Outline of proposed PET/CT scanner.



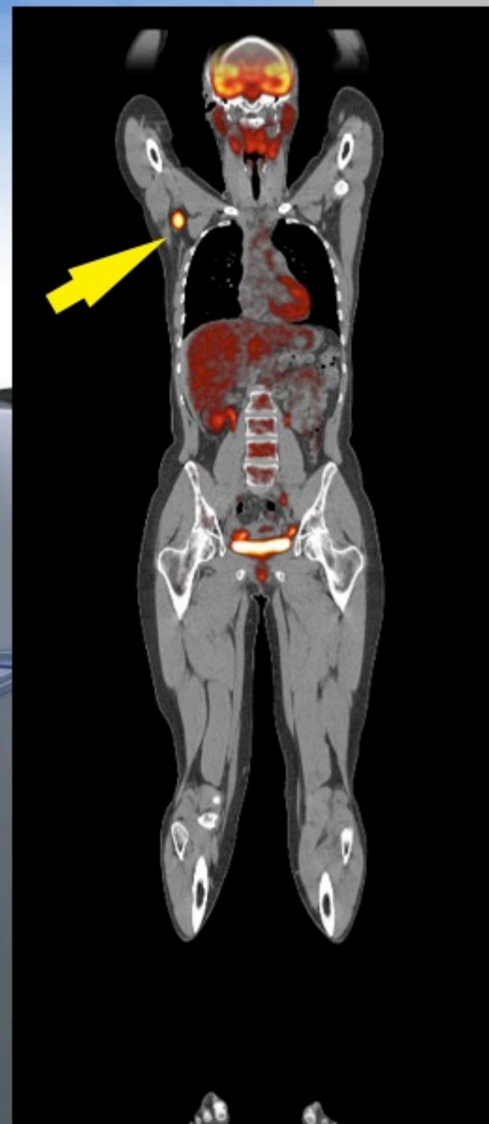
1998

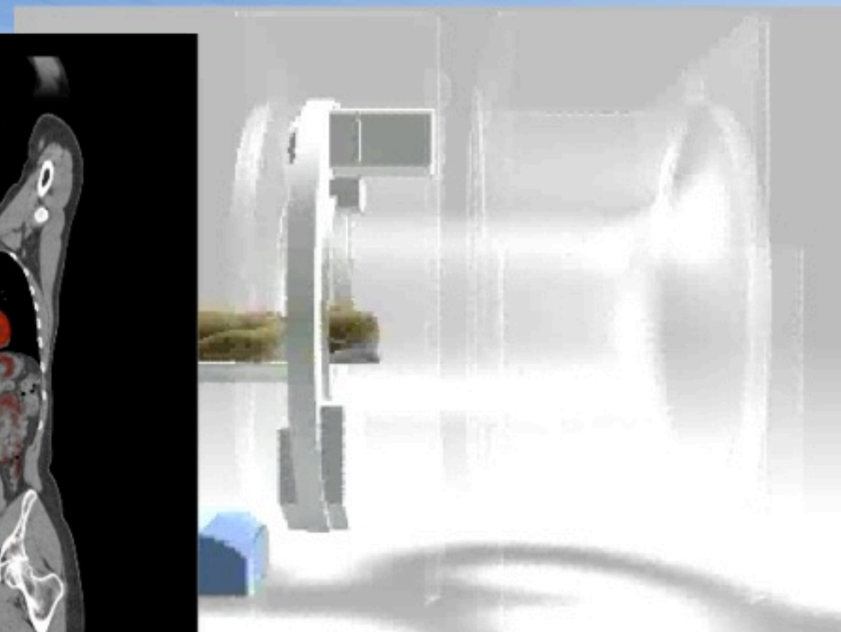
University of Pittsburgh Medical Center



History of hybrid imaging

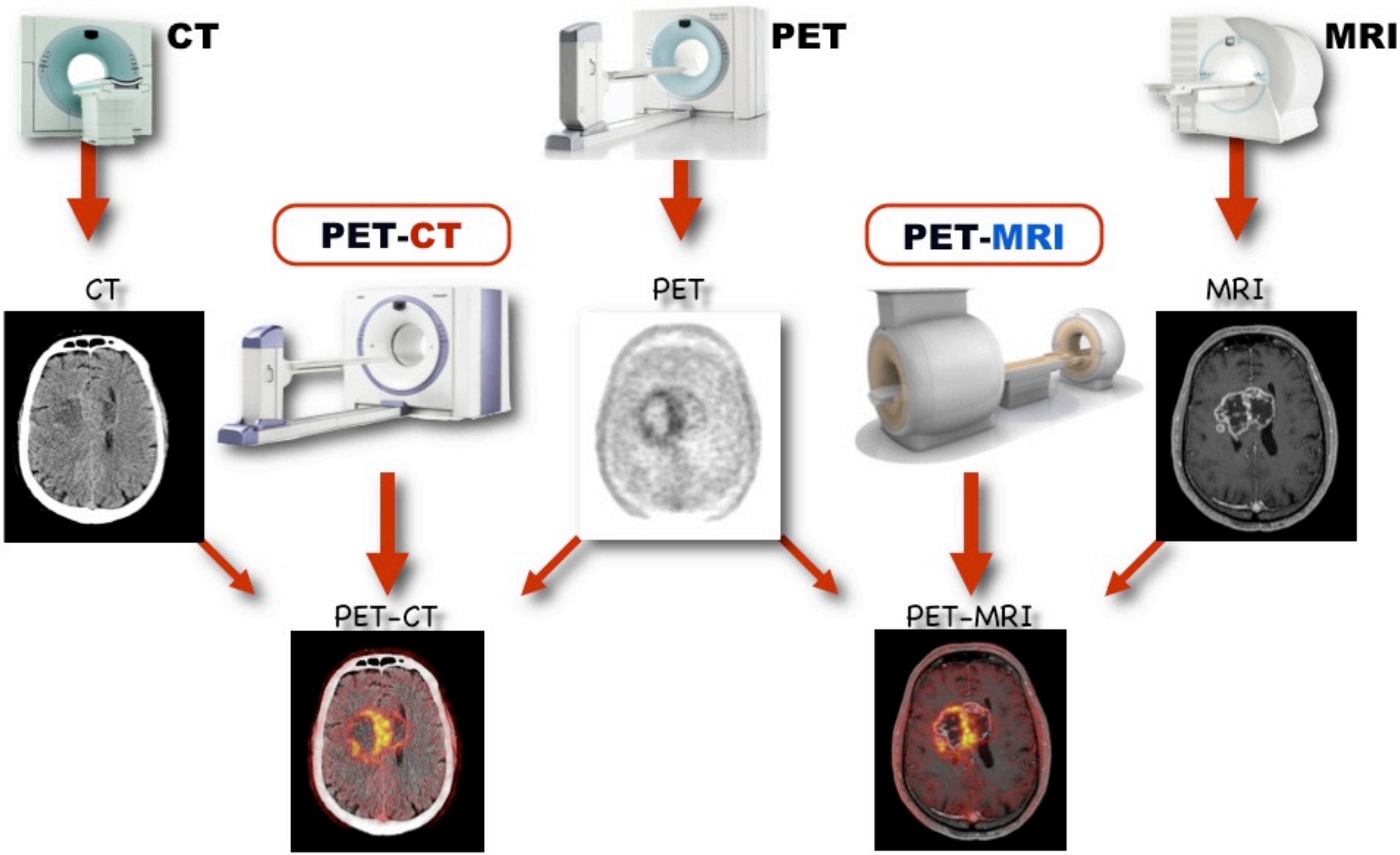
Sequential PET-CT





Hybrid imaging

From PET-CT to PET-MR



PET-MRI developments

Pioneer work by S. Cherry 1994-1996 at UCLA

Phys. Med. Biol. **42** (1997) 1965–1970. Printed in the UK PII: S0031-9155(97)81007-X

Simultaneous PET and MR imaging

Yiping Shao†‖, Simon R Cherry†, Keyvan Farahani‡, Ken Meadors†, Stefan Siegel†, Robert W Silverman† and Paul K Marsden§

† Crump Institute for Biological Imaging, Department of Molecular and Medical Pharmacology, 10833 Le Conte Avenue, UCLA School of Medicine, Los Angeles, C

‡ Department of Radiological Sciences, 10833 Le Conte Avenue, U

Los Angeles, CA 90095, USA

§ Guy's and St Thomas' Clinical PET Centre, Division of Radio

London, UK

Received 14 January 1997, in final form 6 May 1997

Abstract. We have developed a prototype PET detector which is MRI system to provide simultaneous PET and MR imaging. This consists of 48 $2 \times 2 \times 10$ mm^3 LSO crystals in a 38 mm diameter rin placed inside the receiver coil of the MRI system, coupled to three mult housed outside the main magnetic field via 4 m long and 2 mm diame system exhibits 2 mm spatial resolution, 41% energy resolution at 5 resolution. Simultaneous PET and MR phantom images were successfully acquired.

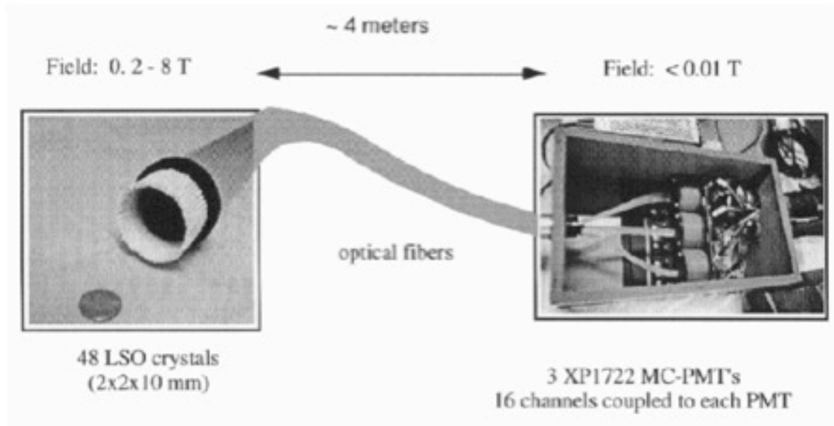


Figure 1. The prototype MR compatible PET system.

PET-MRI developments

First animal prototype S. Cherry 2004-2006

TECHNICAL REPORTS

nature medicine

Simultaneous PET-MRI: a new approach for functional and morphological imaging

Martin S Judenhofer[1], Hans F Wehrl[1], Danny F Newport[2], Ciprian Catana[3], Stefan B Siegel[2], Markus Becker[4], Axel Thielscher[5], Manfred Kneilling[6], Matthias P Lichy[1], Martin Eichner[7], Karin Klingel[8], Gerald Reischl[9], Stefan Widmaier[4], Martin Röcken[6], Robert E Nutt[2], Hans-Jürgen Machulla[9], Kamil Uludag[5], Simon R Cherry[3], Claus D Claussen[1] & Bernd J Pichler[1]

Noninvasive imaging at the molecular level is an emerging field in biomedical research. This paper introduces a new technology synergizing two leading imaging methodologies: positron emission tomography (PET) and magnetic resonance imaging (MRI). Although the value of PET lies in its high-sensitivity tracking of biomarkers *in vivo*, it lacks resolving morphology. MRI has lower sensitivity, but produces high soft-tissue contrast and provides spectroscopic information and functional MRI (fMRI). We have developed a three-dimensional animal PET scanner that is built into a 7-T MRI. Our evaluations show that both modalities preserve their functionality, even when operated isochronously. With this combined imaging system, we simultaneously acquired functional and morphological PET-MRI data from living mice. PET-MRI provides a powerful tool for studying biology and pathology in preclinical research and has great potential for clinical applications. Combining fMRI and spectroscopy with PET paves the way for a new perspective in molecular imaging.

spectroscopy (MRS) and functional MRI (fMRI)[2]. Thus, to combine two or more imaging modalities providing complementary information, such as morphology and function, is a worthwhile goal. Although the combination of PET and CT has already been realized[3] in clinical and preclinical scanners, PET-CT has many limitations. Its major drawback is that the imaging is performed sequentially rather than simultaneously. In preclinical studies, this adds considerable time under anesthesia for the subjects and eliminates any temporal correlation between the two modalities, such as CT perfusion measurements and PET tracer kinetics. Furthermore, CT has limited soft-tissue contrast, and the necessary dose of radiation can be high enough to perturb the animal model under study. Hence, a preferred choice would be to combine PET and MRI, not only because of the absence of ionizing radiation in MRI but also for its excellent soft-tissue contrast, its flexible scan protocols and its capability to perform fMRI and MRS. The simultaneous acquisition of different functional parameters using PET, fMRI or MRS, in addition to high-resolution anatomic MRI information, creates enormous possibilities and provides com

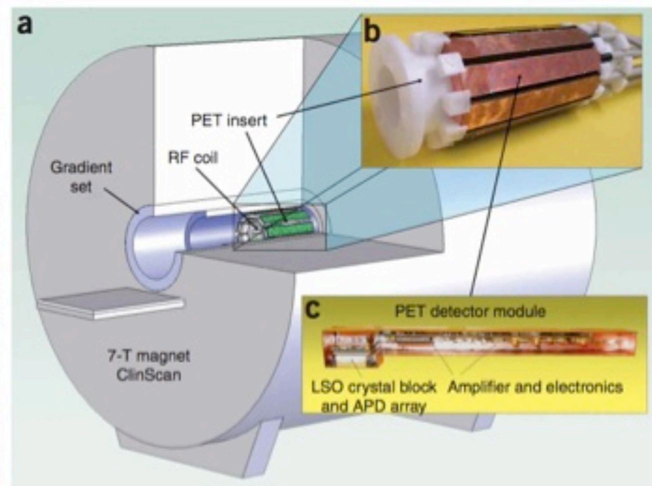
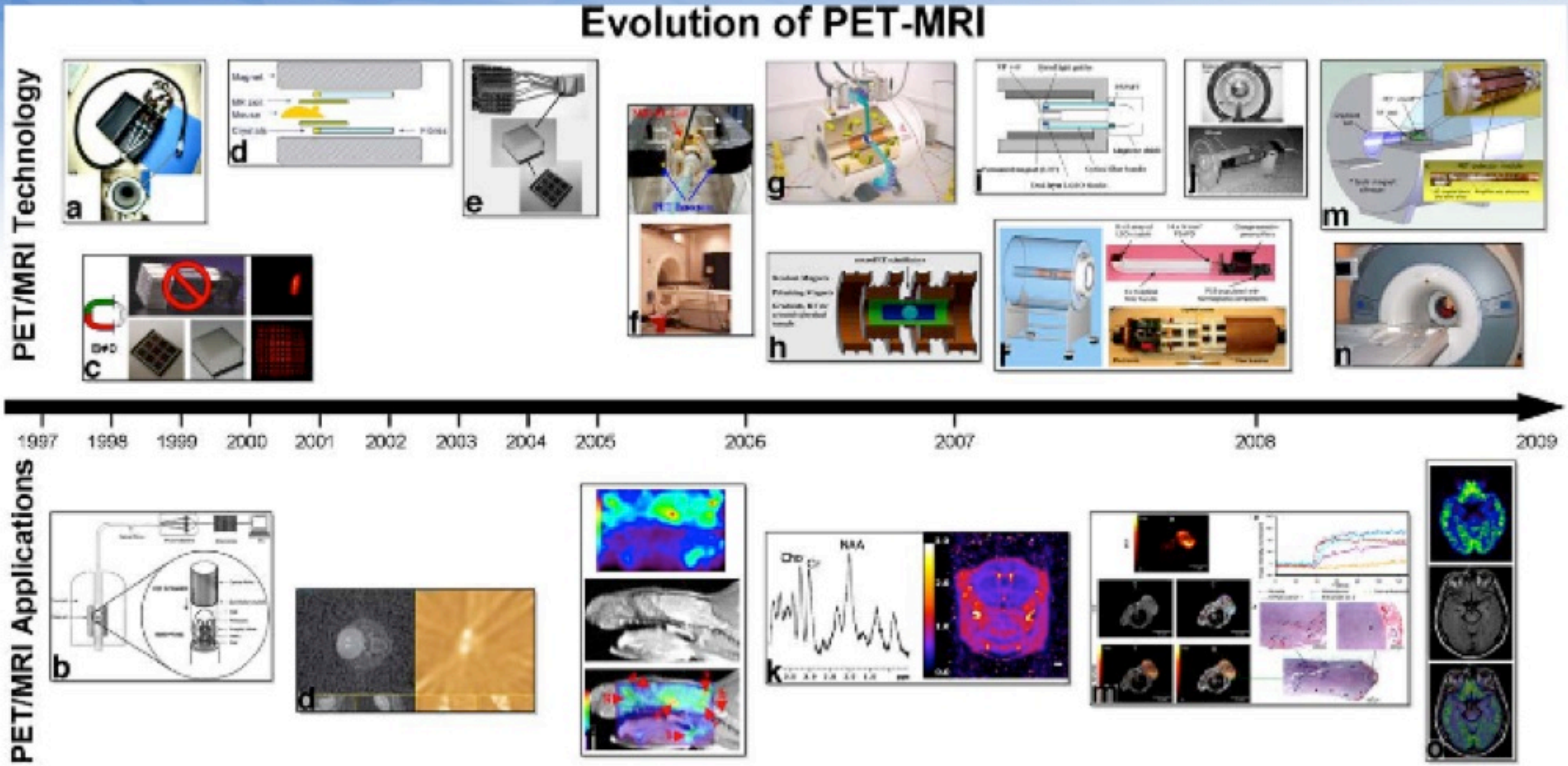


Figure 1 Integration of the multislice PET scanner into a 7-T MRI apparatus. **(a)** Drawing of PET-MRI combination showing the PET insert placed inside the MRI scanner, matching the centers of both fields of view. **(b)** Photograph of the MRI-compatible PET insert consisting of ten radially arranged detector modules. **(c)** Single PET detector module showing the LSO scintillator block, APD array and preamplifier built into a MRI-compatible copper shielding.

PET-MRI developments

History

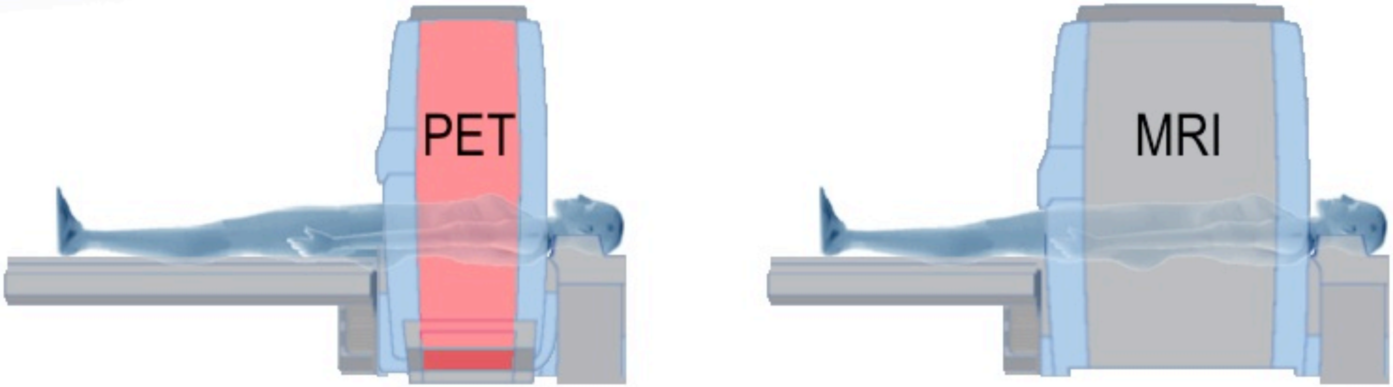


Hans F. Wehrl · Martin S. Judenhofer · Stefan Wiehr · Bernd J. Pichler

Eur J Nucl Med Mol Imaging (2009) 36 (Suppl 1):S56–S68

Hybrid PET-MRI

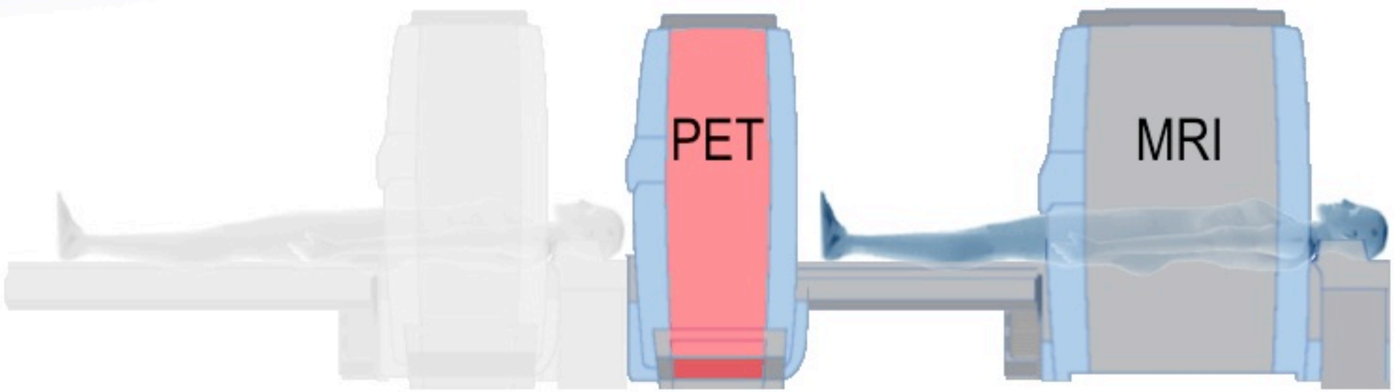
Evolution...



Separate, ≠ *suites*

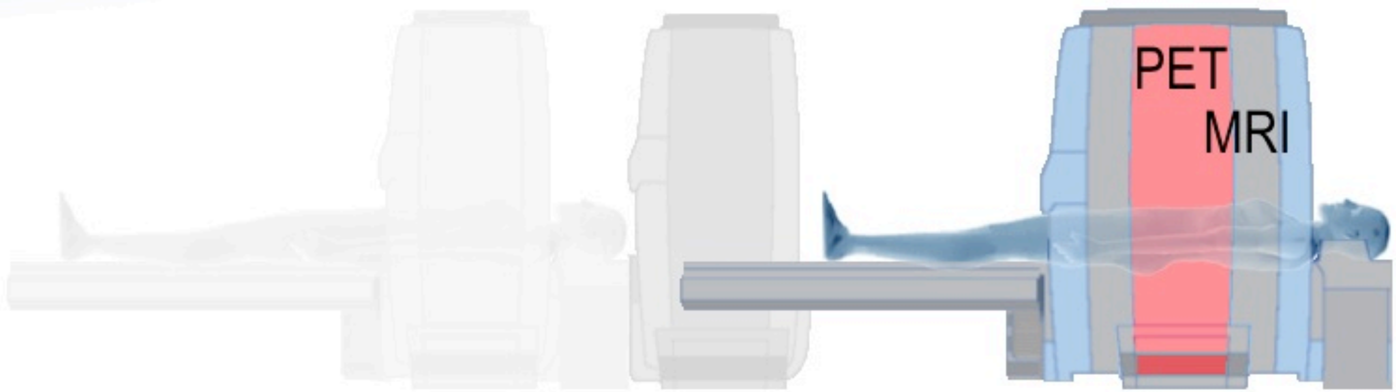
Hybrid PET-MRI

Evolution…



Separate ➟ Co-planar *à la PET-CT*

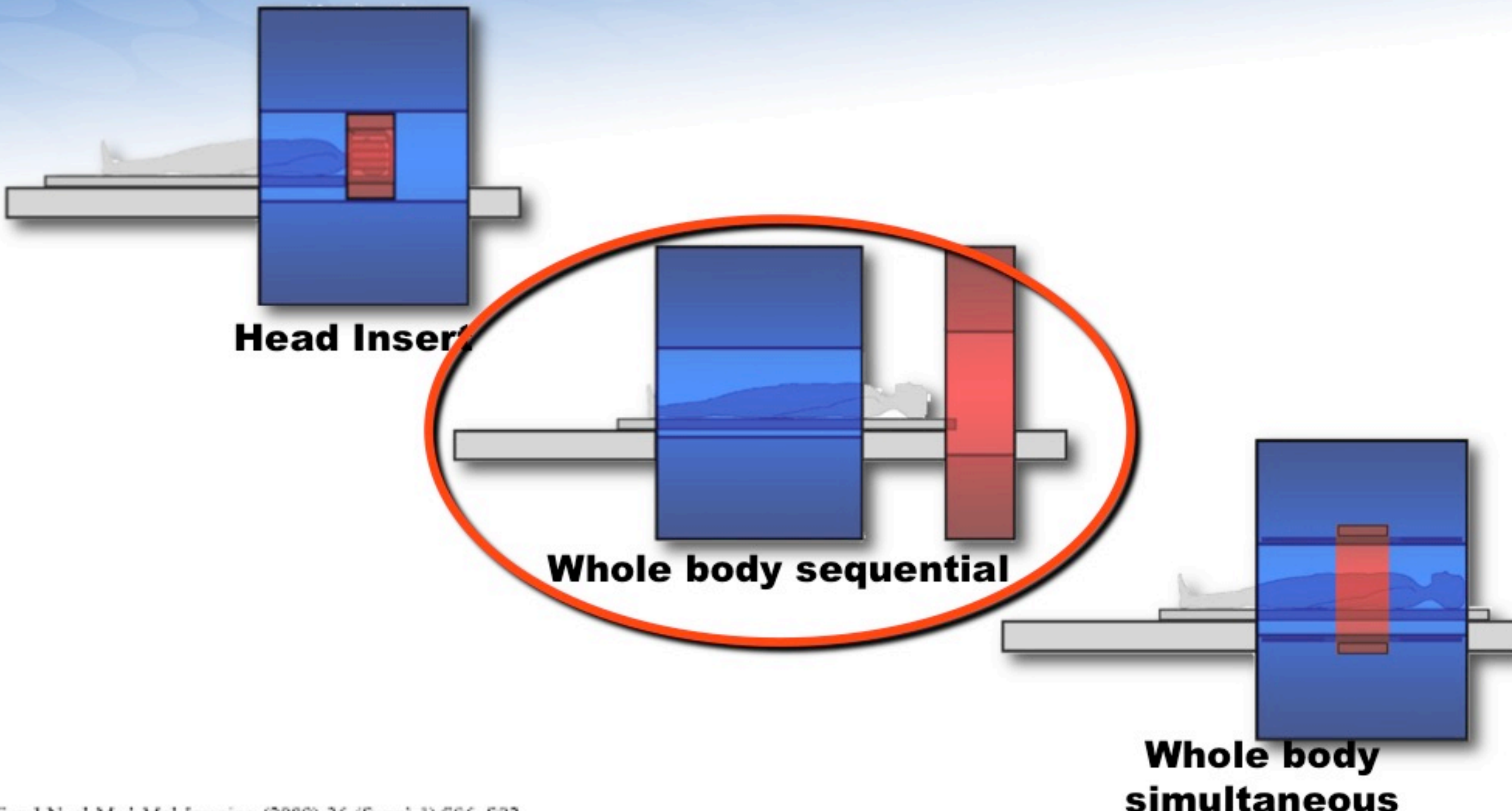
Evolution...



Separate ➟ Co-planar ➟ Integrated

PET-MRI developments

Sequential vs simultaneous acquisition



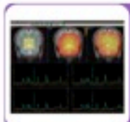
Eur J Nucl Med Mol Imaging (2009) 36 (Suppl 1):S86–S92

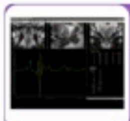
Hybrid whole-body PET-MRI

State of the art of both modalities

Multi-Transmit 3T MRI


Fast & easy Fibertracking


Easy MN Brain Spectroscopy


Prostate Spectroscopy


Routine Coronary Imaging

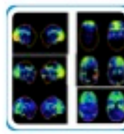

Head-spine Imaging

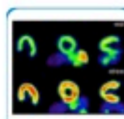
Time-of-flight PET


Time-of-Flight Imaging


Motion Management


Oncology Applications


Neurology Applications

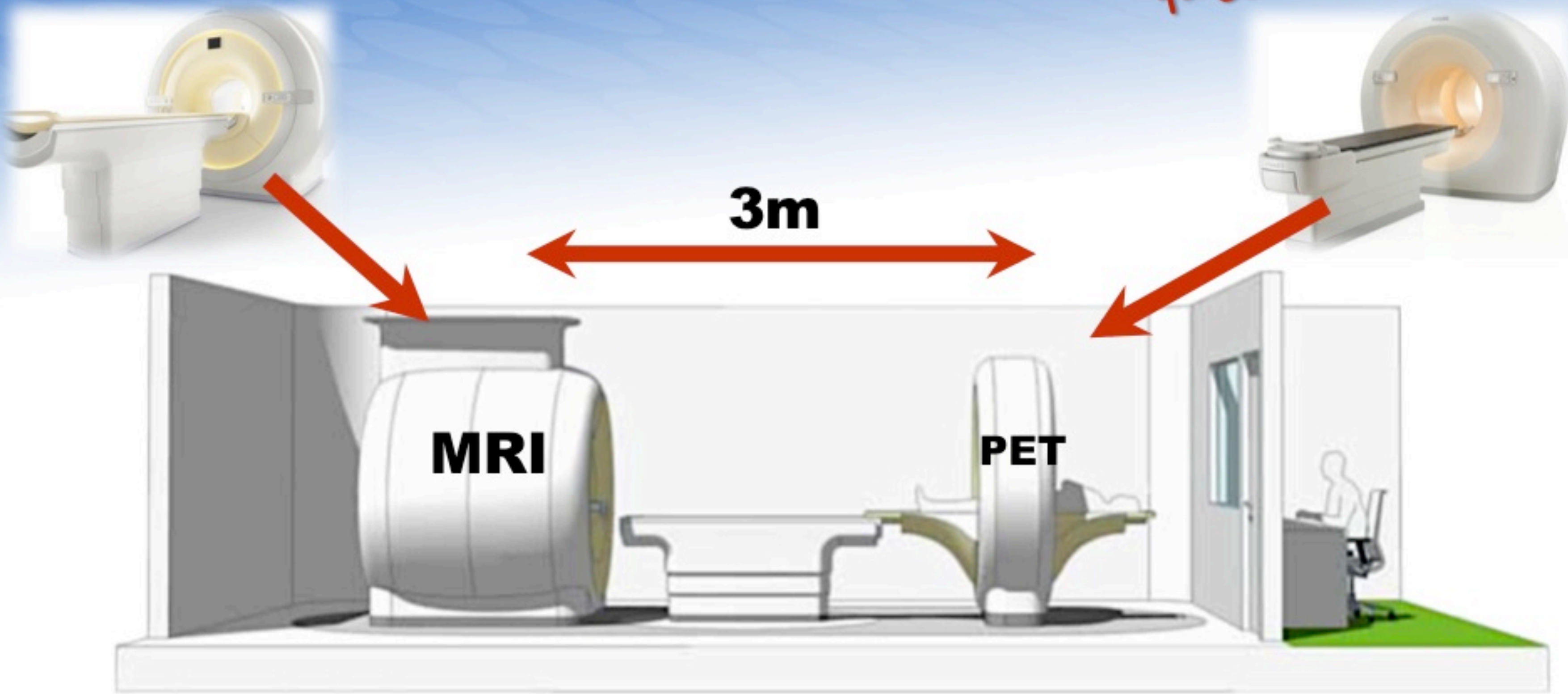

Cardiology Applications

PHILIPS

Hybrid whole-body PET-MRI

State of the art of both modalities

February 2010
1st commercial system



Separate ... in the same suite

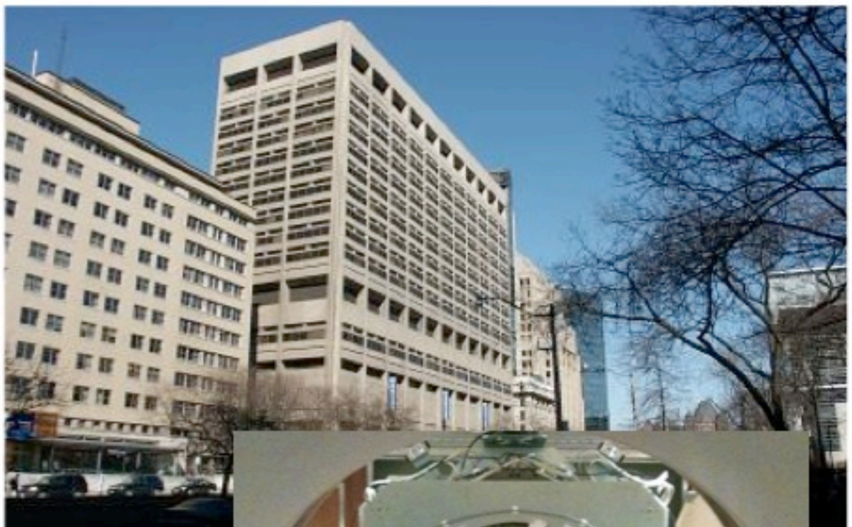
PET-MRI hybrid imaging

Whole-body PET-MRI

February 2010
1st commercial system

Mount Sinai Medical Center
(New York)

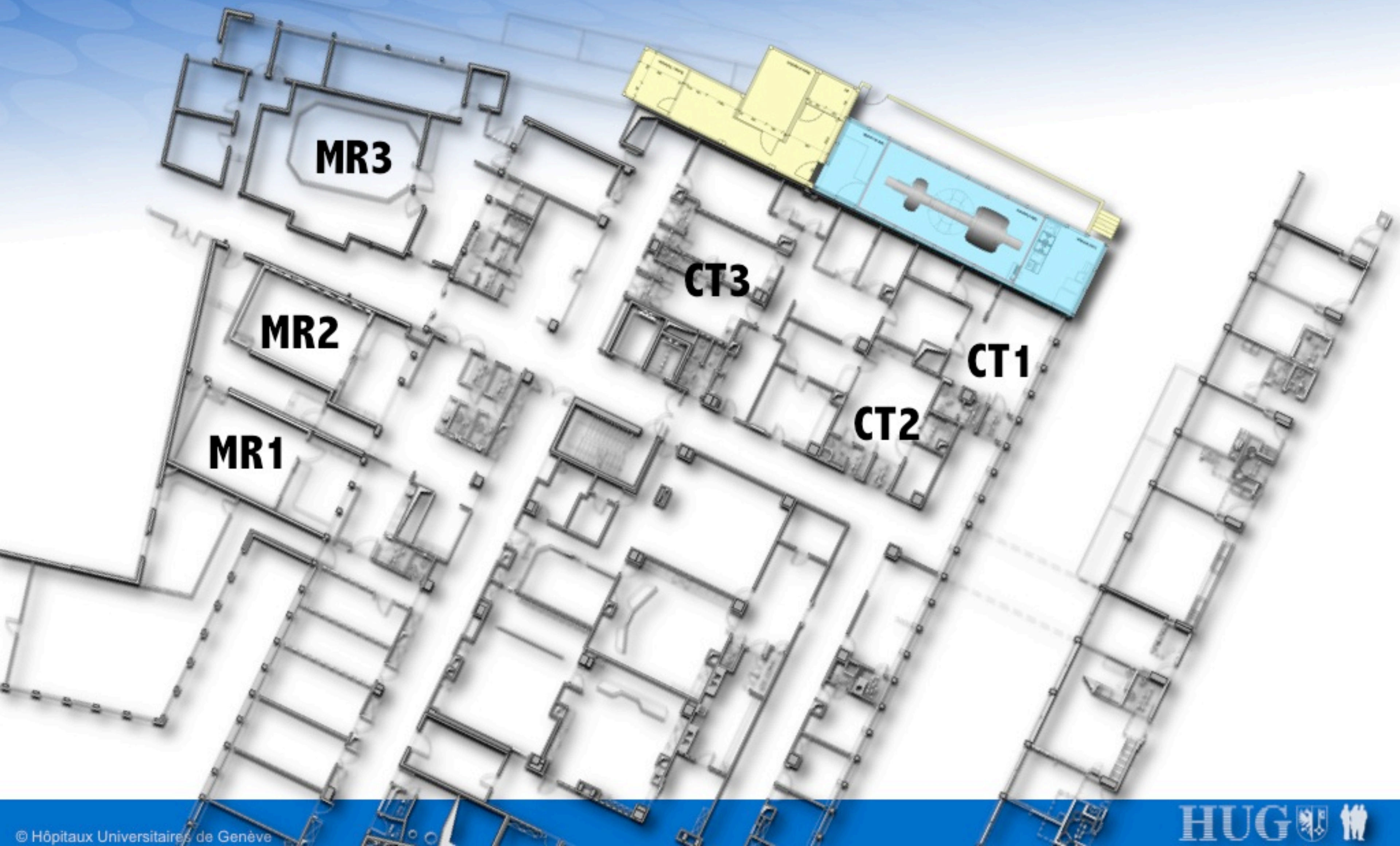
Geneva University Hospital
(Geneva)



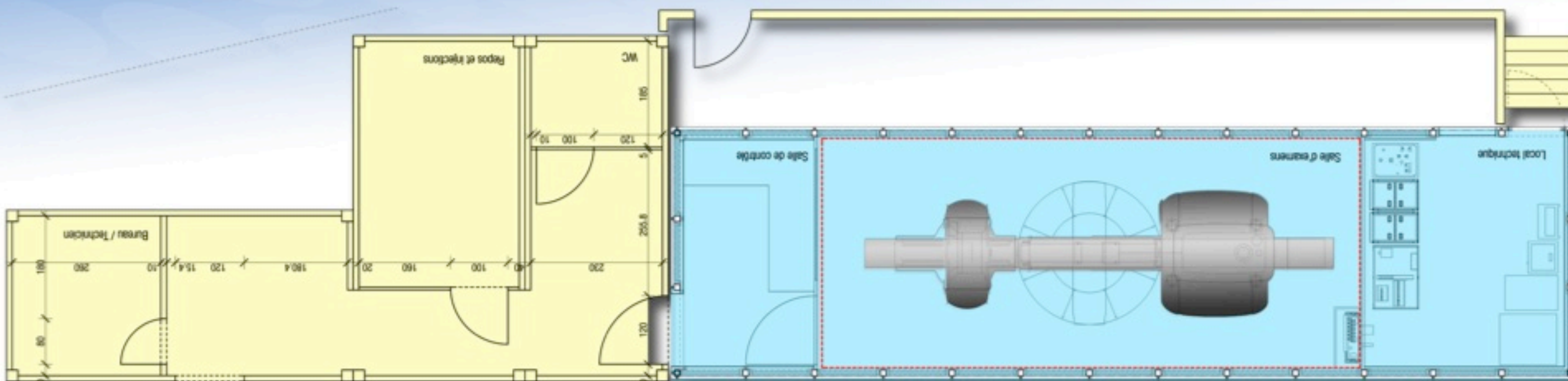
Pr. Z.Fayad

Pr. O.Ratib

PET-MRI in Geneva



PET-MRI in Geneva



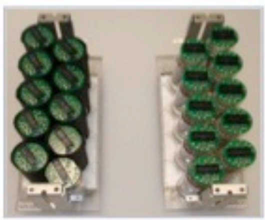
GEMINI TF PET/MR – PMT-based - Hardware shielding

Individual PMT
Shield Placement

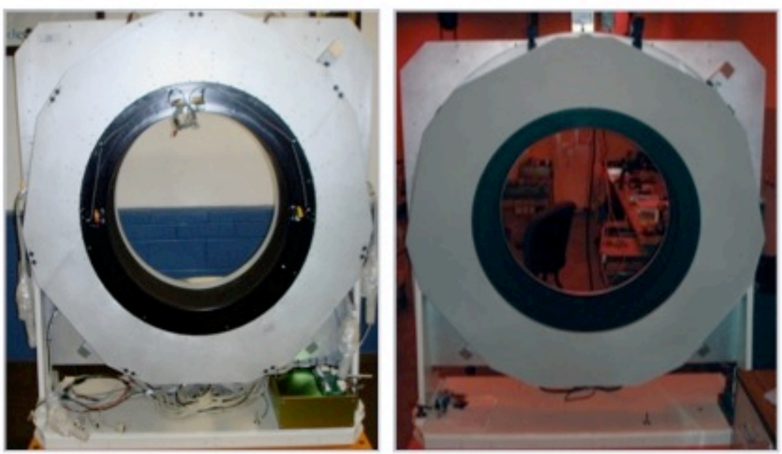
GEMINI TF PET/MR
Crystal Module

GEMINI TF PET/CT
Crystal Module

- **Magnetic MU metal shielding of individual PMT's**
- **PMT orientation in clocked / rotated orientation to improved shielding of cathode from magnetic field**



GEMINI TF PET/MR cathode rotated to align with MR flux lines



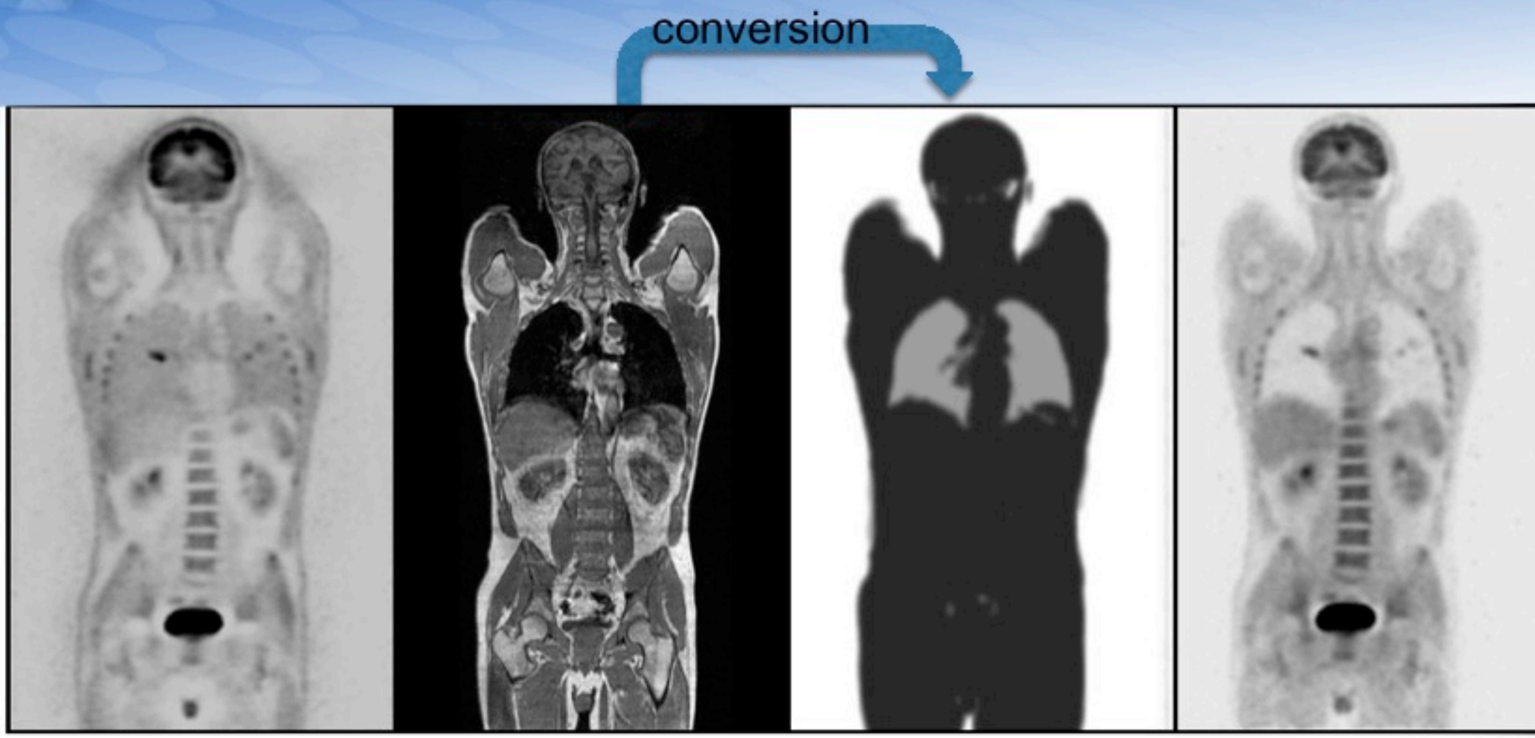
- **Modular shielded construction in gantry**
- **Laminated steel shield on PET gantry MR face**
- **Z-axis distance control to reduce magnetic impact**

GEMINI TF PET/MR
Gantry with laminated
steel shield

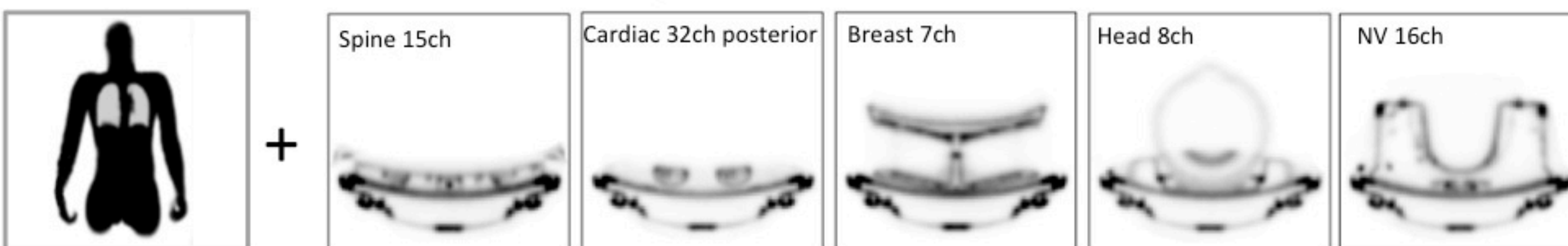
PHILIPS

Whole-body PET-MRI

MR-based attenuation correction

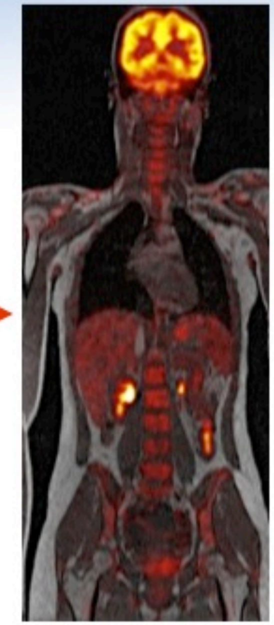


Uncorrected PET **Whole body MRI** **Attenuation Mask** **Corrected PET**

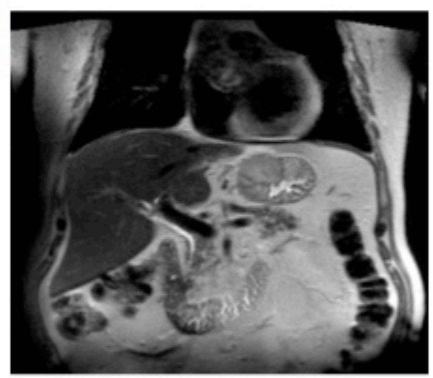


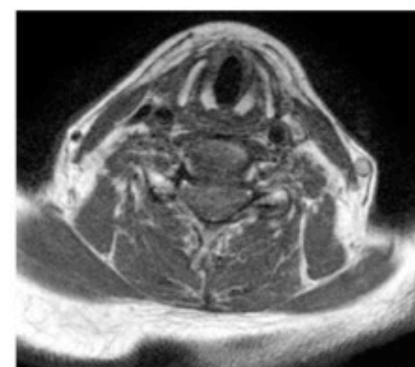
Whole-body PET-MRI

Clinical workflow



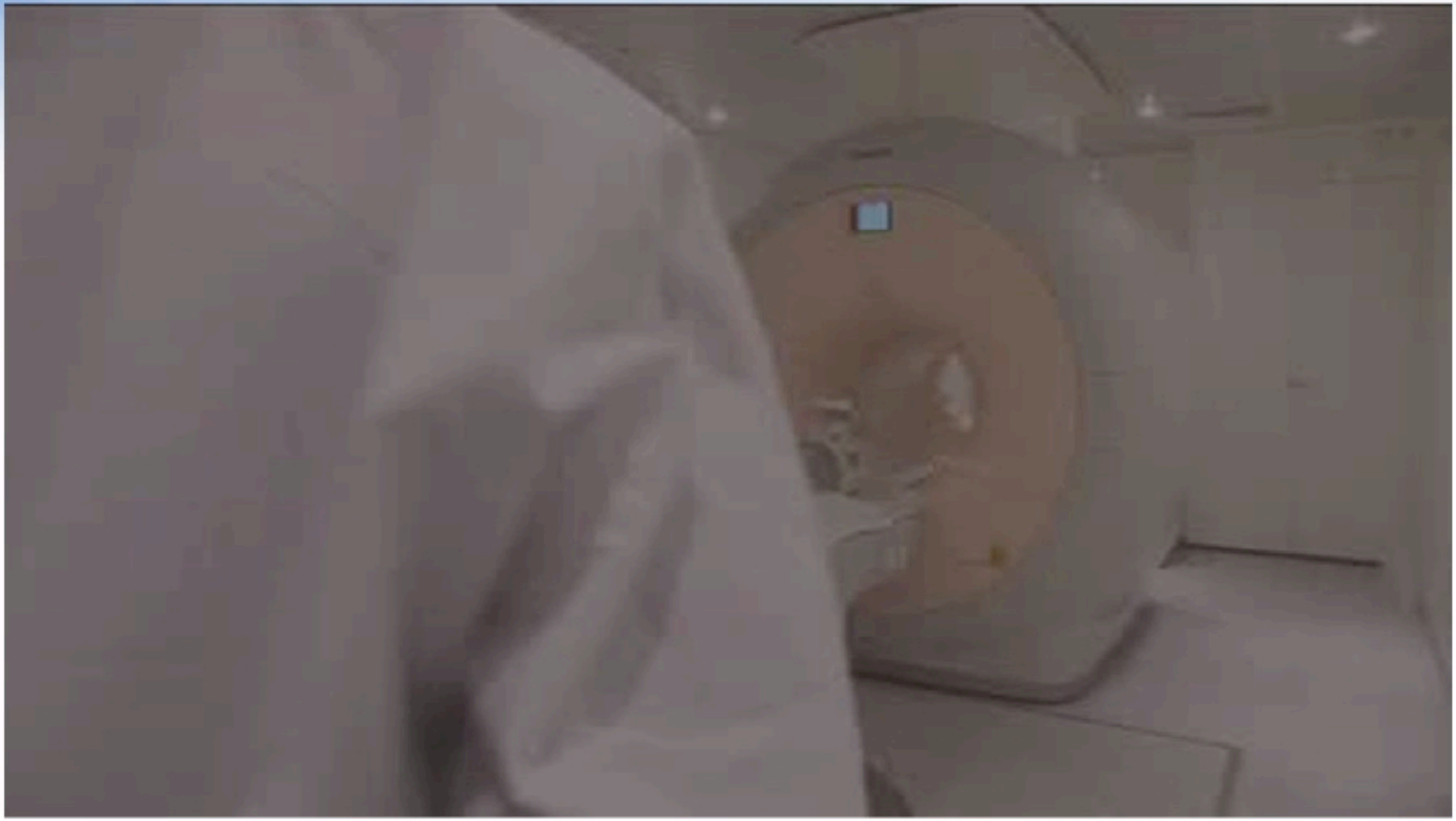
1. **Whole body MRI (AC and localization)**
2. **Whole body PET**
3. **Additional diagnostic MR images**





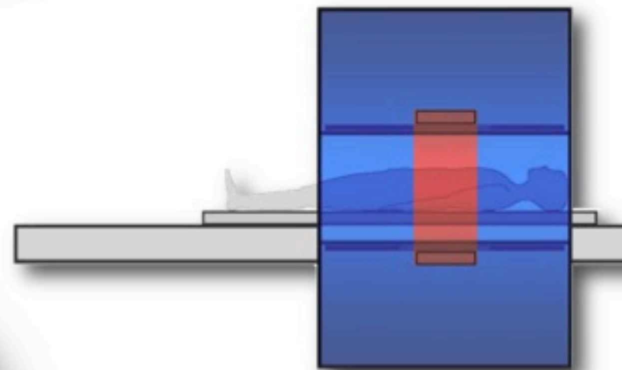
Whole-body PET-MRI

Clinical workflow

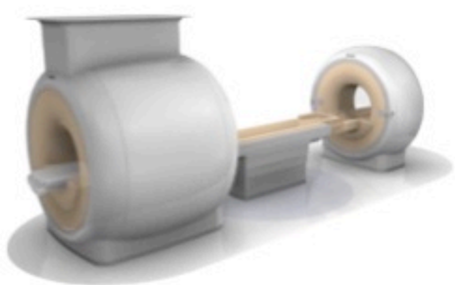


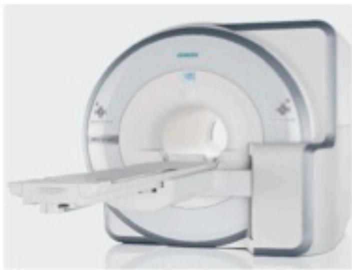
PET-MRI protocols
Sequential vs simultaneous acquisition

Whole body sequential



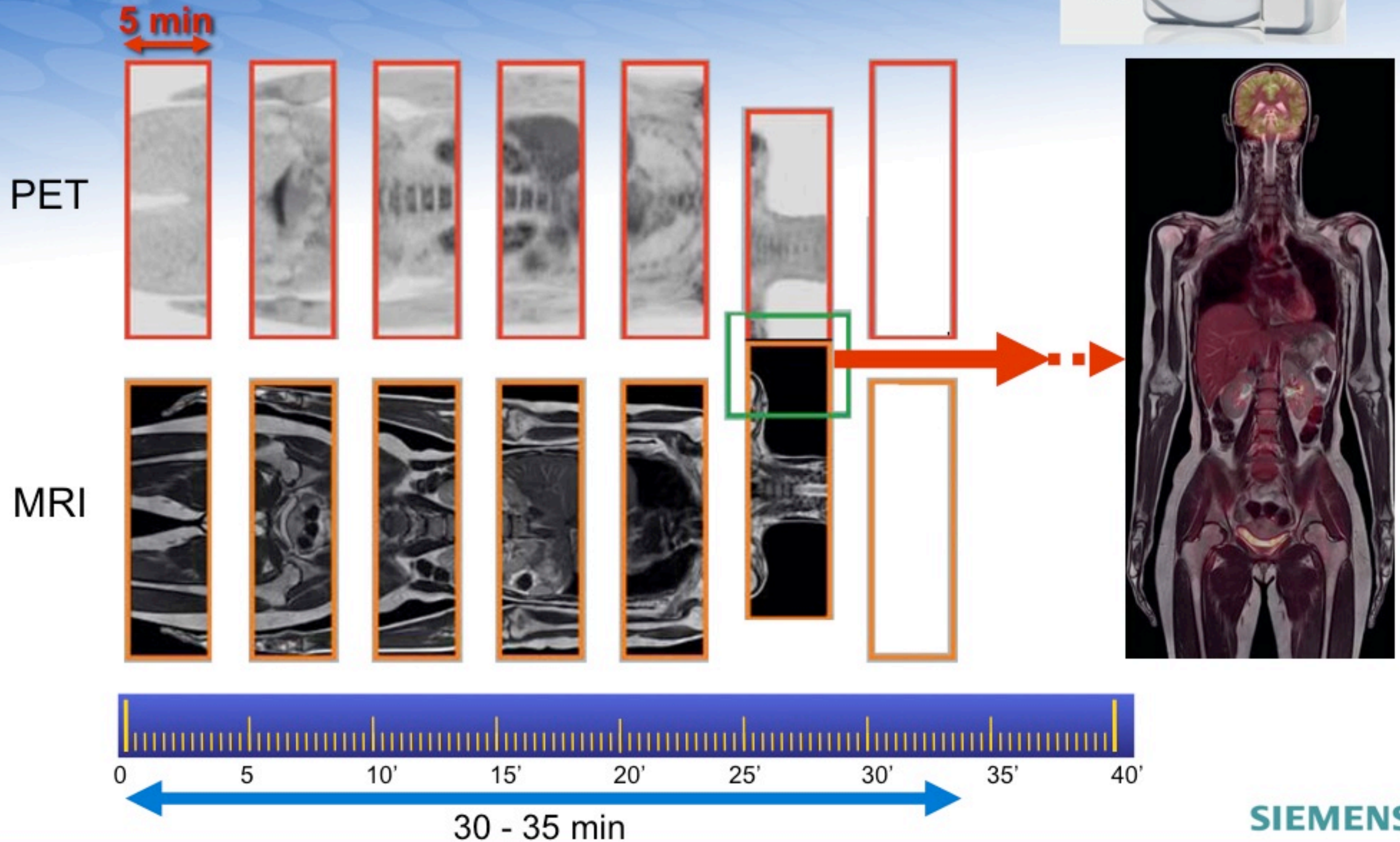
Whole body simultaneous





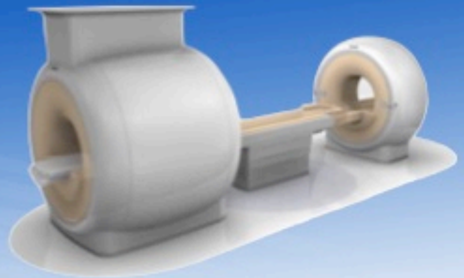
PET-MRI protocols

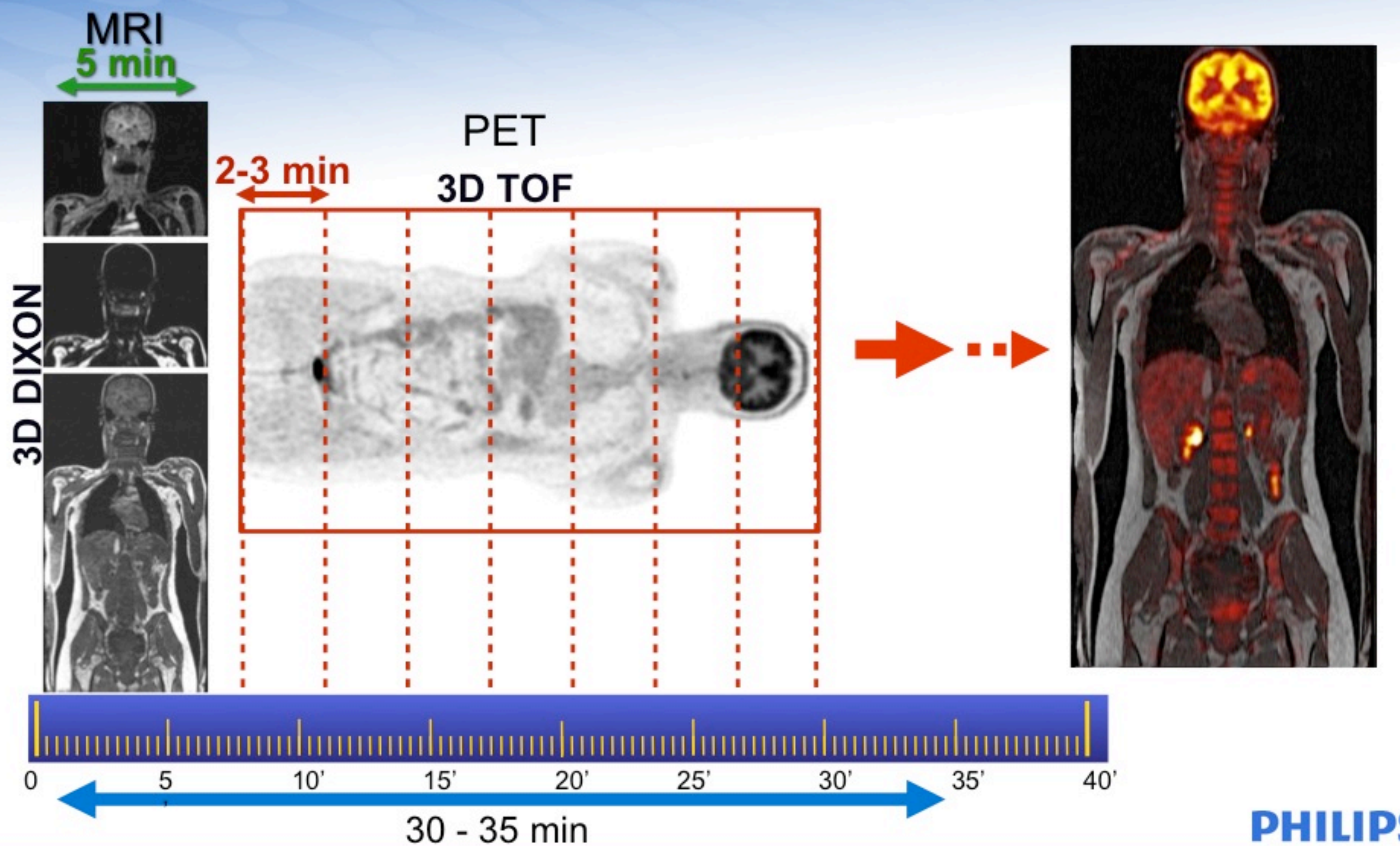
Simultaneous acquisition timeline



PET-MRI protocols

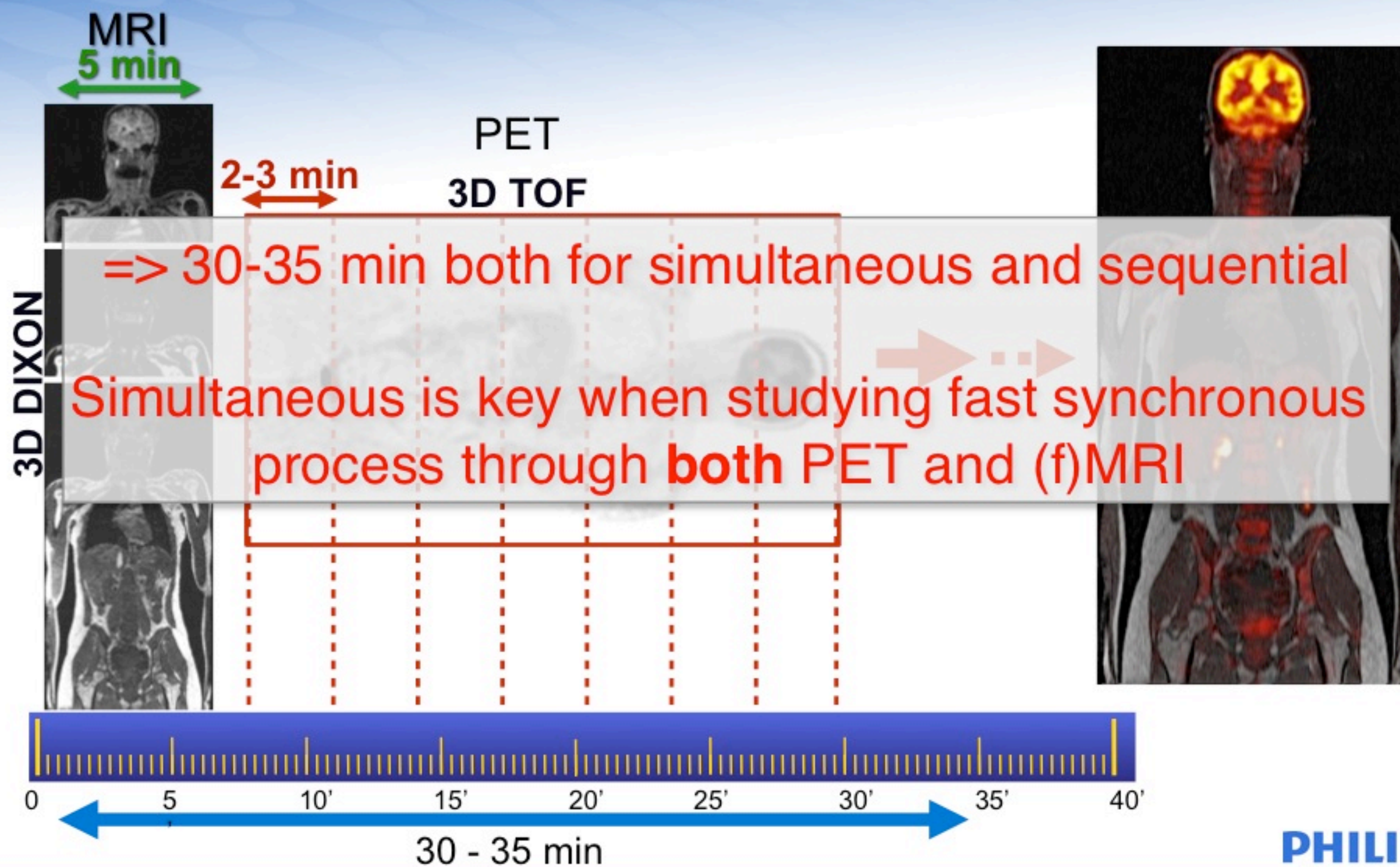
Sequential acquisition timeline





PET-MRI protocols

Sequential acquisition timeline



=> 30-35 min both for simultaneous and sequential

Simultaneous is key when studying fast synchronous process through **both** PET and (f)MRI

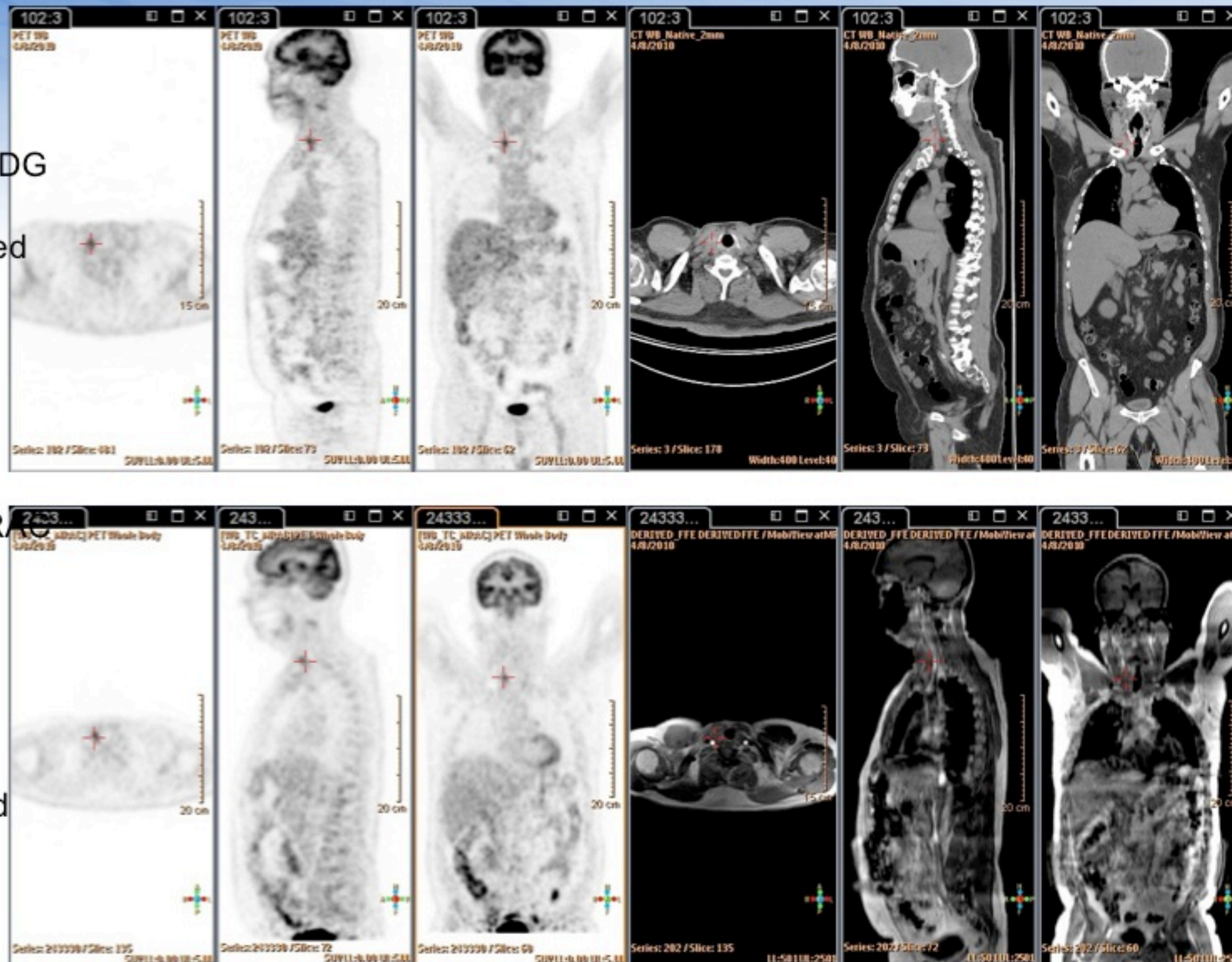
PHILIPS

HUG

PET-MRI in Geneva

First patient with dual hybrid modality study

April 8, 2010



Clinical **PET/CT**

- Injected with 10 mCi FDG at 8:26am
- PET/CT scan performed at 09:30

Taken to Philips **PET/MR**

- PET WB scan with MRAC at 10:45
- 4 minutes for atMR
- PET acquisition 32 minutes/11 positions

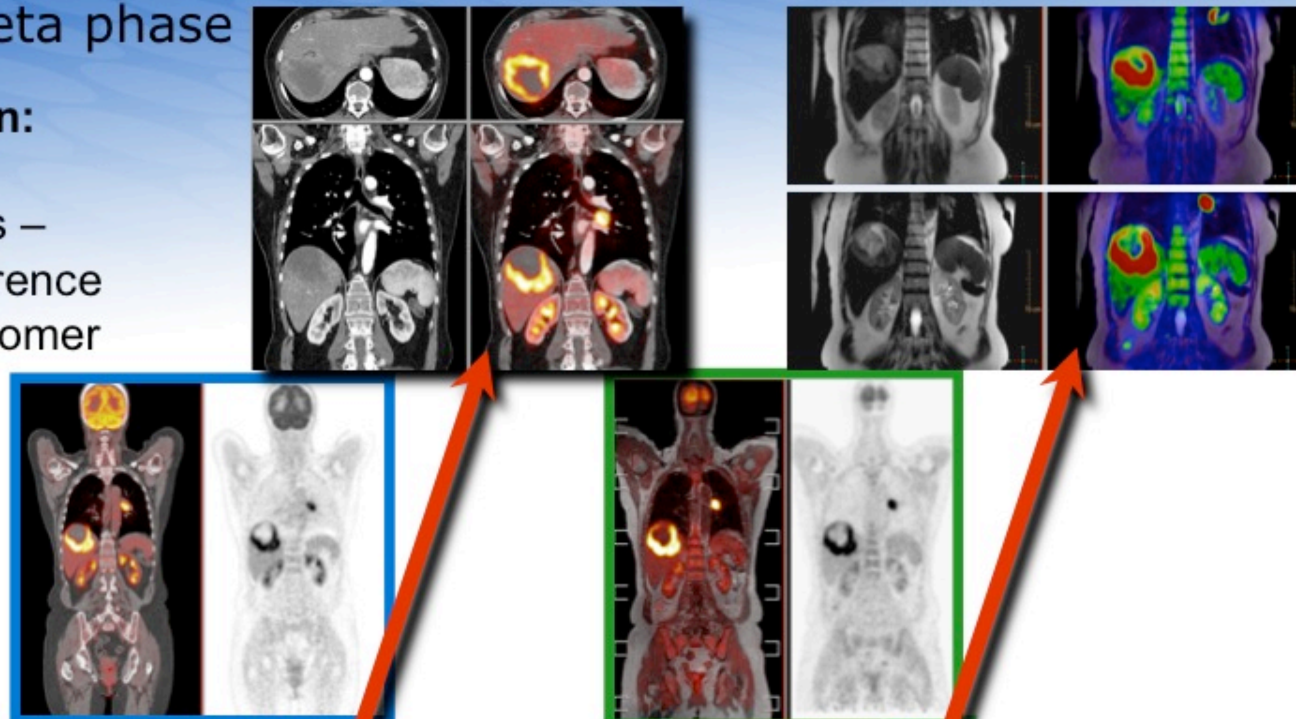
Findings:

- Hypermetabolic thyroid nodule

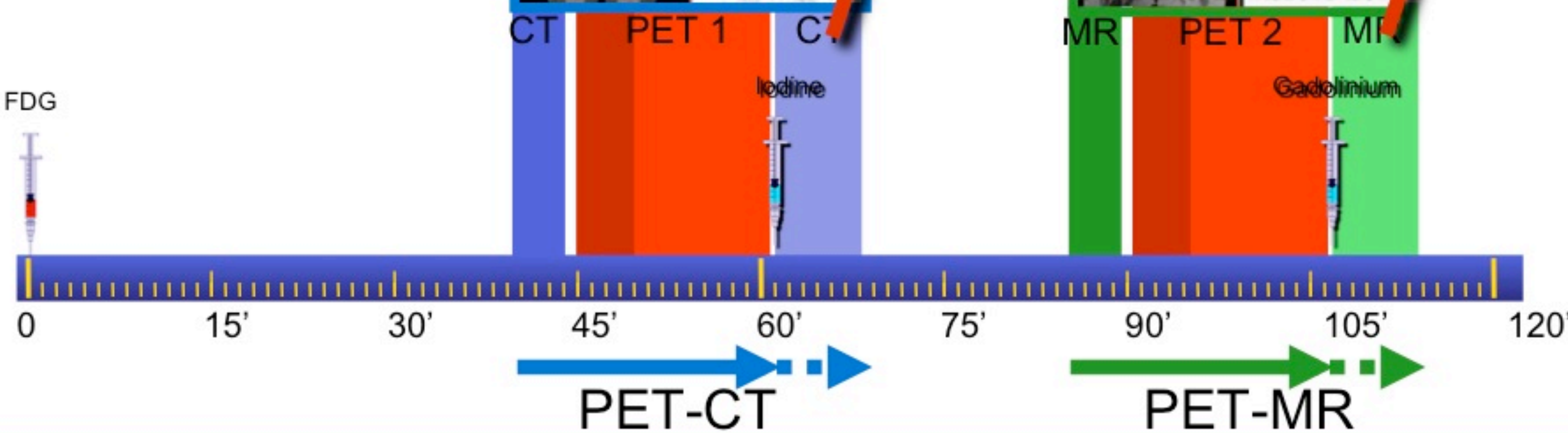
PET-MRI in Geneva

Alpha & beta phase

Evaluation/Validation:
need to compare
– on the same patients –
PET(/CT) as current reference
with PET(/MRI) as new comer



PET-CT & PET-MR workflow



PET-MRI in Geneva

Alpha & beta phase

April - December, 2010

could have been randomised to ensure count-rates/deadtime/etc. didn't matter, but PET/CT is clinical reference and thus needs to be performed as per protocol

- Alpha: 62 patients had a PET-CT followed by a PET-MR
- Average time between studies was 85 ± 22 minutes ranging from 49 minutes to 120 minutes
- Most patients had a complementary diagnostic MRI
- Images were interpreted by a team of radiologists and nuclear medicine physicians
- PET Image quality was graded and compared between PET-CT and PET-MR
- SUV were measured and compared on both PET studies

PET-MRI in Geneva

Beta phase

September - November, 2010

- Clinical validation in routine diagnotic procedures of patients requiring a PET and MRI in their clinical workup
- Comparative PET-CT is not required
- Optimization of MR protocols
- Identification of possible acquisition artifacts or problems

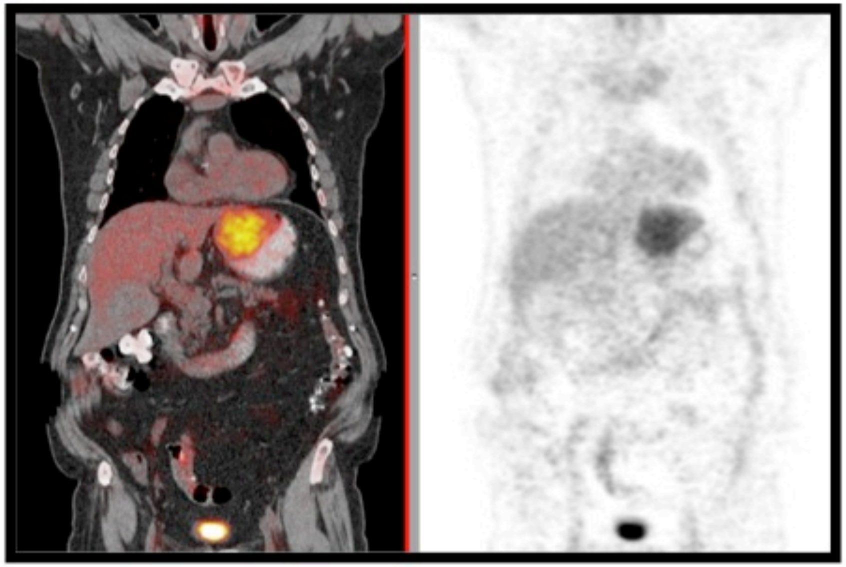
Results

- **No significant difference** in image quality and identification of abnormal lesions were found between the two PET scans of each case
- Images performed on the **PET-MR were comparable to those acquired on the PET-CT** scanner and often showed higher contrast with less background noise due to a well known FDG redistribution
- **No significant artifacts** from attenuation correction or from interference between the two scanners were observed
- **Whole-body MRI** sequence were often **suboptimal** for accurate anatomical localization and additional high resolution images of selected anatomical regions were used

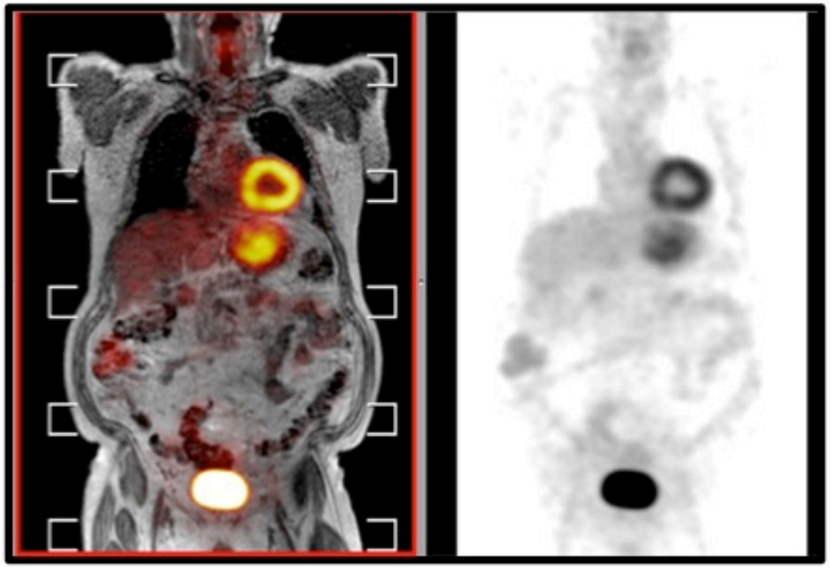
PET-MRI in Geneva

Results

- SUV measurements performed on two sequential PET studies (separated by 85 ± 22 minutes) showed a *significant variation** in biodistribution in different organs, but showed *comparable results* in tumor lesions (* also affected by AT, ongoing physiology and clearance...)



PET-CT



PET-MR

PET-MRI in Geneva

Results

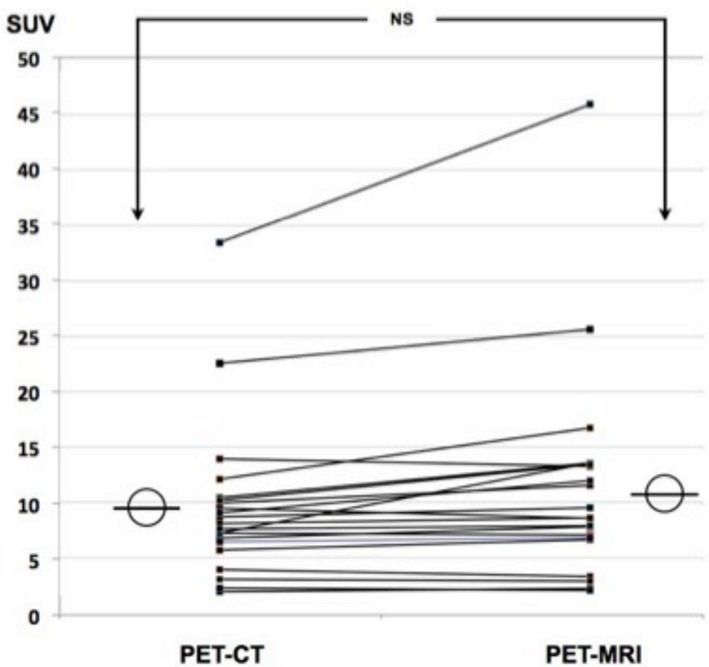
- SUV measurements performed on two sequential PET studies (separated by 85 ± 22 minutes) showed a significant variation in biodistribution in different organs, but showed comparable results in tumor lesions

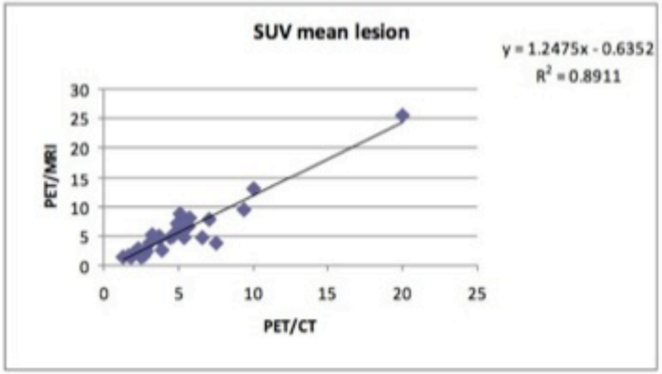
SUV mean	PET/CT	PET/MR	P value (paired t-test)
Brain	6.7 ± 1.9	5.7 ± 2.2	↘ <0.001
Lung	0.5 ± 0.1	0.5 ± 0.2	→ 0.629
Heart	3 ± 1.5	3 ± 1.9	→ 0.811
Liver	2.2 ± 0.5	1.9 ± 1.6	↘ 0.001
Psoas muscle	0.7 ± 0.2	0.9 ± 0.4	↗ 0.004
Gluteus muscle	0.6 ± 0.2	0.7 ± 0.2	↗ 0.111
Bone (L 4 vertebral body)	2 ± 0.6	2.1 ± 0.9	→ 0.221
Lesion	5.1 ± 3.7	5.6 ± 4.9	↗ 0.193

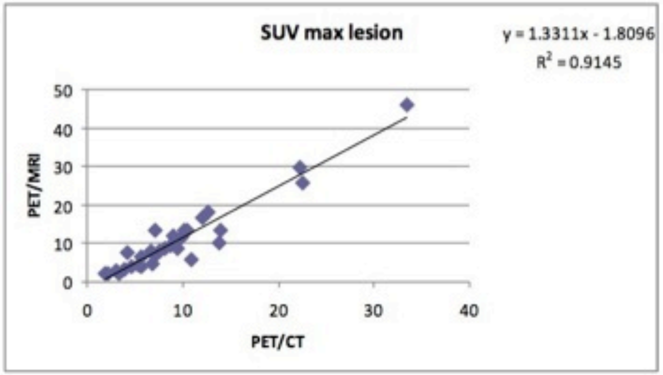
PET-MRI in Geneva

Results

- SUV measurements performed on two sequential PET studies (separated by 85 ± 22 minutes) showed a significant variation in biodistribution in different organs, but showed comparable results in tumor lesions







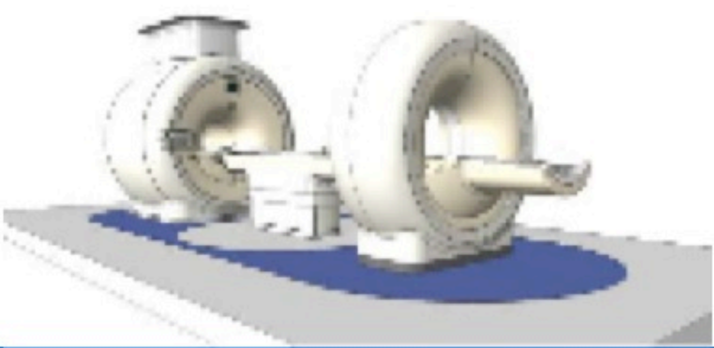
PET-MRI in clinical routine

Emerging clinical applications

Certified for clinical use since Jan 2011

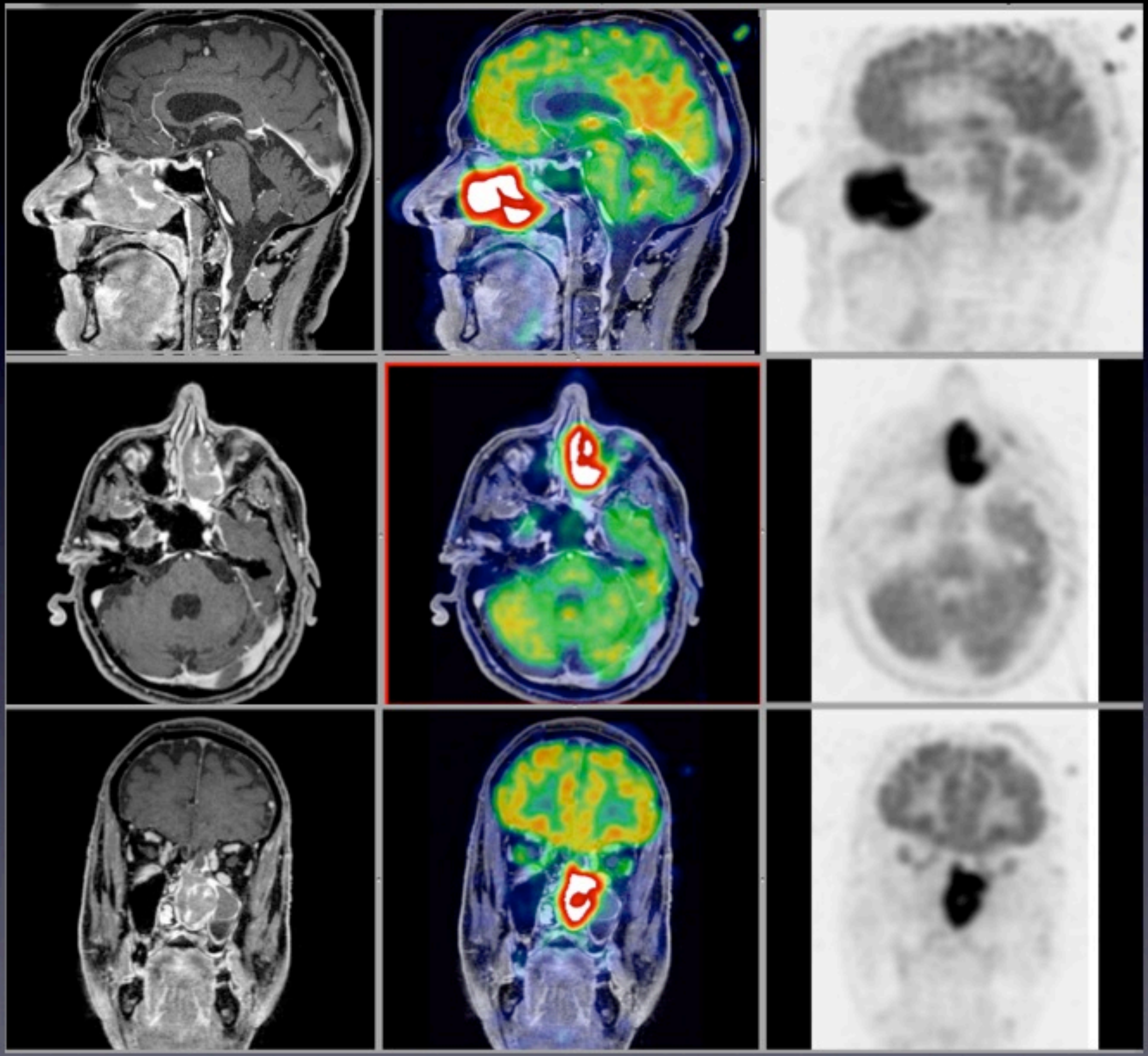
- Oncology investigation that require already a diagnostic MRI in addition to PET-CT:
  - **Head & Neck cancer (pre and post-op)**
  - **Prostate cancers**
  - **Breast imaging**
  - **Pediatric oncology**

- New emerging clinical applications:
  - **Cardiac imaging (viability, ischemia?)**
  - **Gynecological cancers**
  - **Brain imaging**
  - **Bone metastases (F^{18}-NaF)**



Lymphoma of nasal fossa

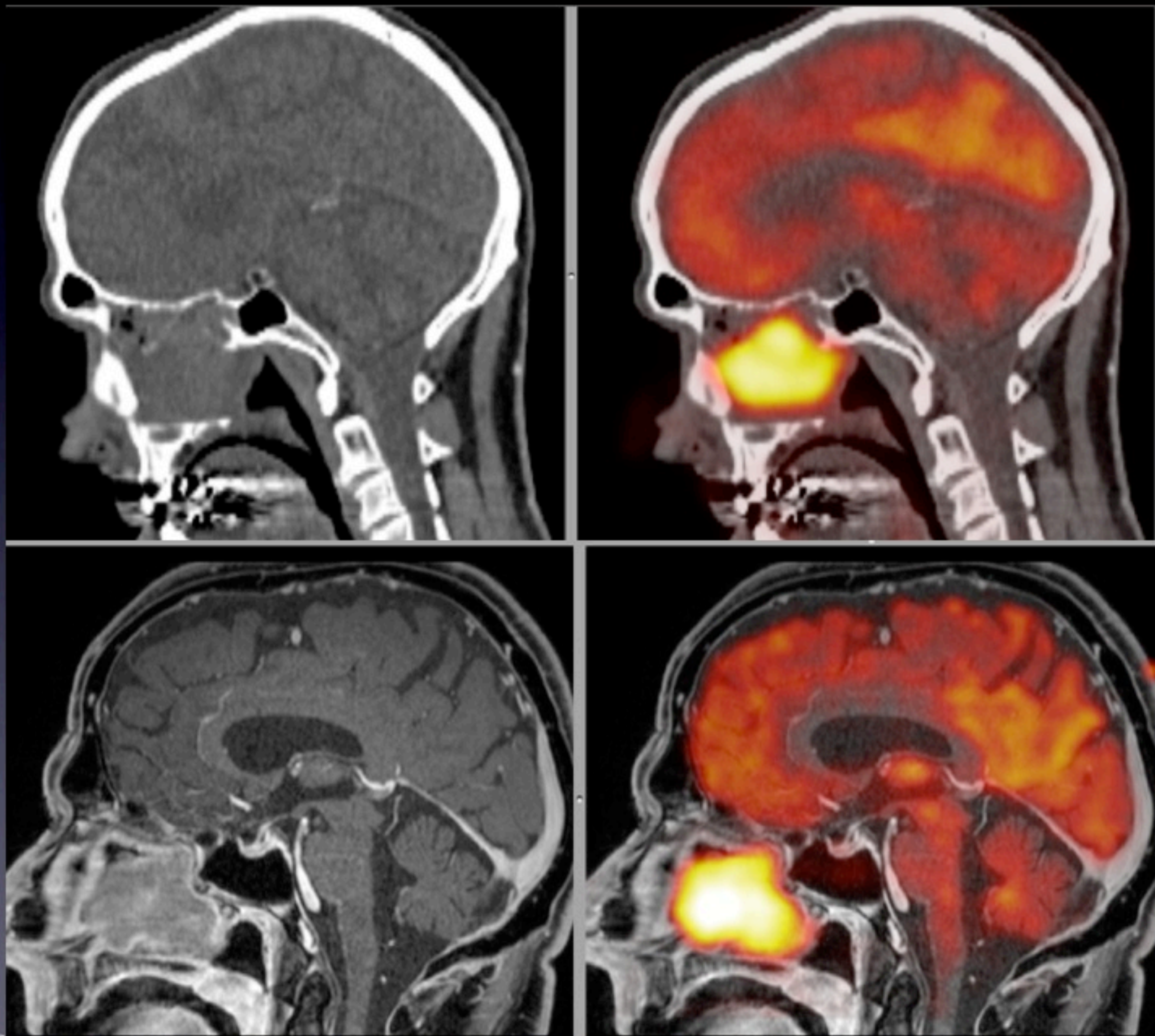
Pt. A.W. 1942



PET-MR

Lymphoma of nasal fossa

Pt. A.W. 1942

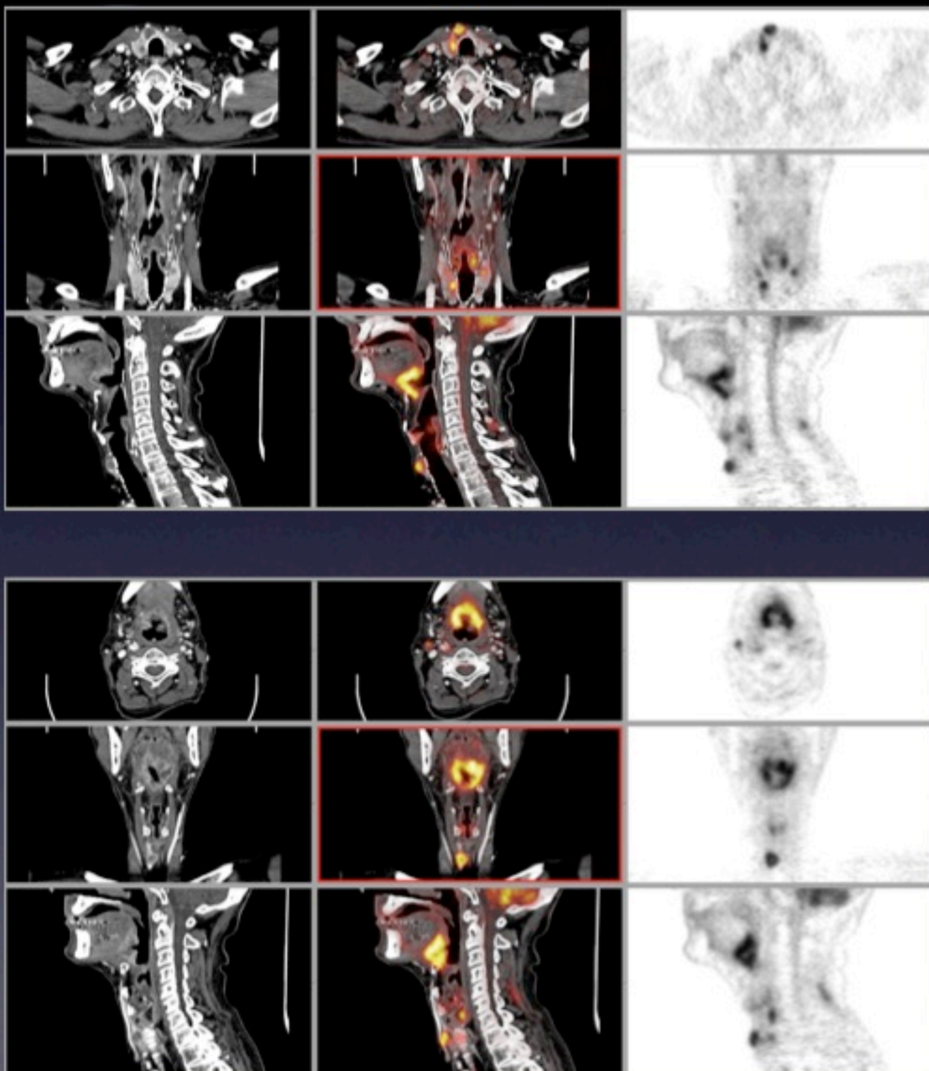


PET-CT

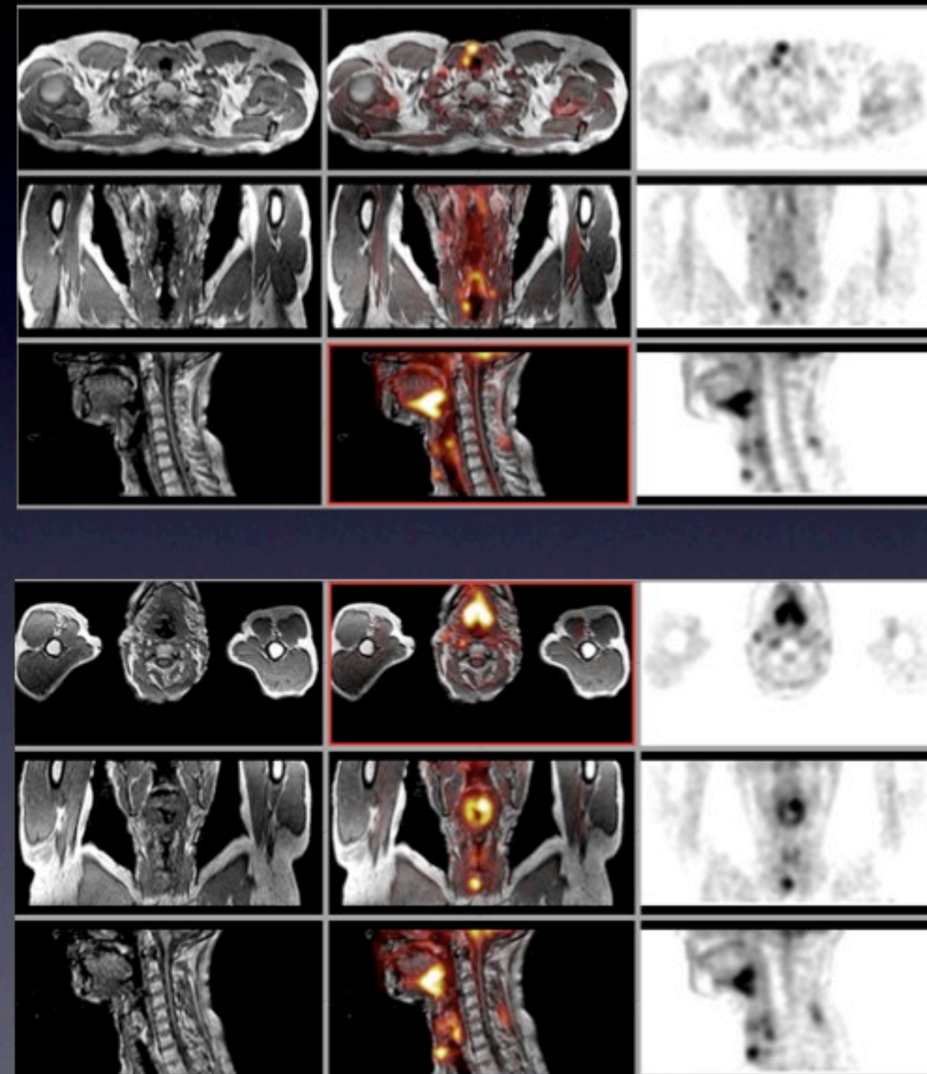
PET-MR

Head & Neck cancer

Pt. M.J. 26.6.1955



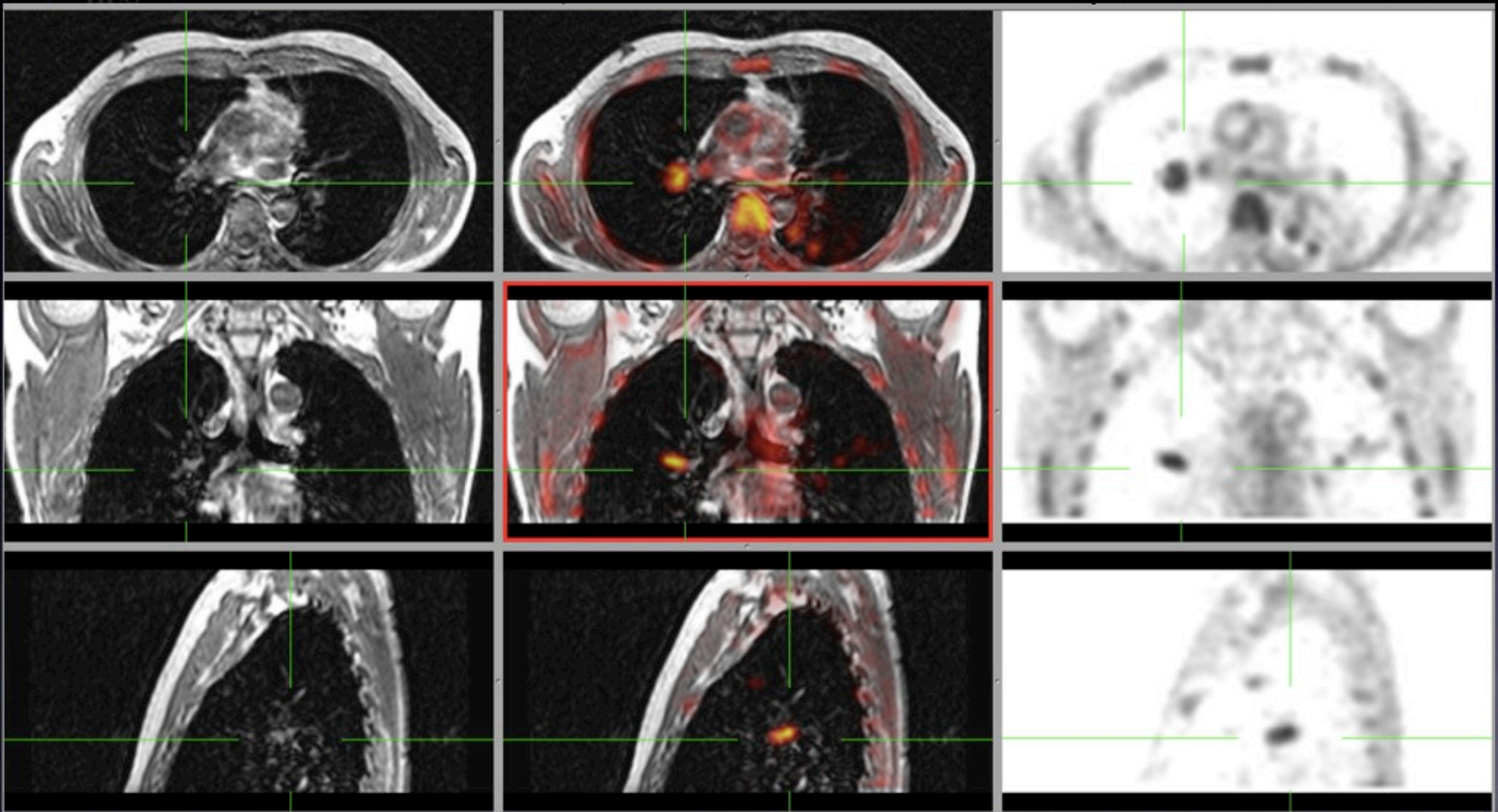
PET-CT



PET-MR

Head & Neck cancer

Pt. M.J. 26.6.1955



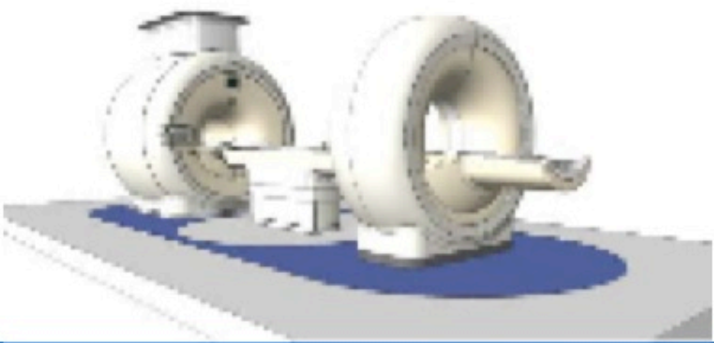
PET-MR

PET-MRI in clinical routine

Emerging clinical applications

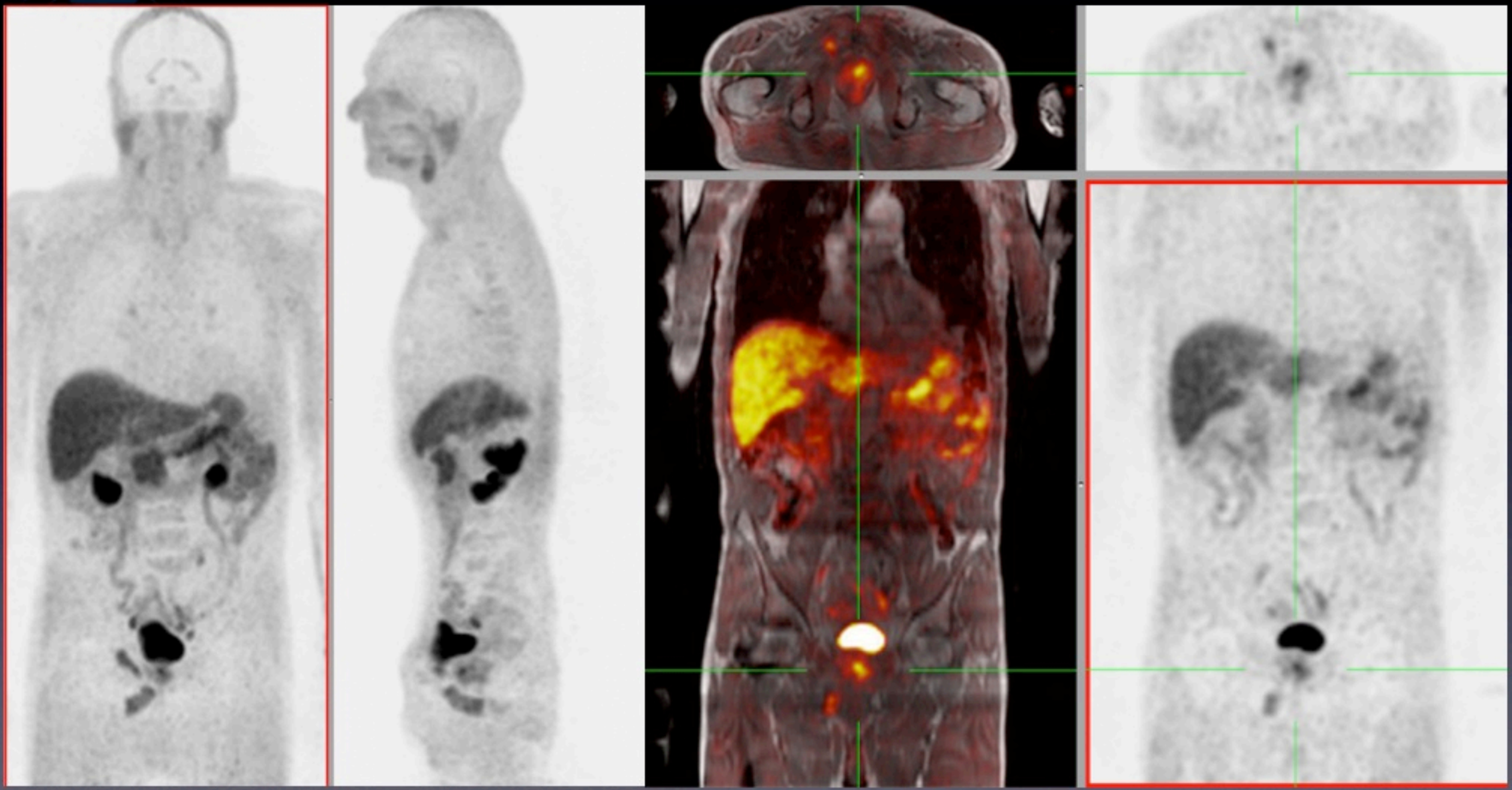
- Oncology investigation that require already a diagnostic MRI in addition to PET-CT:
  - **Head & Neck cancer (pre and post-op)**
  - **Prostate cancers**
  - **Breast imaging**
  - **Pediatric oncology**

- New emerging clinical applications:
  - **Cardiac imaging (viability, ischemia?)**
  - **Gynecological cancers**
  - **Brain imaging**
  - **Bone metastases (F^{18}-NaF)**



Metastatic prostate cancer (F^{18}-Choline)

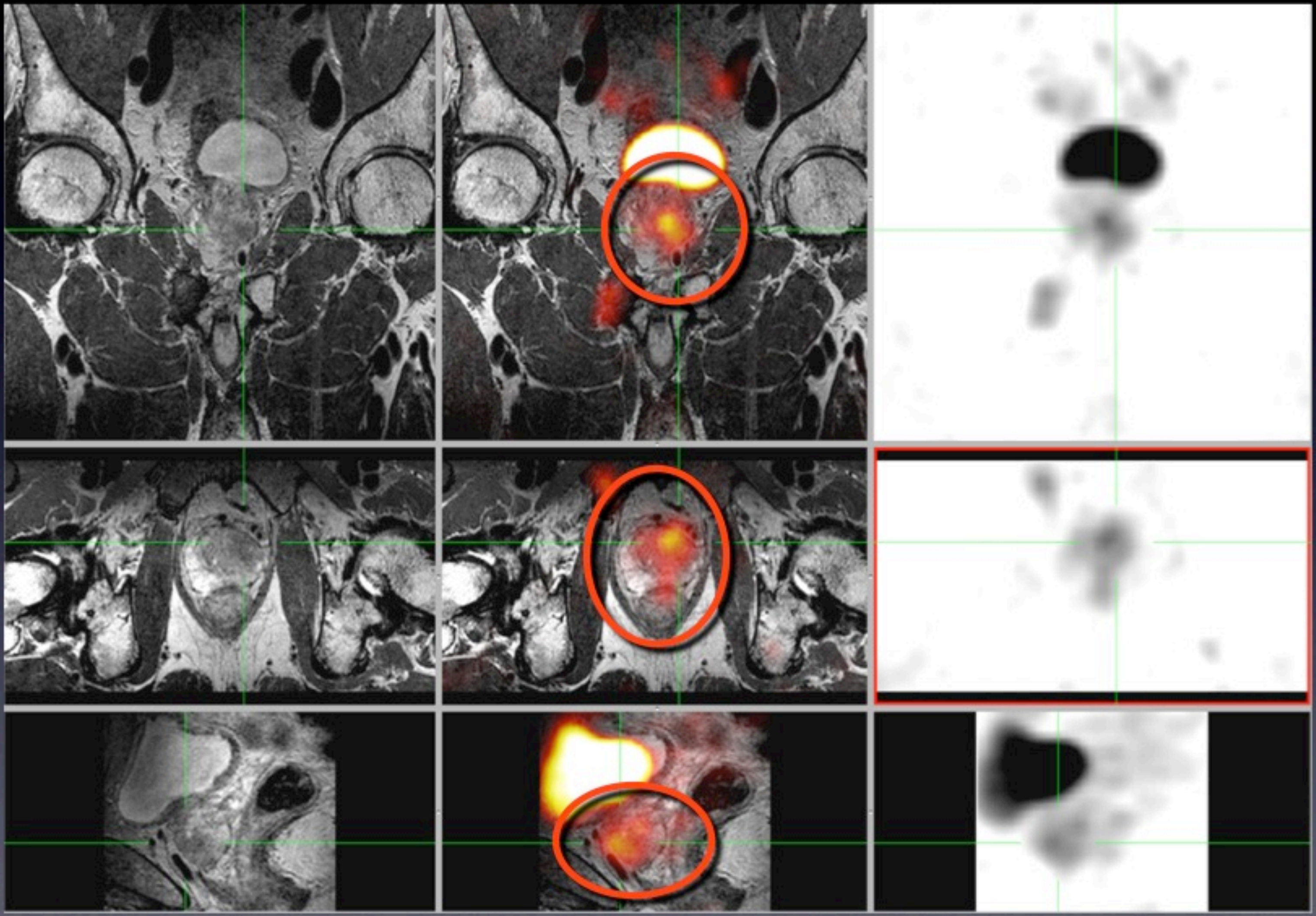
Pt. F.R. 11.14.1942



HUG

Metastatic prostate cancer (F^{18}-Choline)

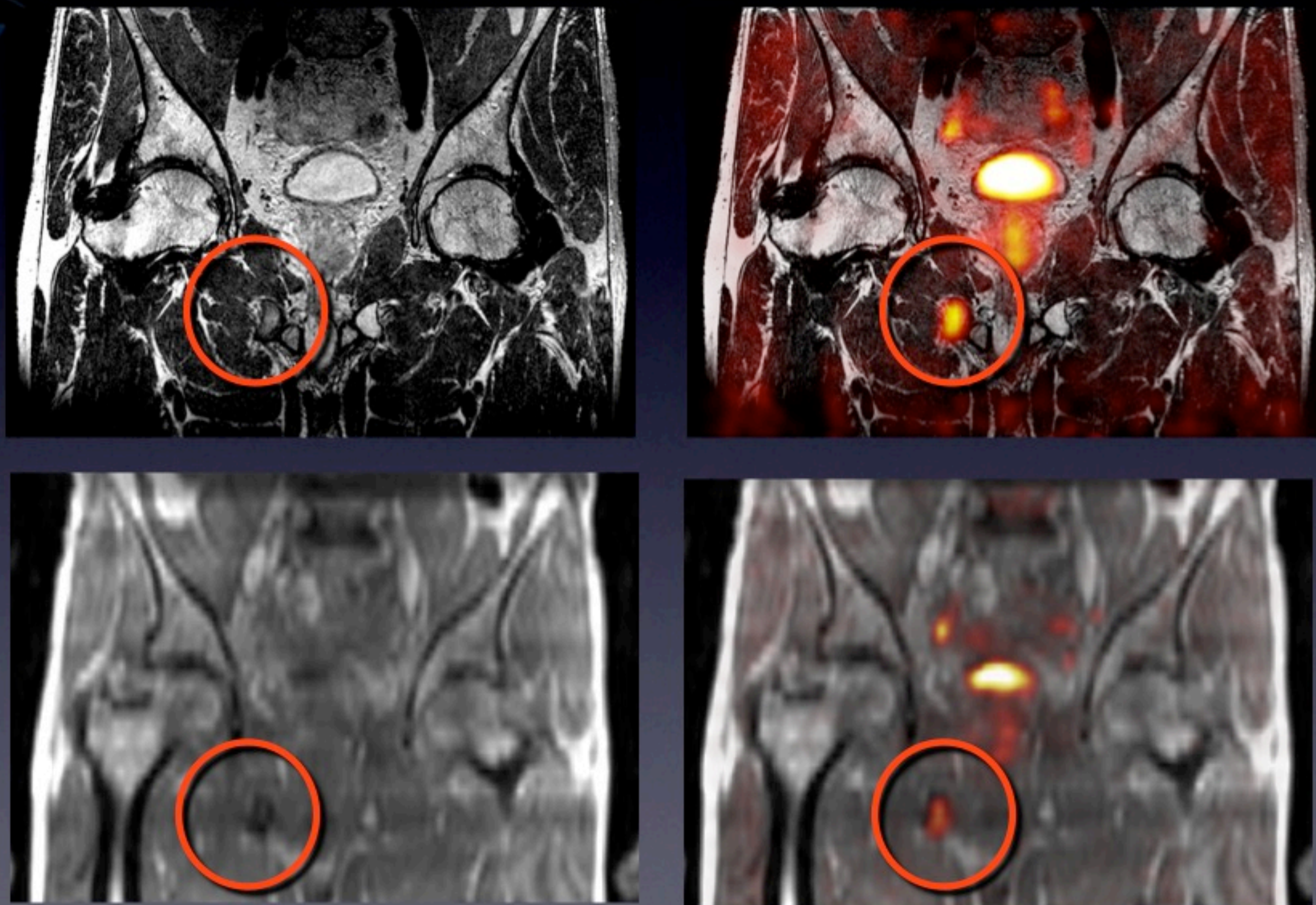
Pt. F.R. 11.14.1942



PET – MR (gland)

Metastatic prostate cancer (F^{18}-Choline)

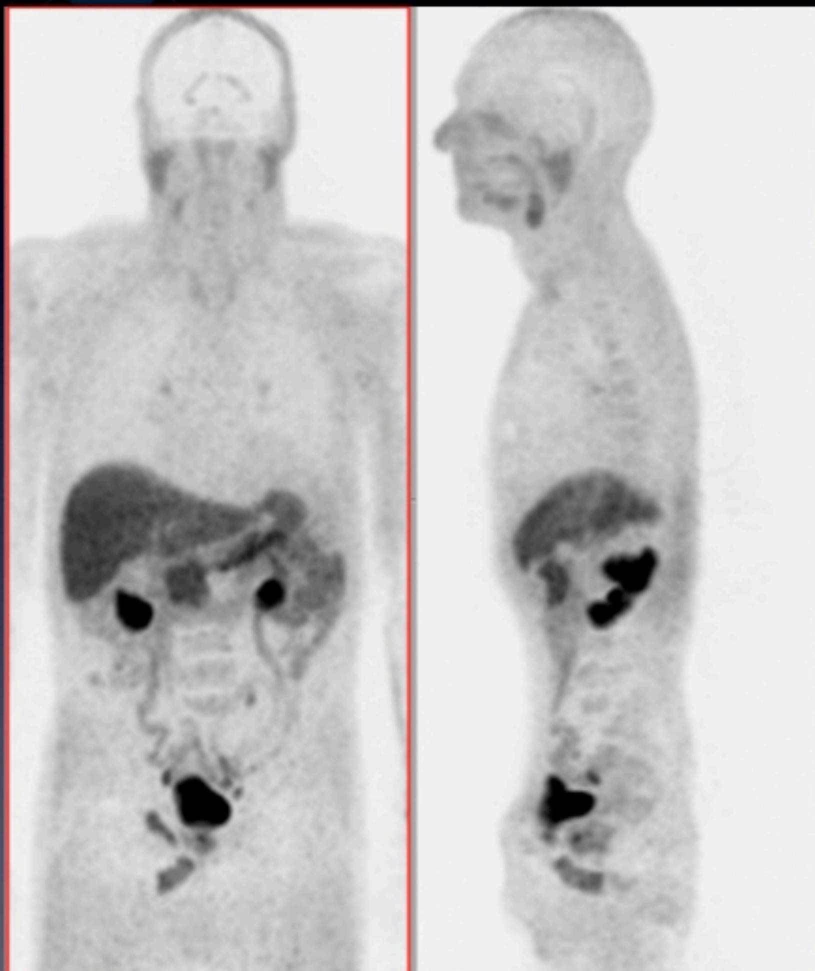
Pt. F.R. 11.14.1942

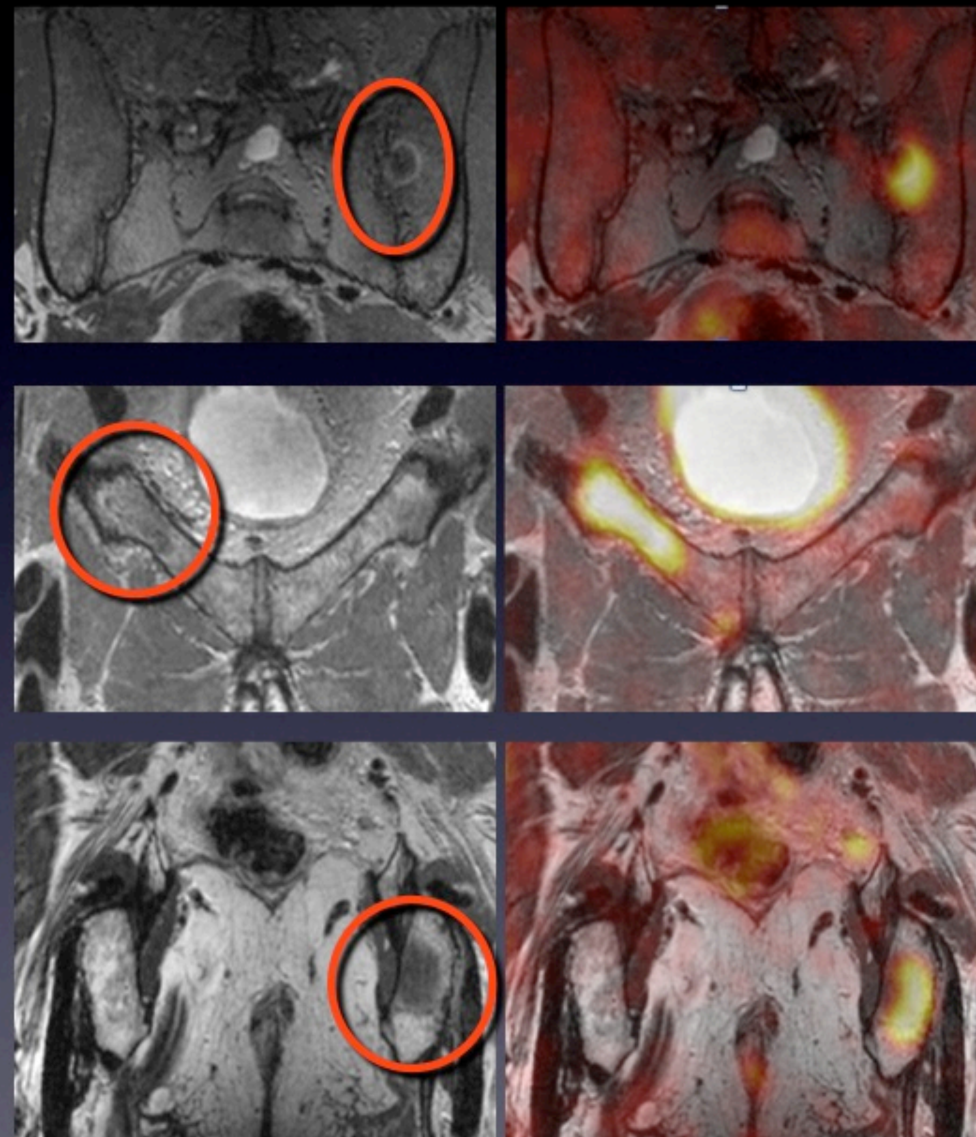


PET – MR (pelvis A)

Metastatic prostate cancer (F^{18}-Choline)

Pt. F.R. 11.14.1942



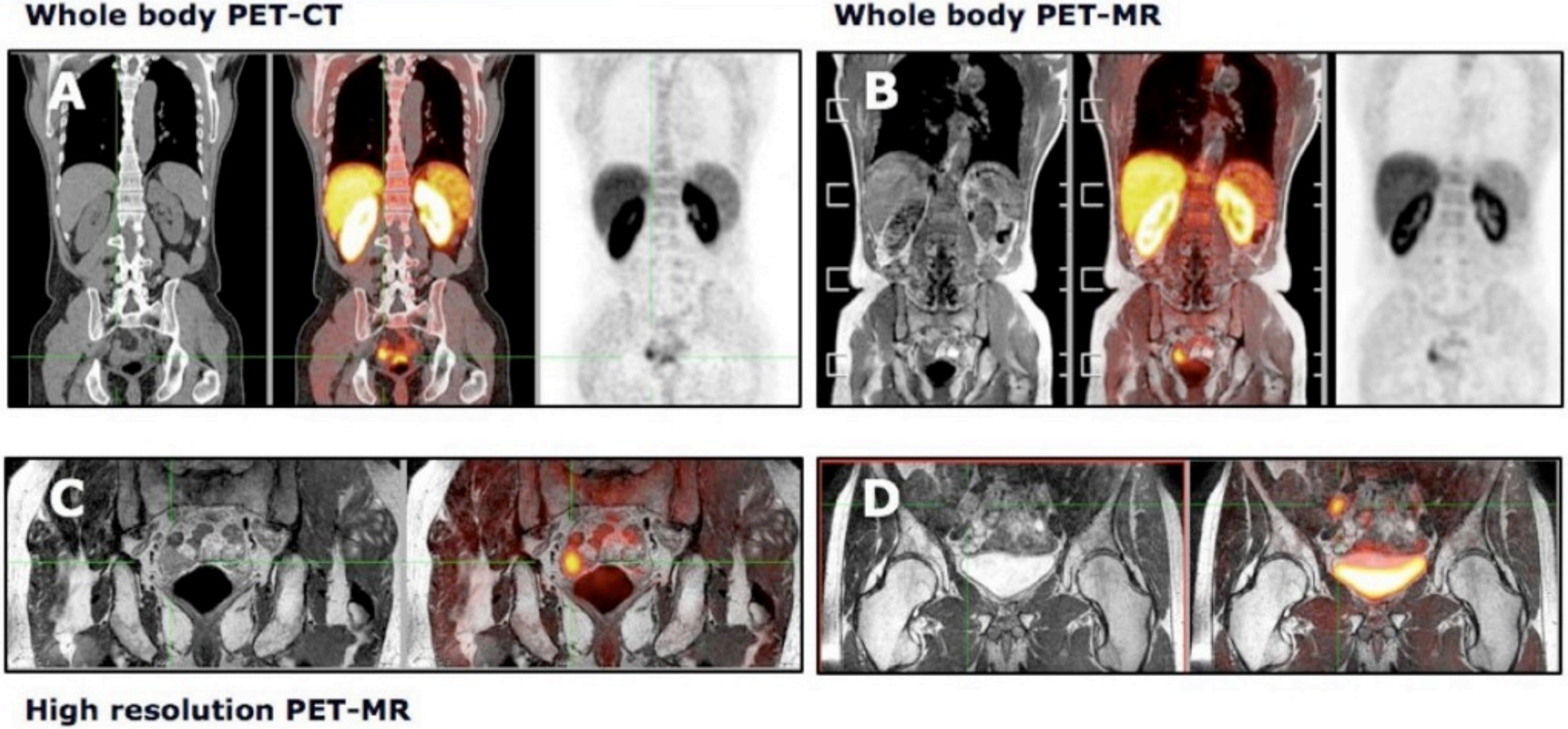


PET – MR (pelvis B)

Prostate cancer Study

Whole-Body PET/MR in prostate cancers

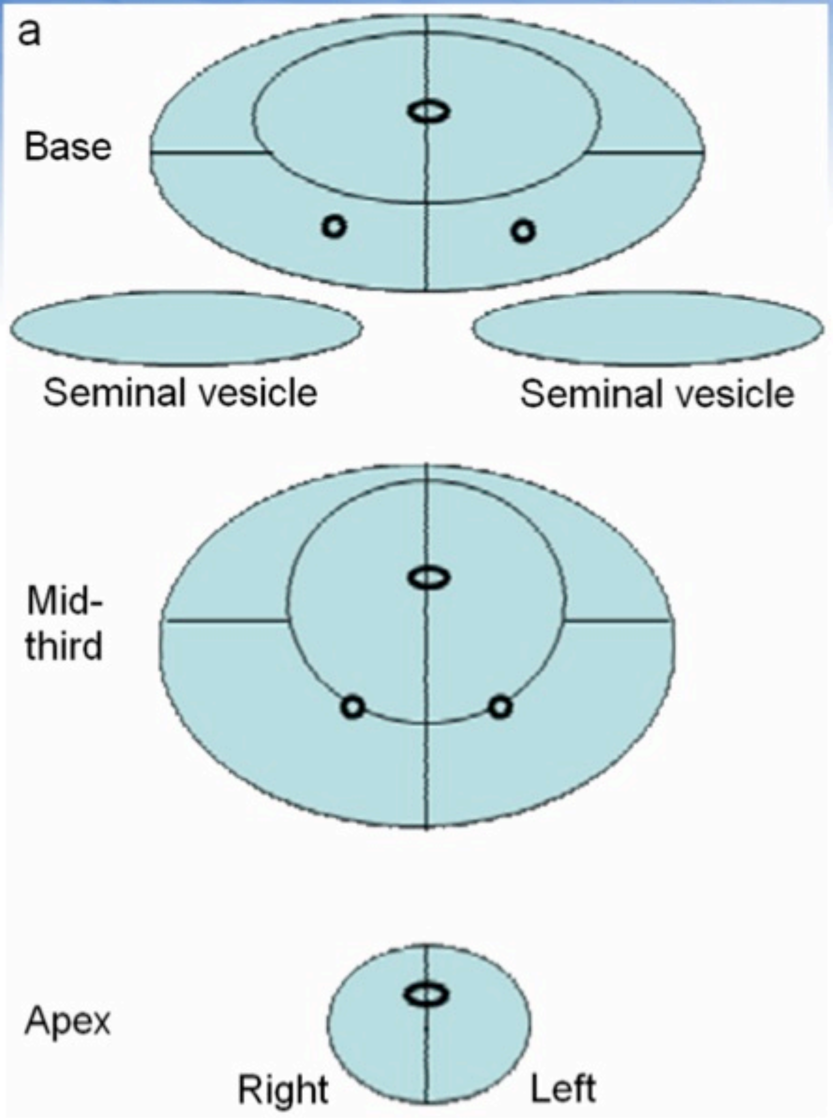
Validation studies:



Our study

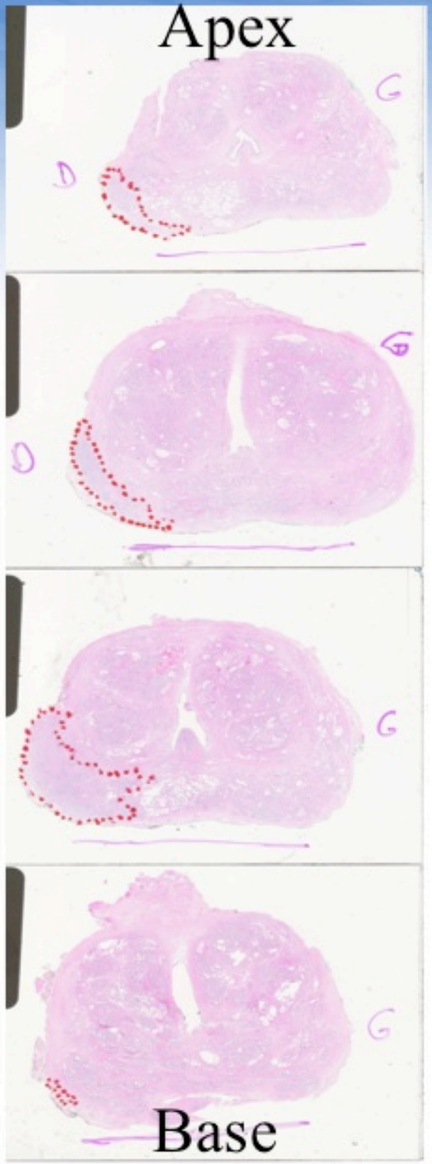
- **15 patients with biopsy-proven prostate cancer**
- **Initial staging**
- **No exclusion criteria besides classical MRI contraindications (pacemaker, ...)**
- **PSA and Gleason score noted**
- **Prostatectomy (histopathology) +/- pelvic lymphadenectomy at follow-up**

Prostate segmentation



Histopathological analysis

Right

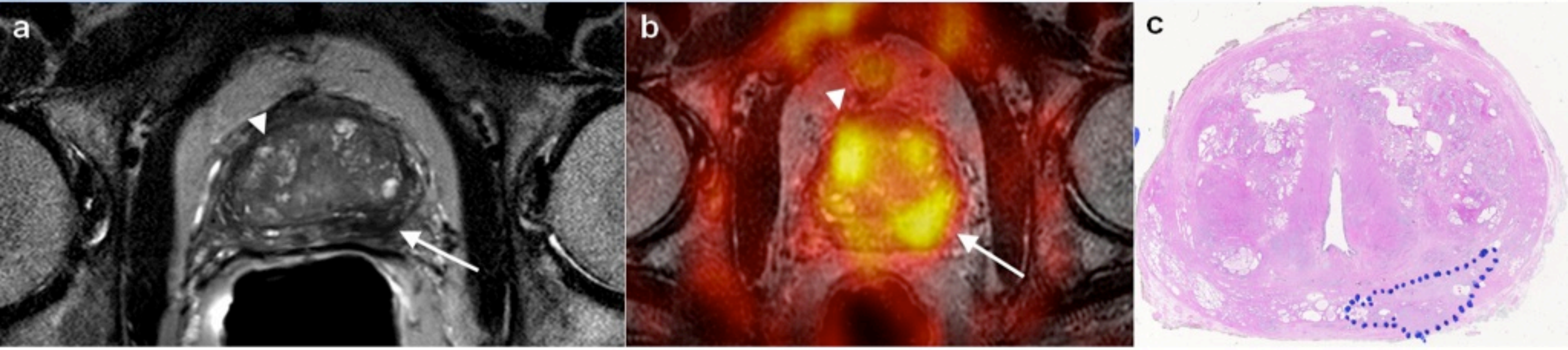


Left

Methods

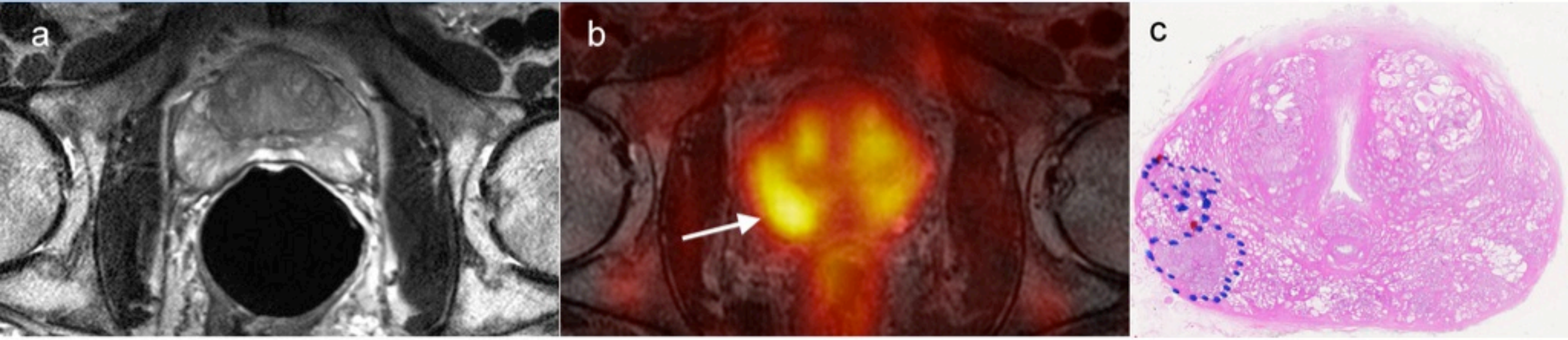
- PET : max SUV noted for each segment
- MRI : visual analysis, including all available sequences
- PET and MRI interpreted independently by a nuclear medicine physician and a radiologist
- Both were asked to rate their index of suspicion for neoplasia for each segment of the prostate :
  - 0 : no evidence of neoplasia
  - 1 : equivocal
  - 2 : suspect
  - 3 : positive for neoplasia
  - 4 : uninterpretable
- Results were compared to histopathological findings

Example 1 : prostate PET +, MRI +



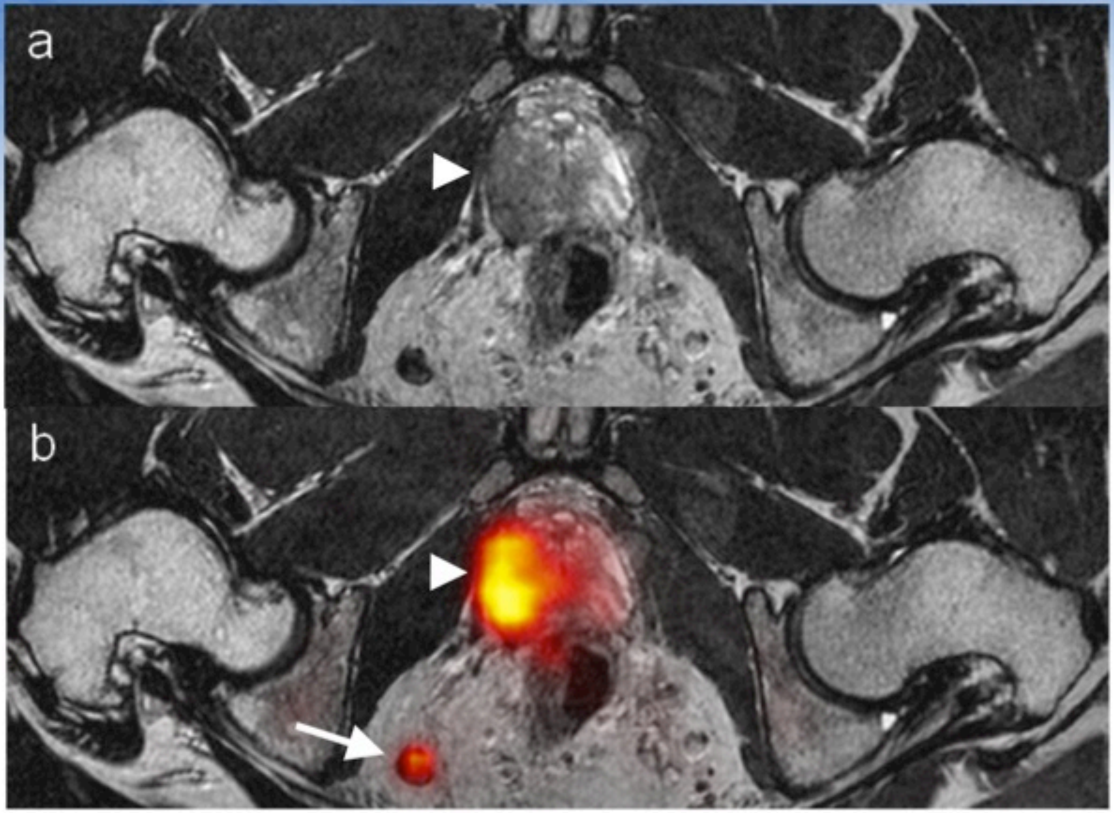
Patient N.8 : left postero-lateral tumor in peripheral zone (arrow) and transitional zone hyperplasia (arrowhead)

Example 2 : prostate PET +, MRI -



Patient N.9 : no signal abnormality on endorectal T2-weighted MRI, hypermetabolic right postero-lateral tumor in peripheral zone

Example 3 : lymph node PET +, MRI -



Patient N.6 : hypermetabolic infracentimetric metastatic right internal iliac lymph node (arrow).
Neoplasia in right peripheral prostatic zone (arrowhead).

Conclusion (of prostate study)

Our preliminary data with limited patient population shows that:

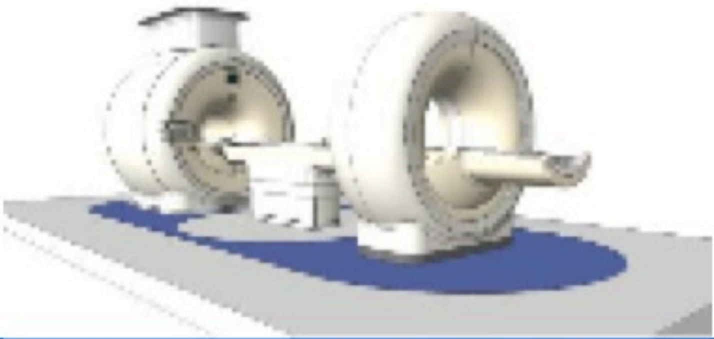
- **PET can increase MRI sensitivity** for detection of prostate cancer and staging of metastatic dissemination
- **MRI adds its better specificity** to PET in characterizing prostatic lesions and allows to distinguish the peripheral and transitional zones
- Hybrid imaging allows **both imaging modalities** to be acquired during the same session
- Dosimetry to the patient is cut **almost by half** compared to PET-CT
- *Other potential application* : increase the detection rate of cancer on repeated biopsies in patients who have a high risk of prostate cancer and who have undergone multiple TRUS-guided biopsies with negative findings.

PET-MRI in clinical routine

Emerging clinical applications

- Oncology investigation that require already a diagnostic MRI in addition to PET-CT:
    - **Head & Neck cancer (pre and post-op)**
    - **Prostate cancers**
    - **Breast imaging**
    - **Pediatric oncology**

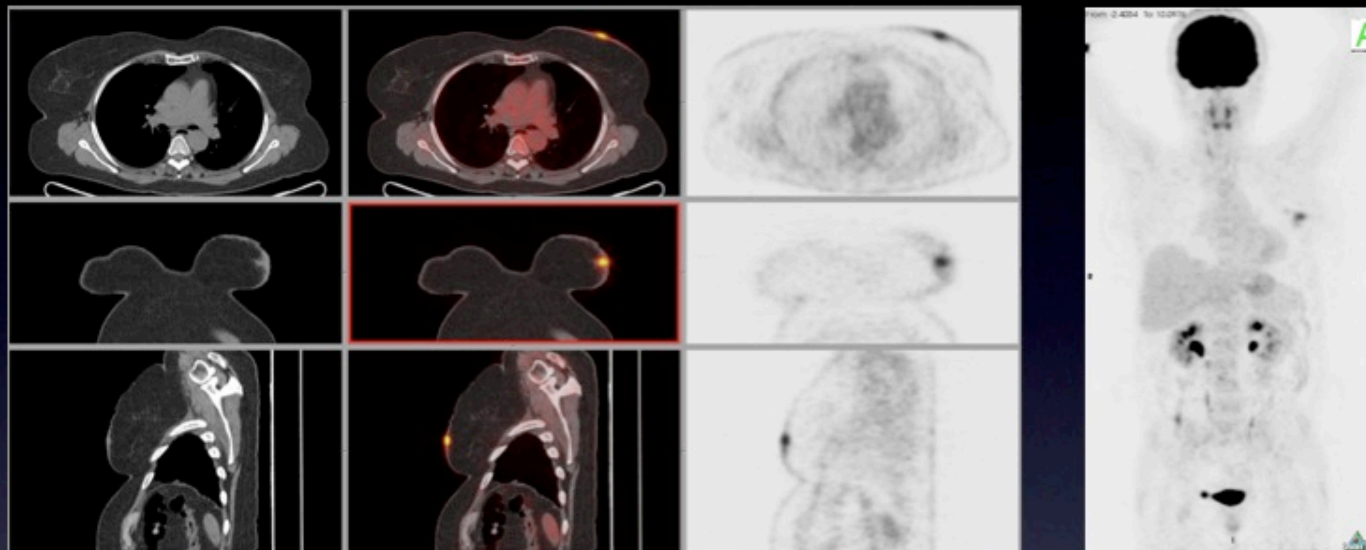
- New emerging clinical applications:
    - **Cardiac imaging (viability, ischemia?)**
    - **Gynecological cancers**
    - **Brain imaging**
    - **Bone metastases (F^{18}-NaF)**



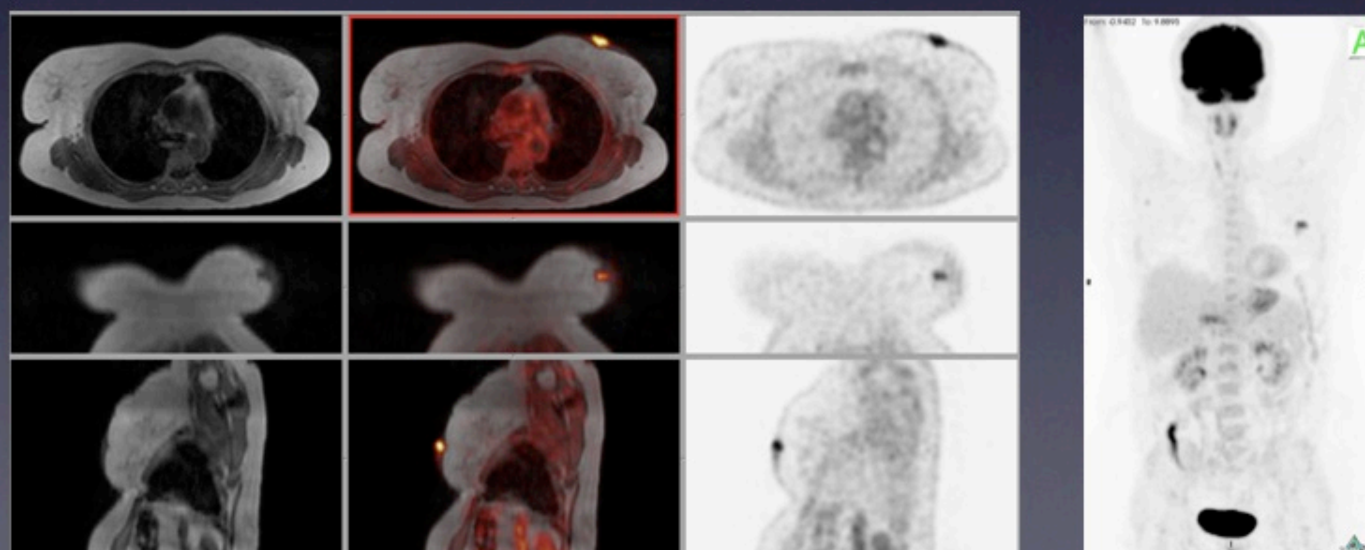
Breast cancer

Pt. B.S. 1948

PET-CT

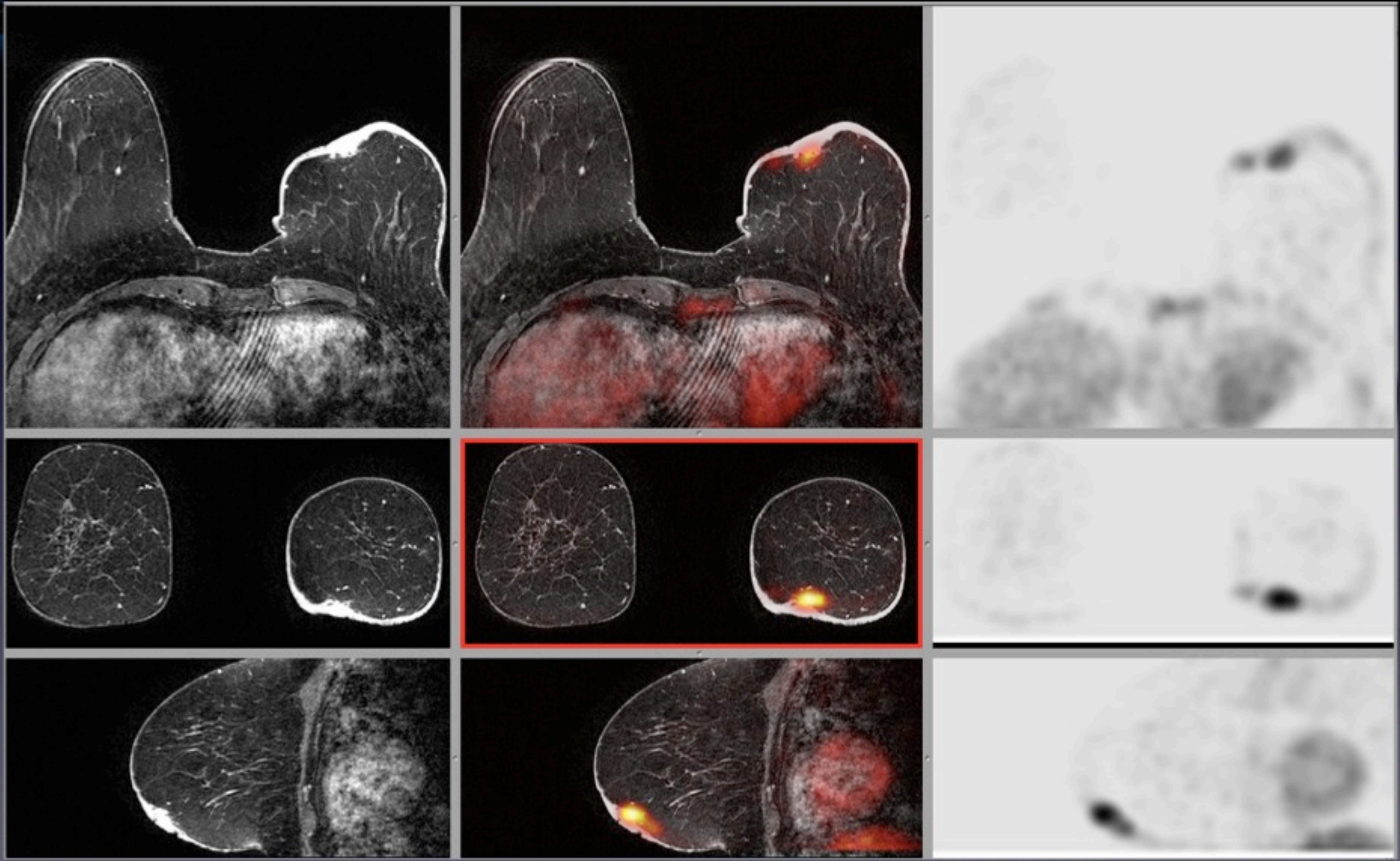


PET-MR



Breast cancer

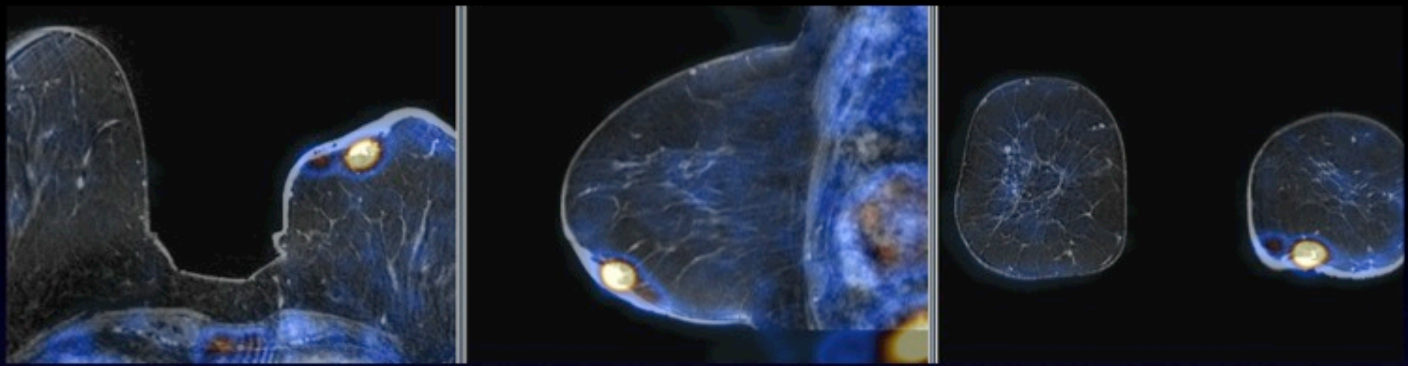
Pt. B.S. 1948

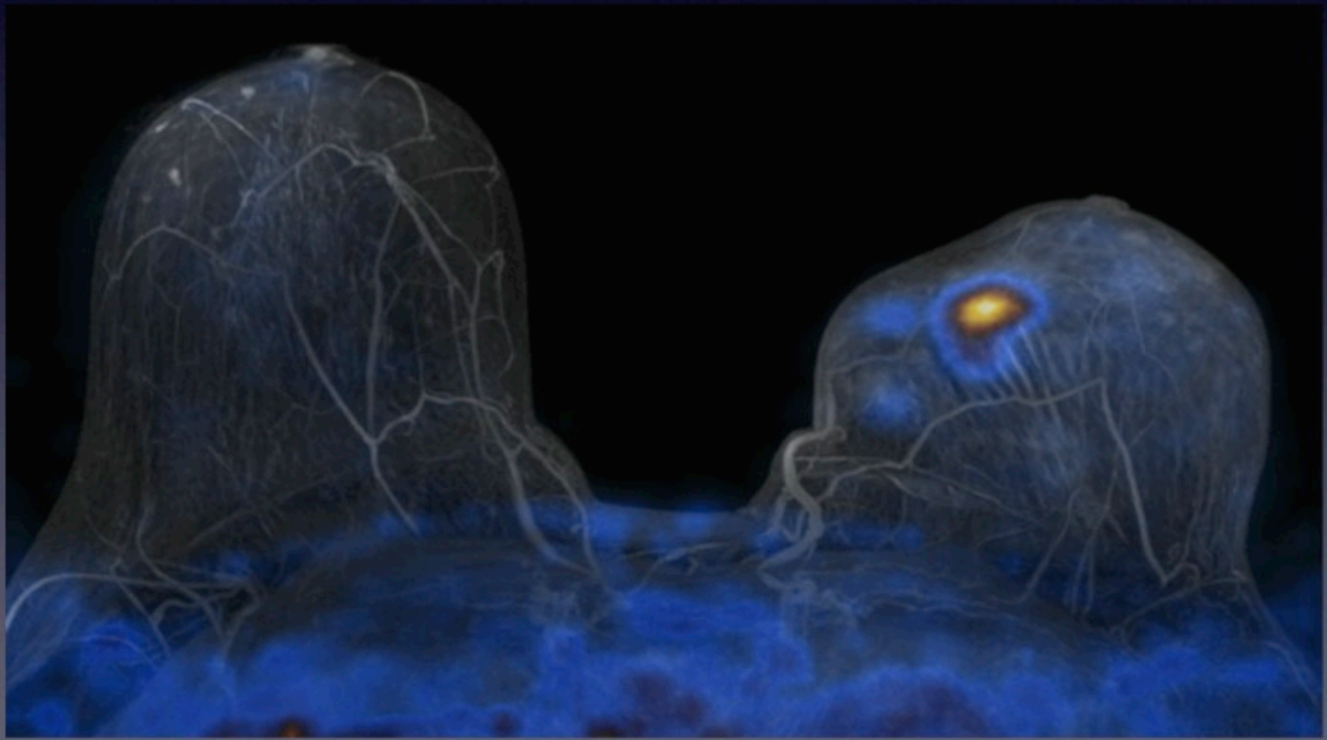


PET-MR

Breast cancer

Pt. B.S. 1948

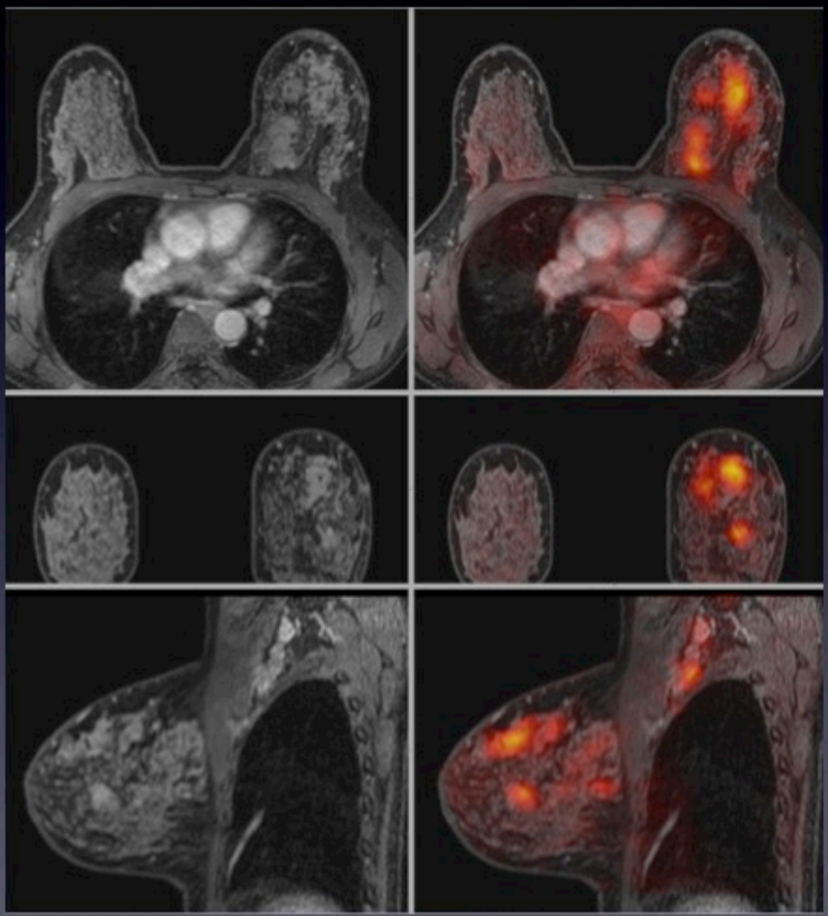


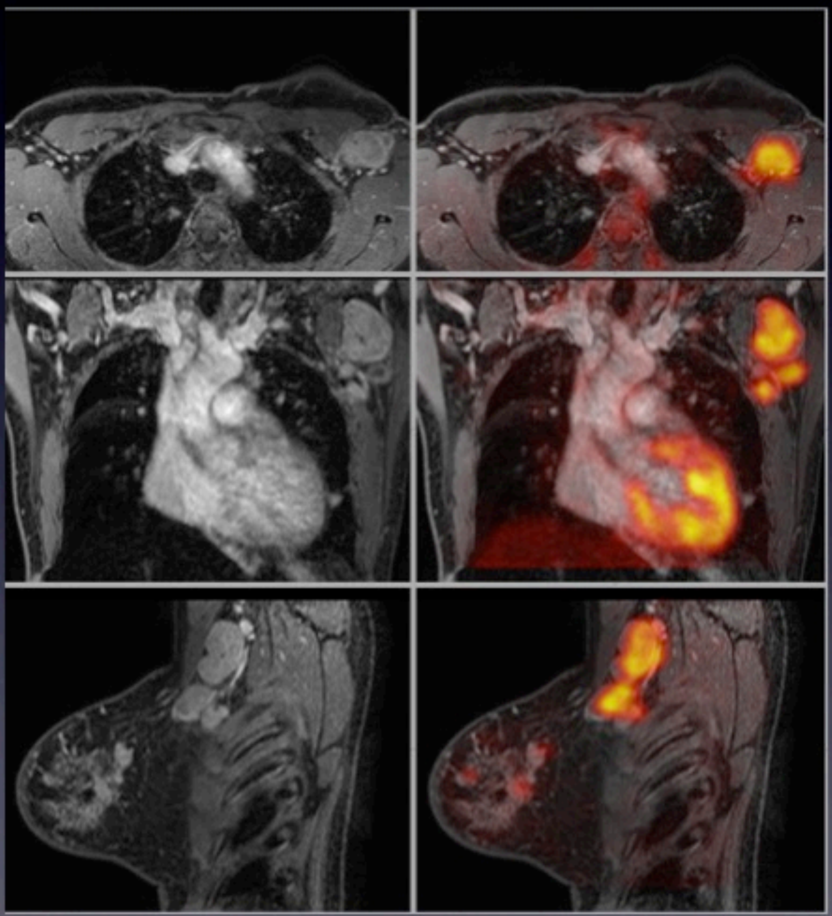


PET-MR

Multi-focal Breast Cancer

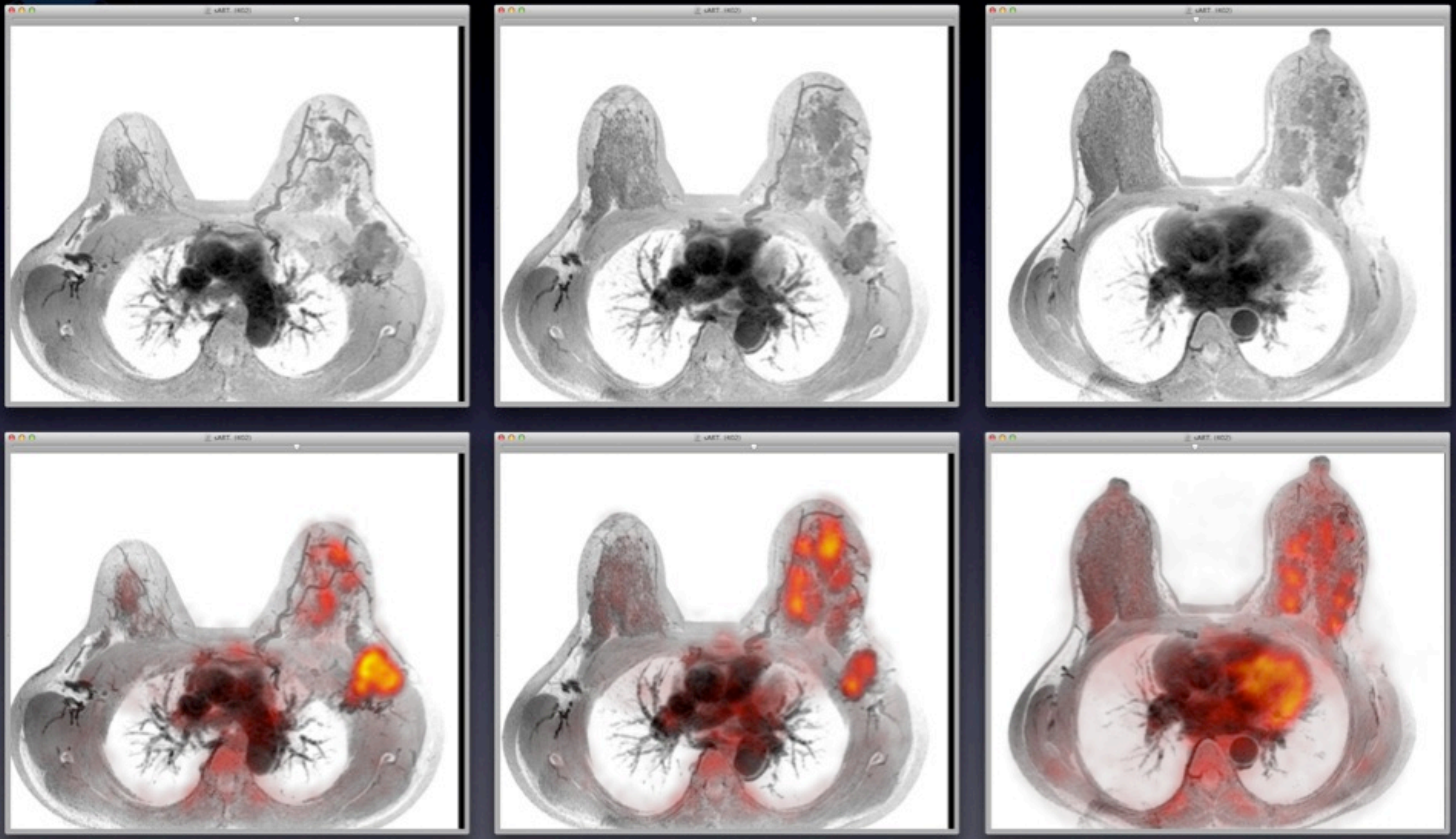
Pt. K.N.





Multi-focal Breast Cancer

Pt. K.N.

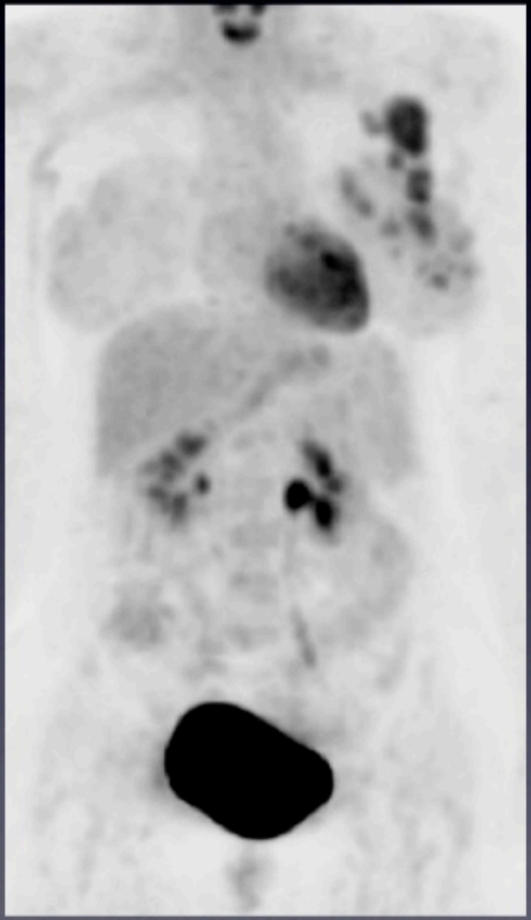


Fusion of Gd enhanced MR and FDG PET

Multi-focal Breast Cancer

Pt. K.N.

Diffusion MR imaging vs PET...
mpMR is new clinical reference for breast cancer
but PET with various tracers can provide information about type and TRA...

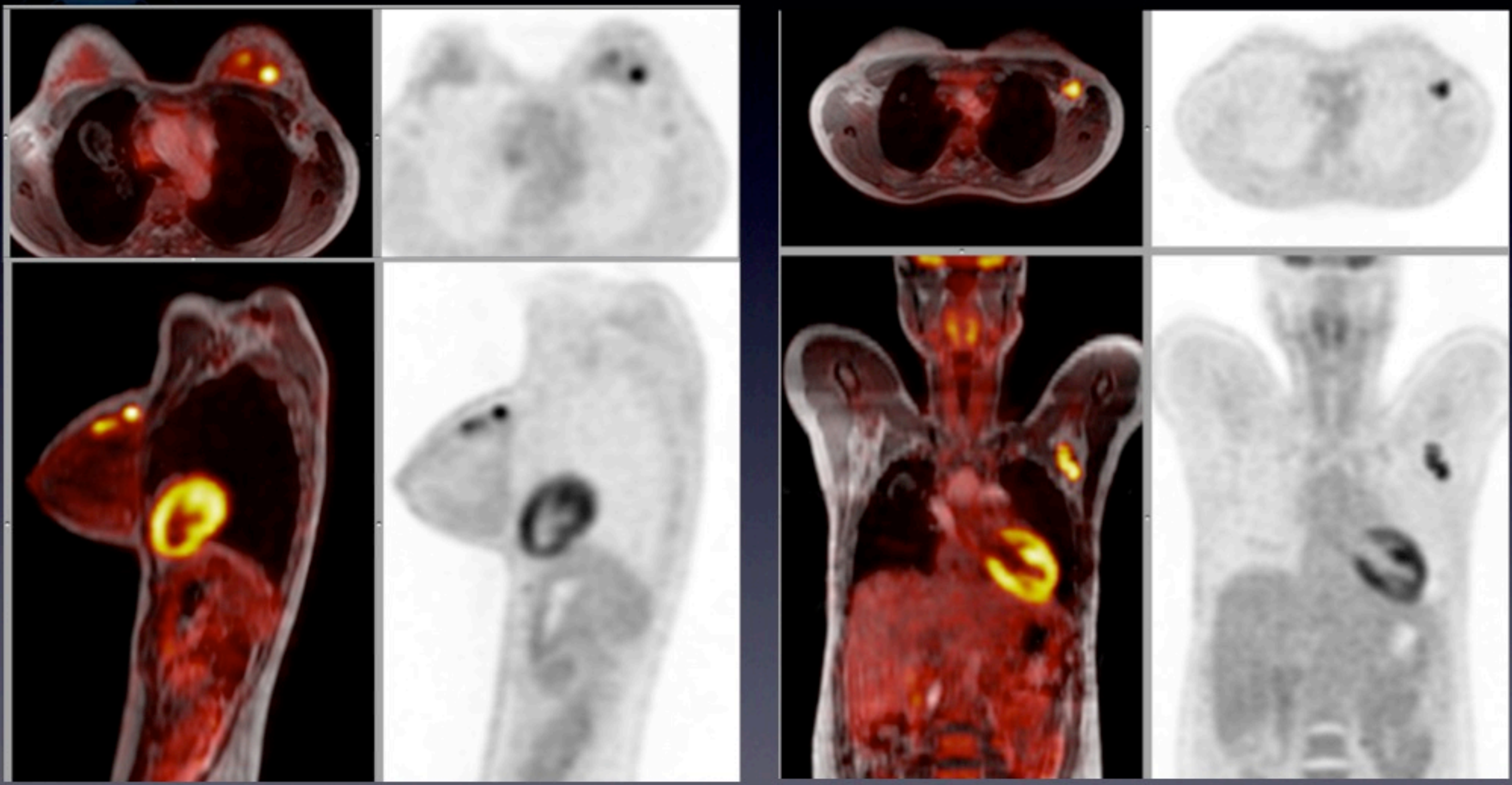


FDG-PET

DWIBS-MRI

Breast Cancer

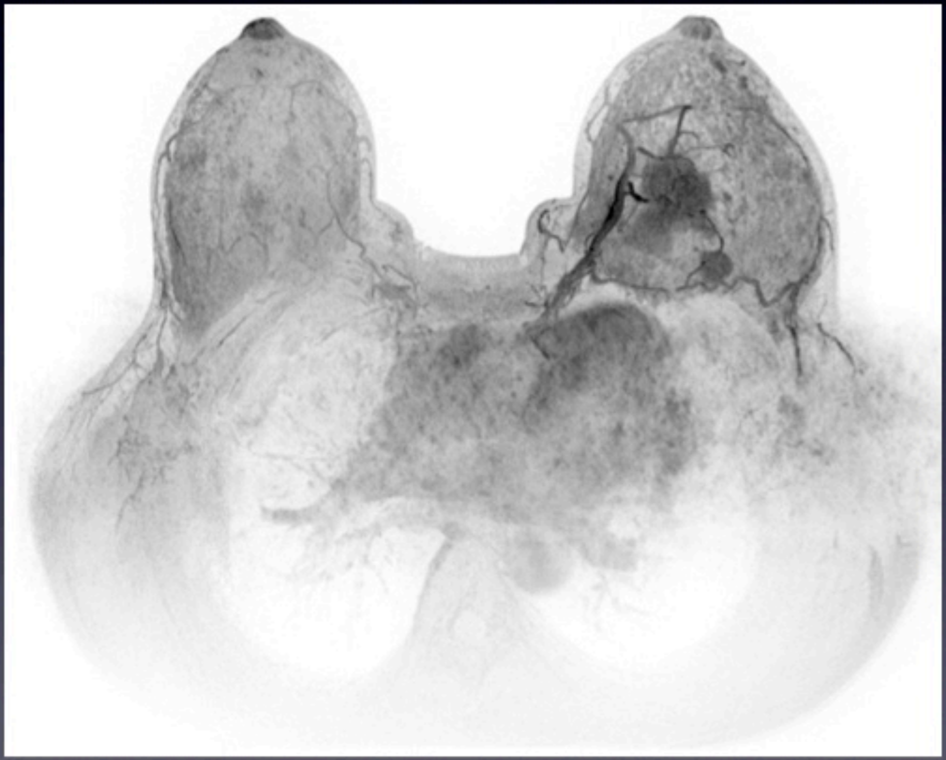
Pt. G.H. 01.06.50



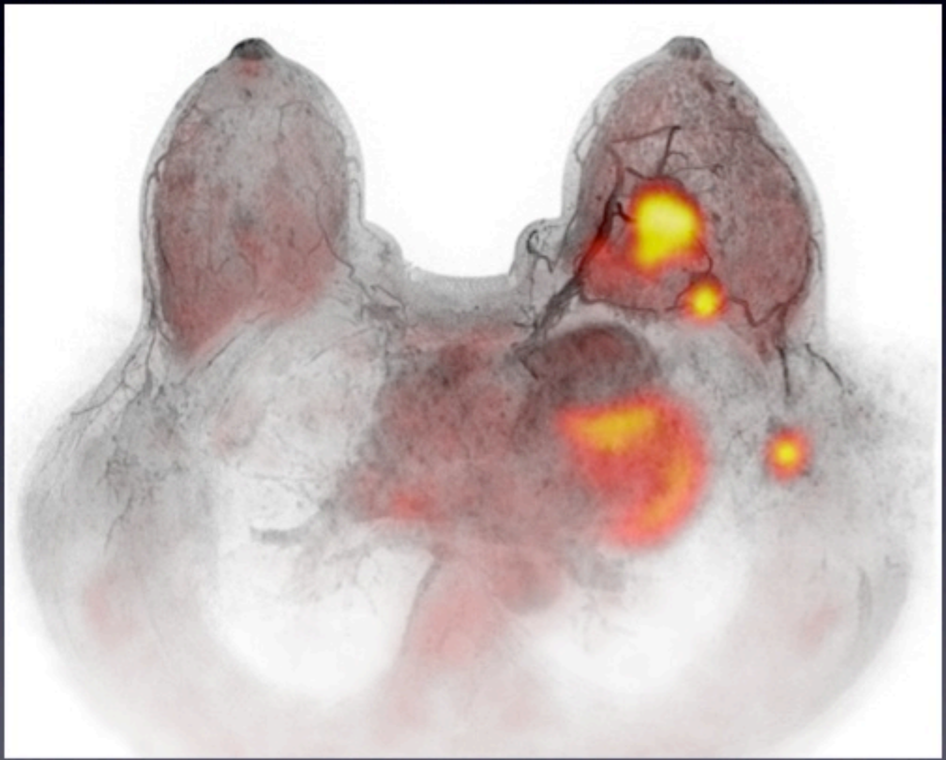
PET-MR

Breast Cancer

Pt. G.H. 01.06.50



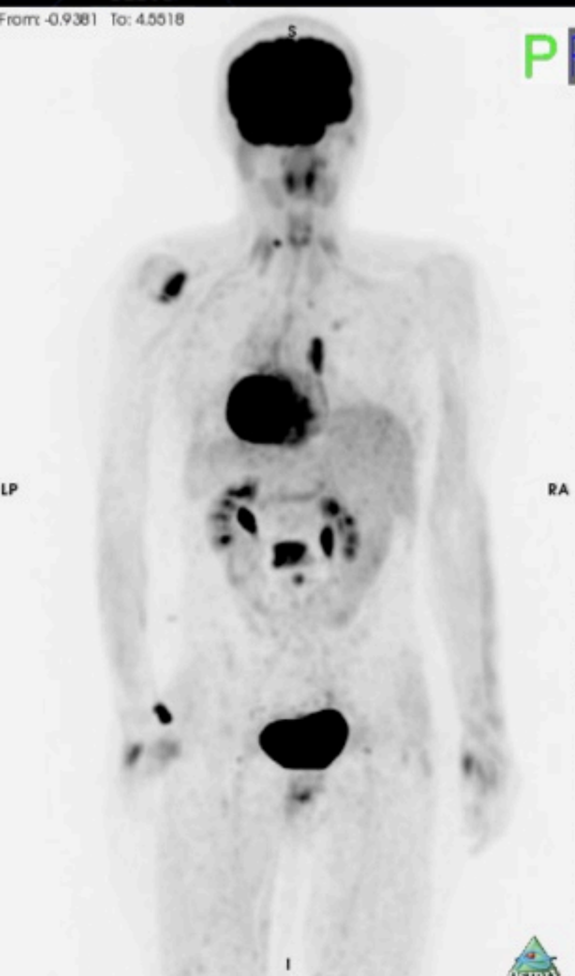
MRI

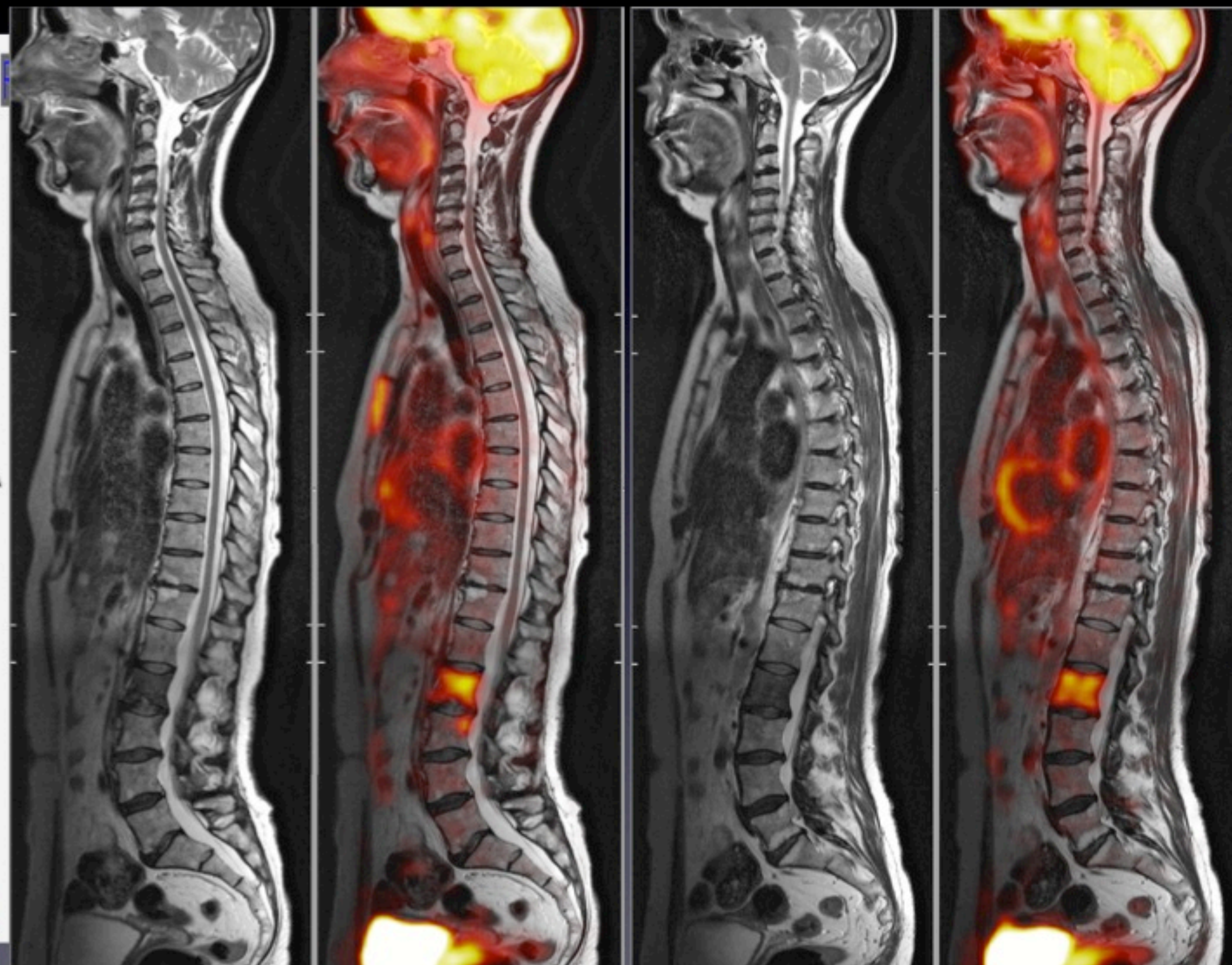


PET-MR

Breast Cancer

Pt. G.G. 01.06.50





PET-MRI in clinical routine

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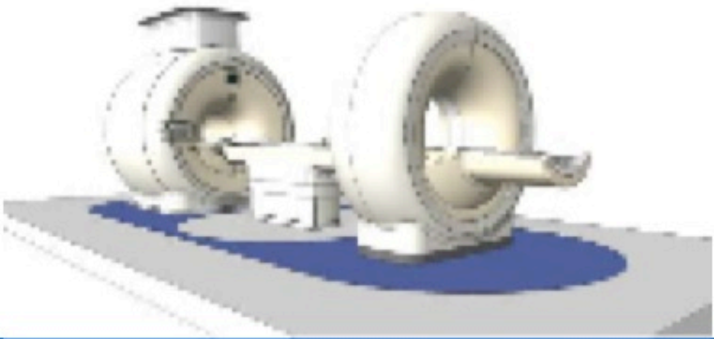
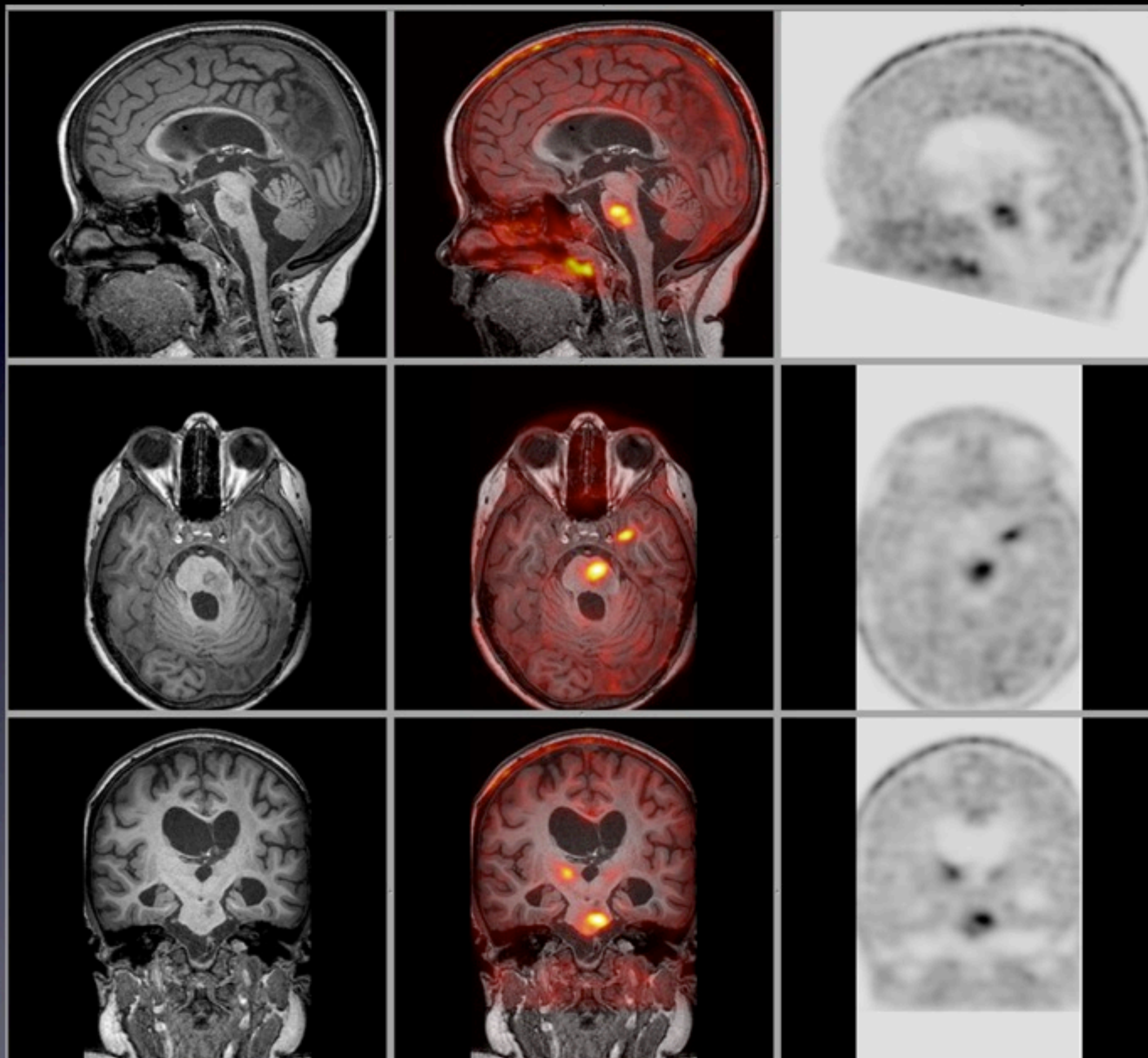


Pediatric case with brain tumor ([^{18}F]FET)

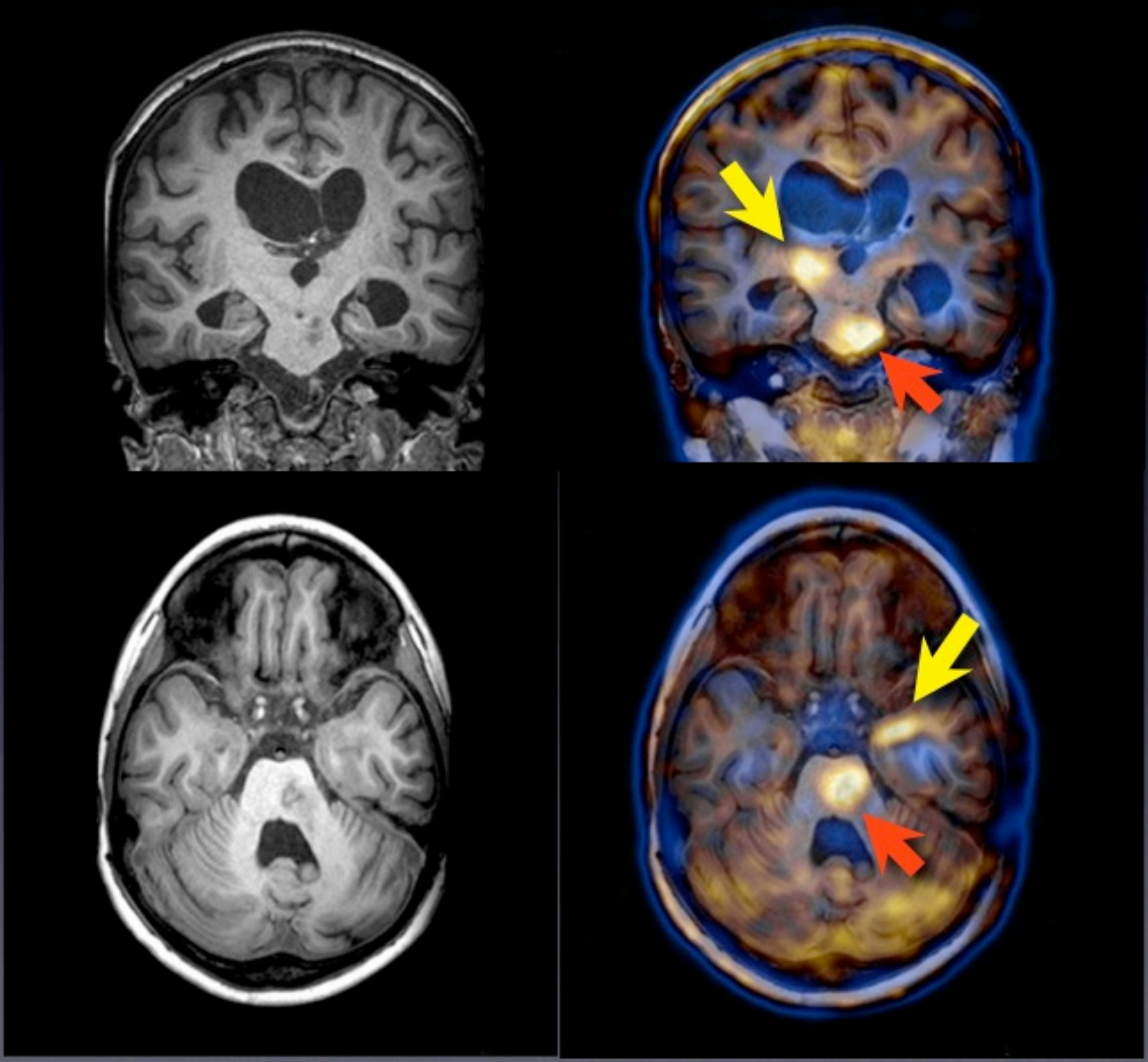
Pt. S.A. 02.08.2004

MR dose = 0



Pediatric case with brain tumor ([^{18}F]FET)

Pt. S.A. 02.08.2004



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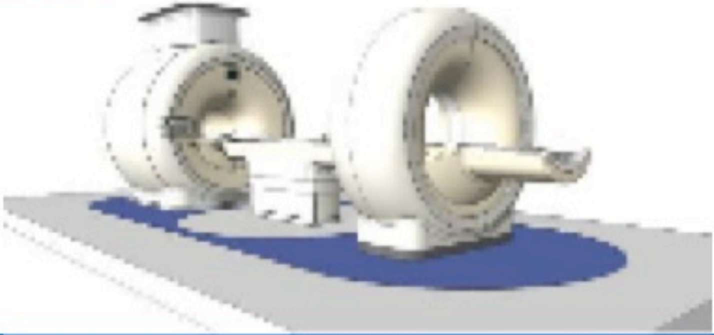
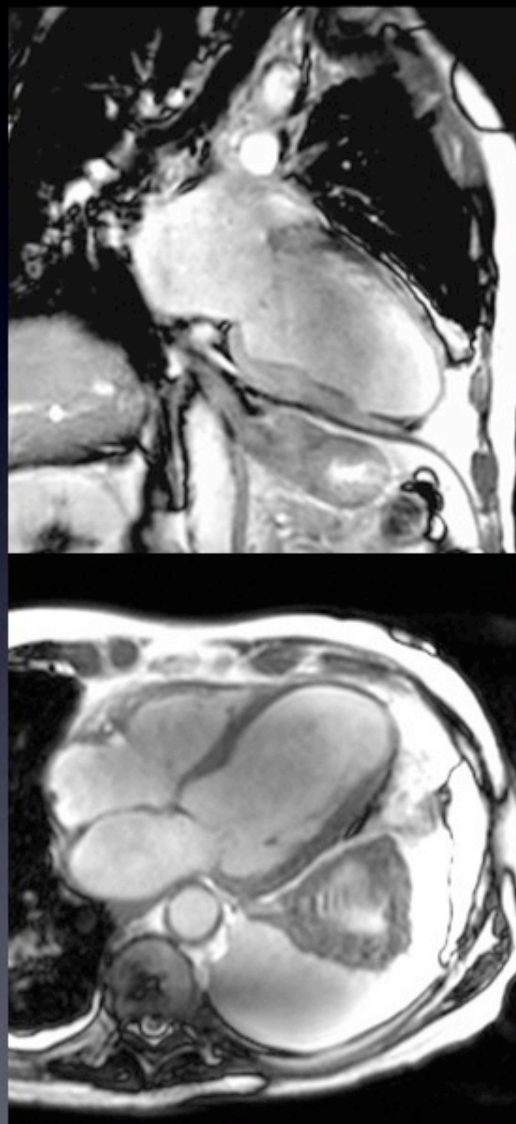
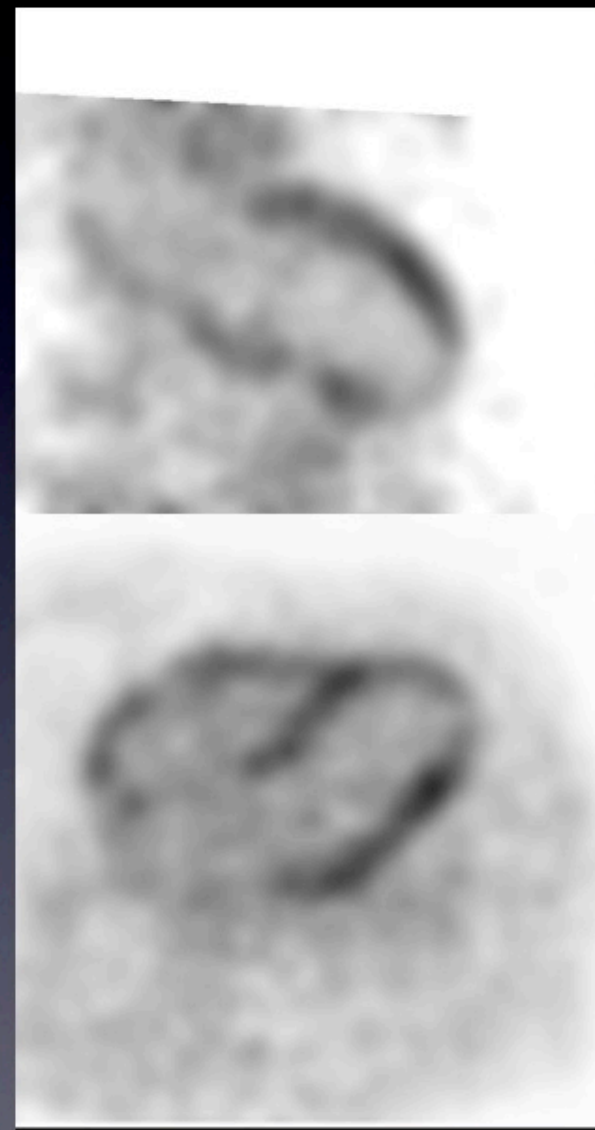


Cardiac Viability post myocardial infarct

Pt. F-V.J. 06.28.1924





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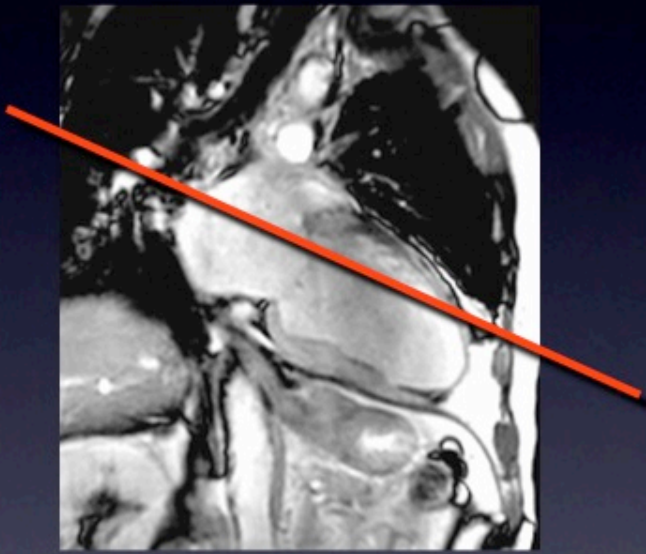
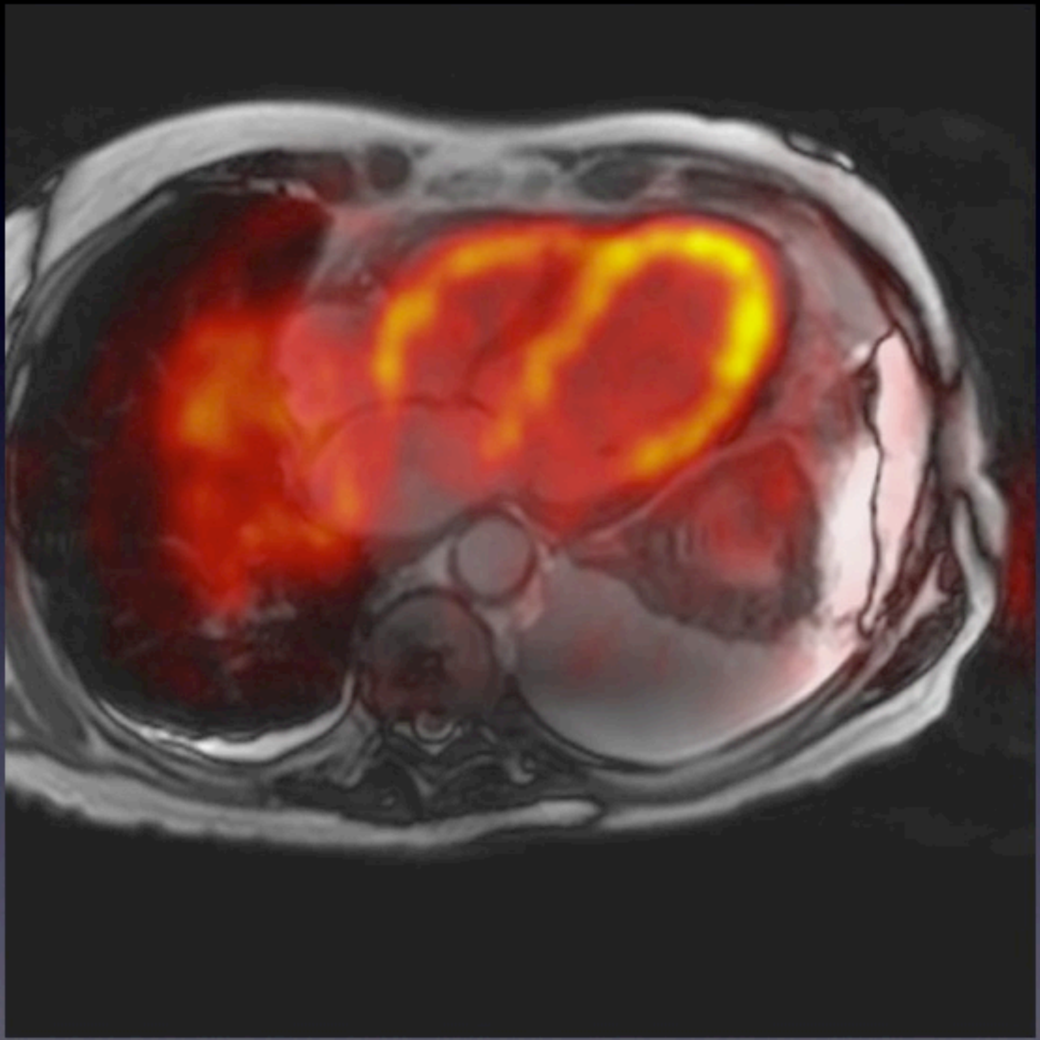


Upper level



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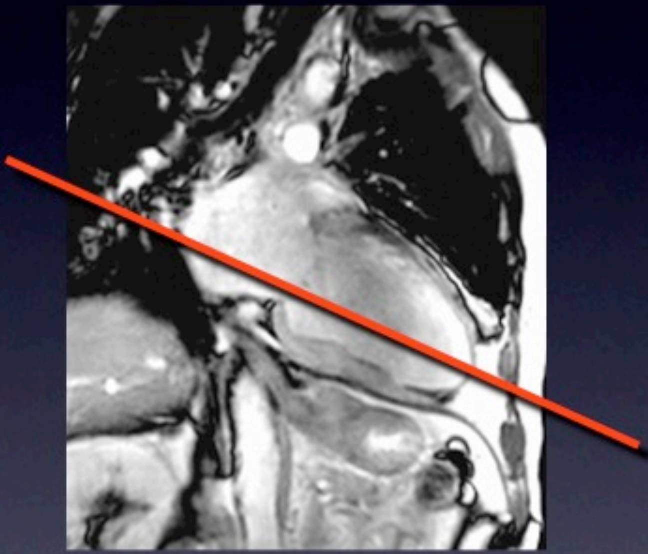
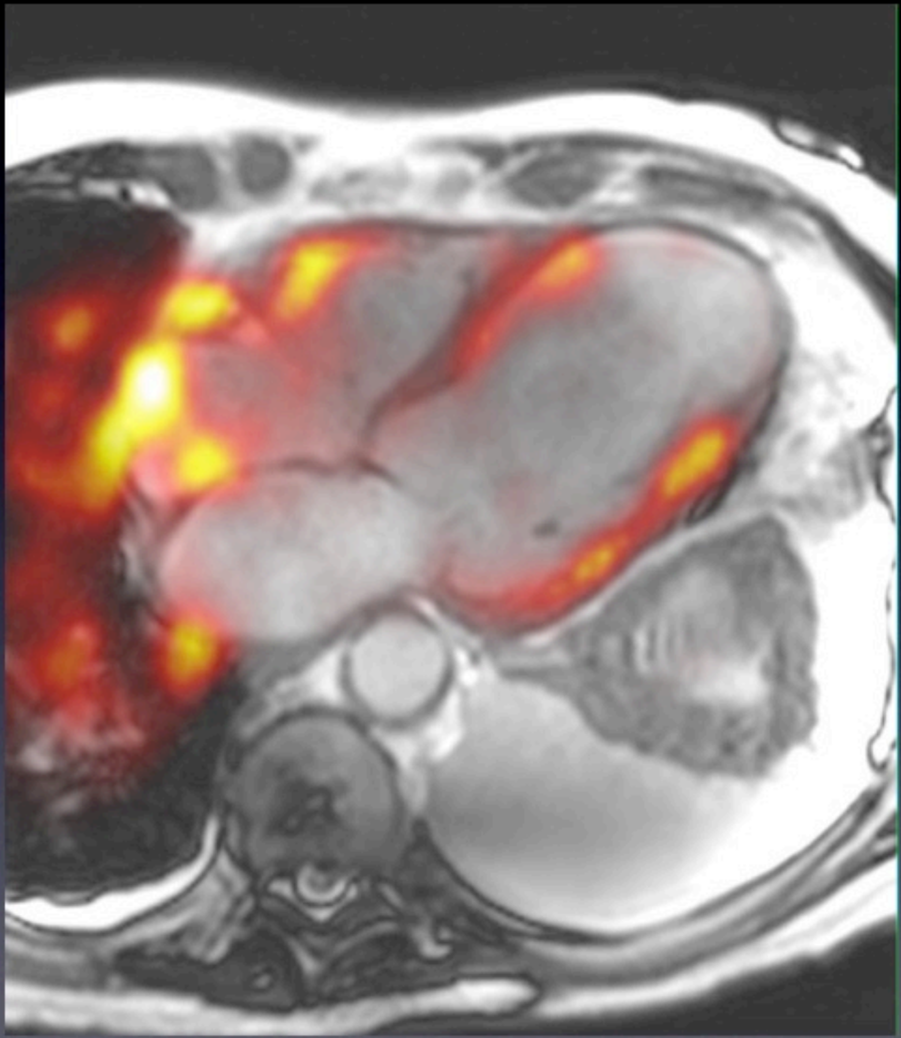
Pt. F-V.J. 06.28.1924

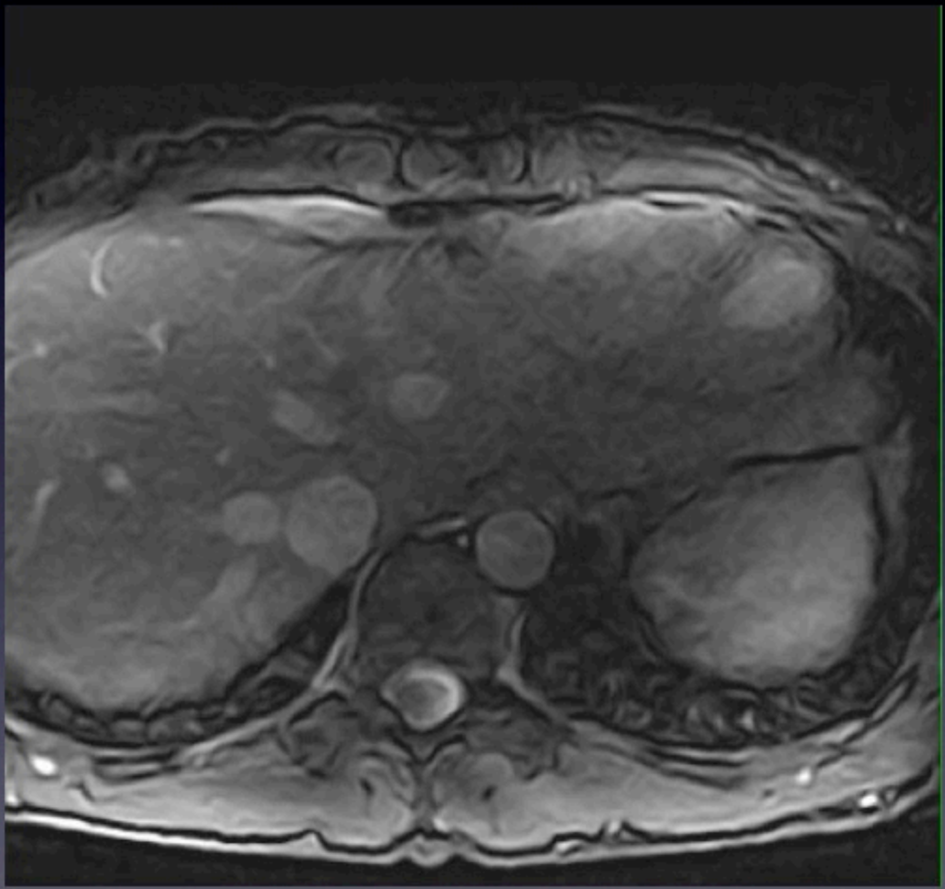


Lower level



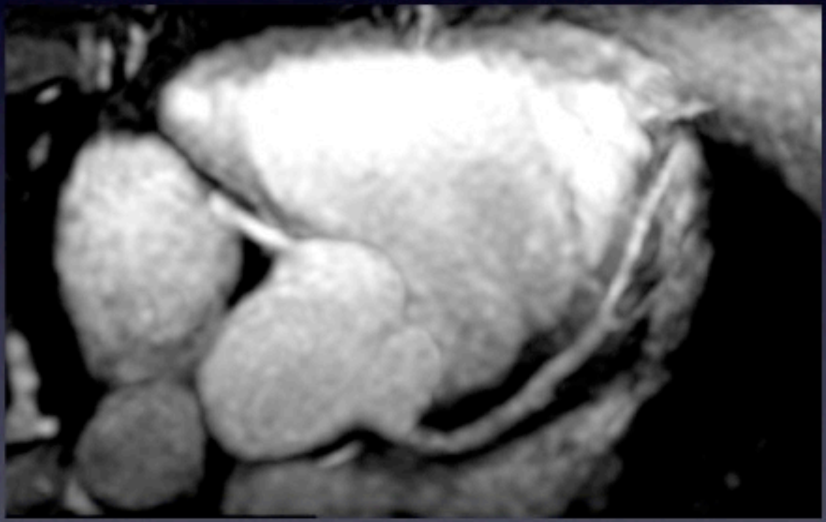
Cardiac coronary MRA

Normal volunteer



Cardiac coronary MRA

Normal volunteer



PET-MRI in clinical routine

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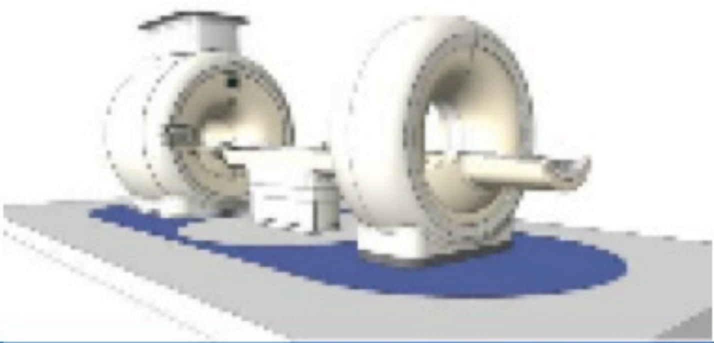
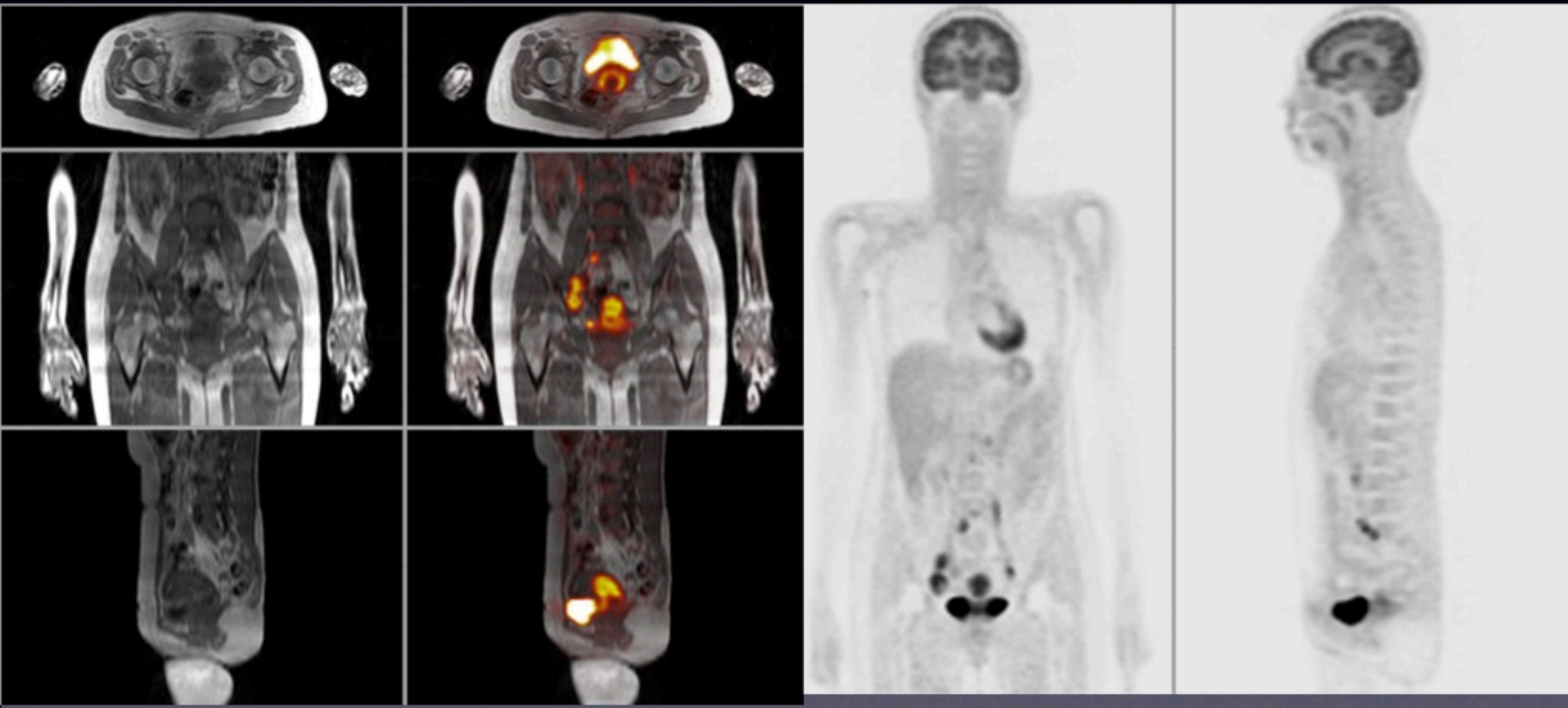


Cervix cancer

Pt. F.S. 1.12.1961

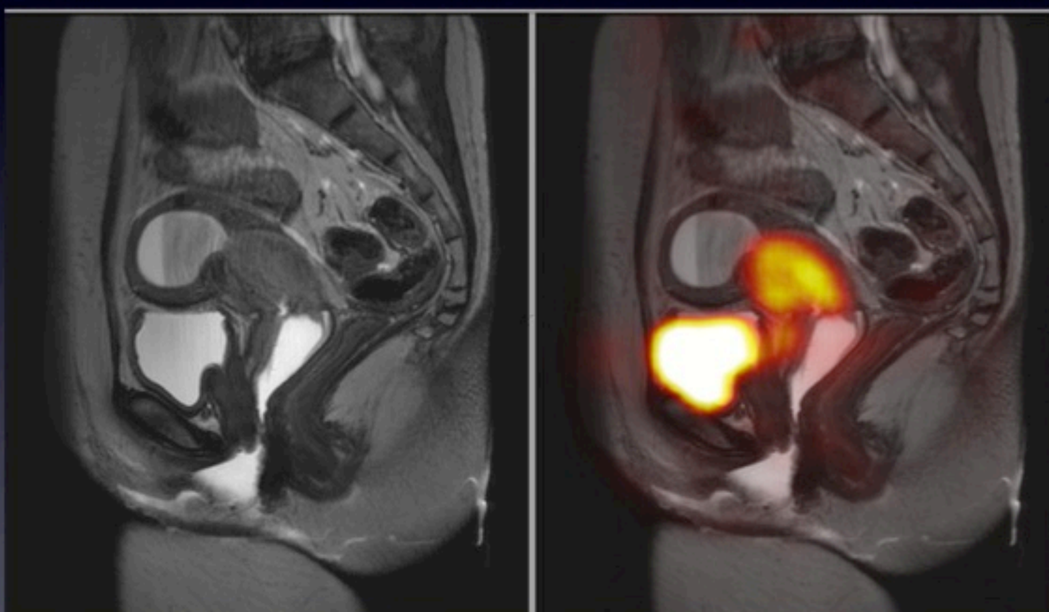


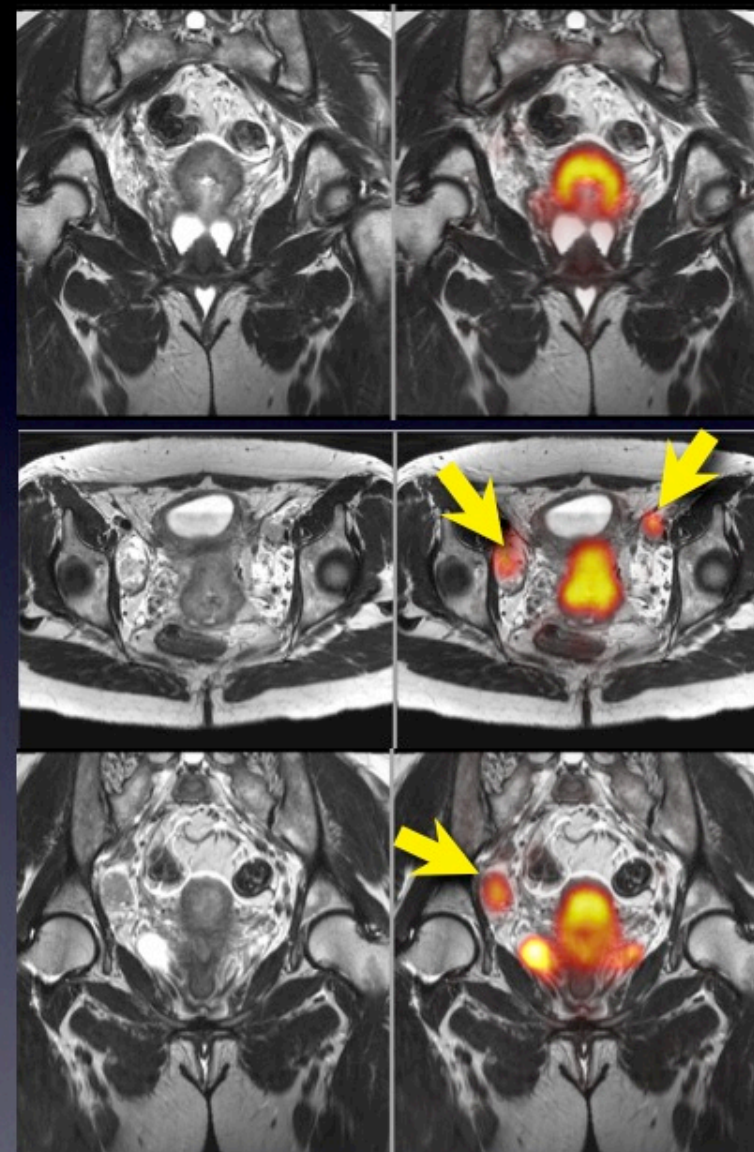
PET - MR

PET

Cervix cancer

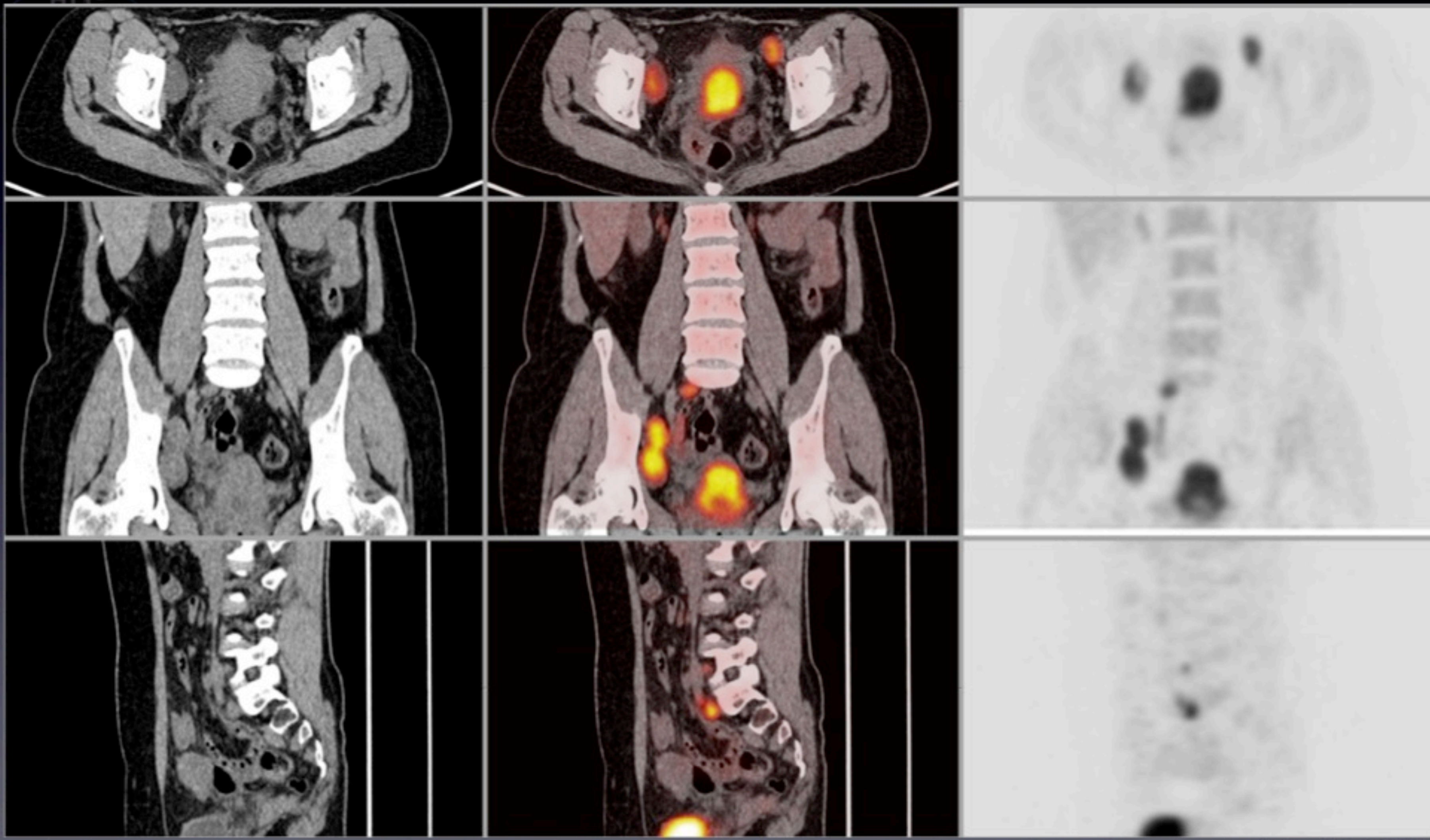
Pt. F.S. 1.12.1961





Cervix cancer

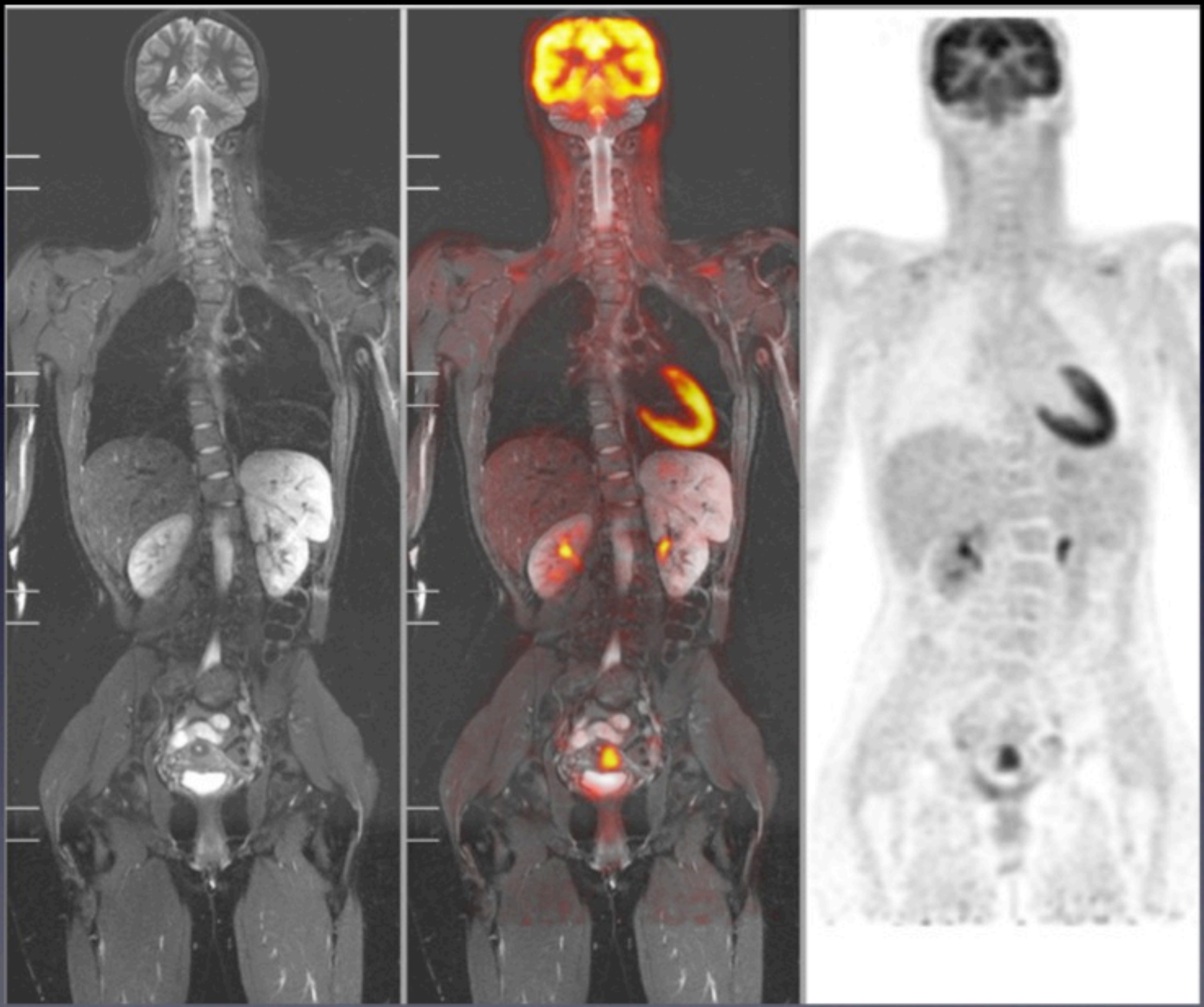
Pt. F.S. 1.12.1961



PET - CT

Uterus cancer

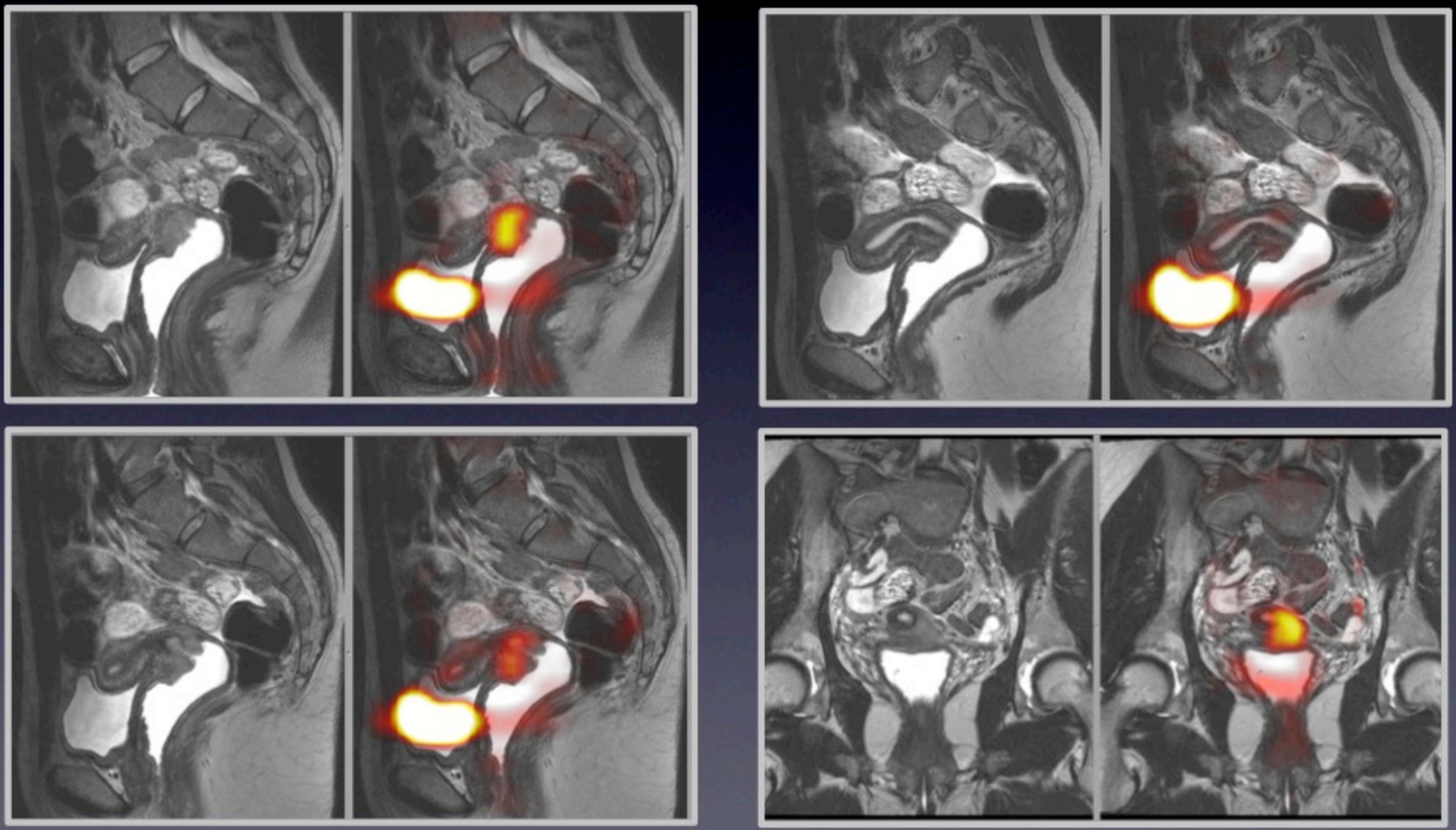
Pt. M.M-J. 30.05.1988



PET - MR

Uterus cancer

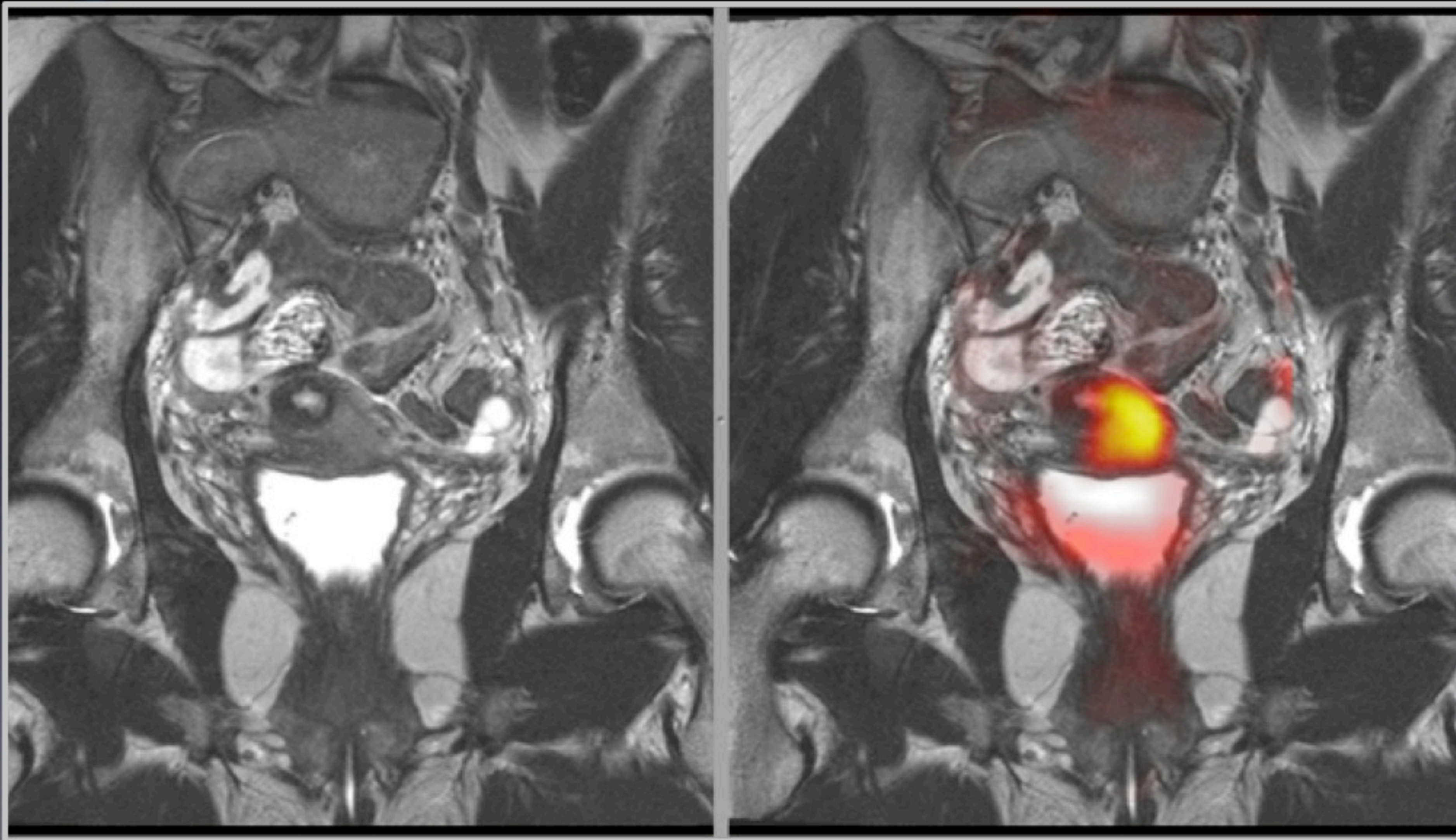
Pt. M.M-J. 30.05.1988



PET - MR

Uterus cancer

Pt. M.M-J. 30.05.1988



PET - MR

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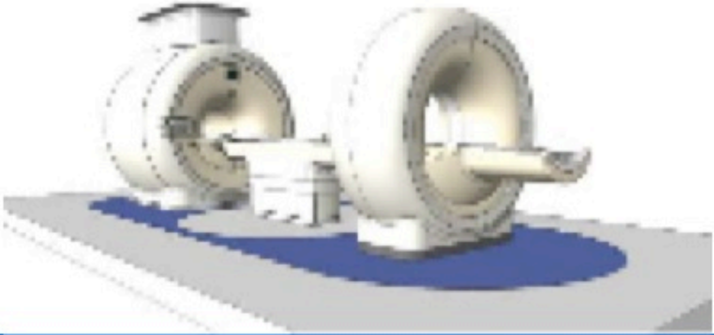
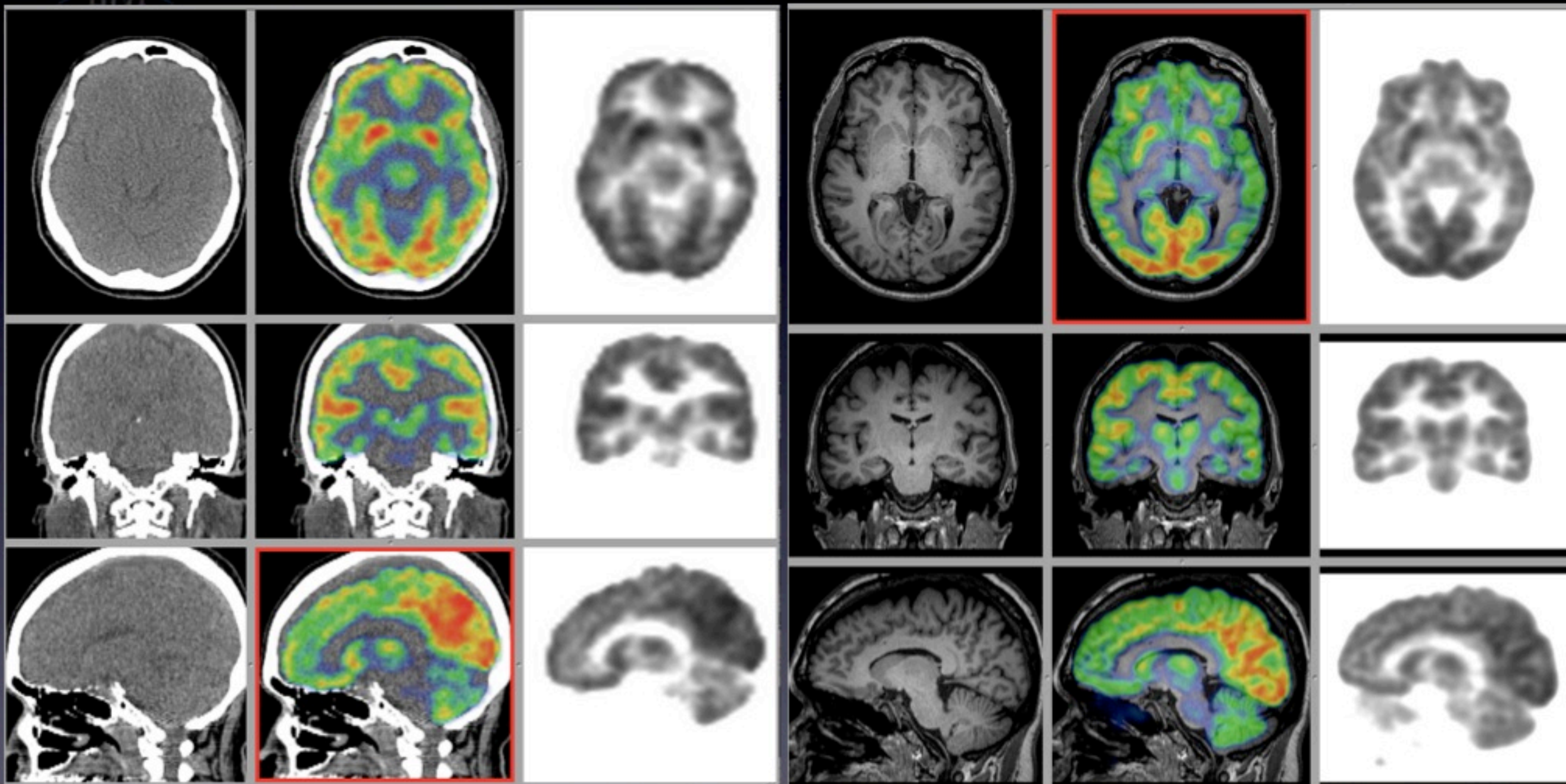


Brain study (Normal)

Pt. O.R. 25.06.1955

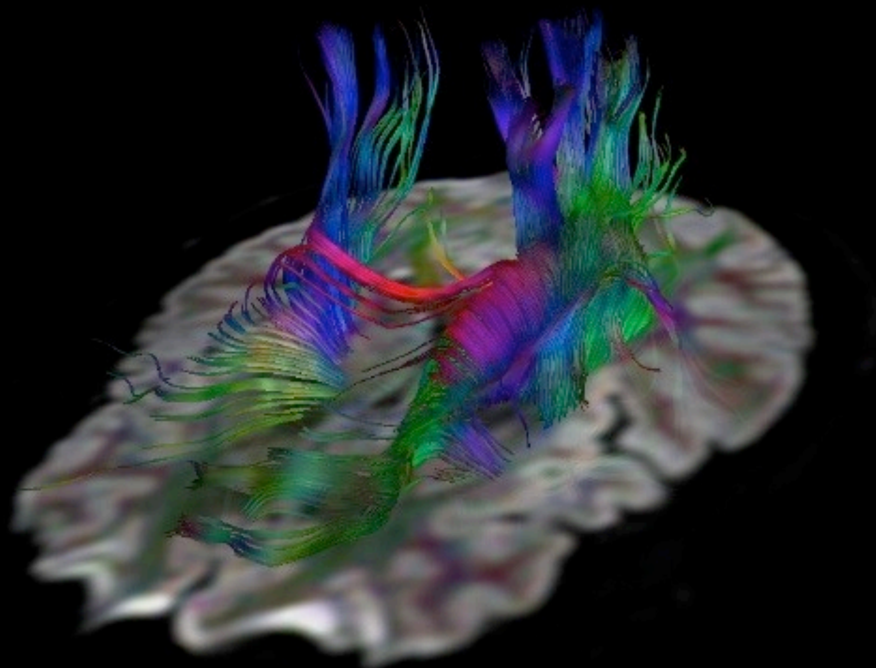


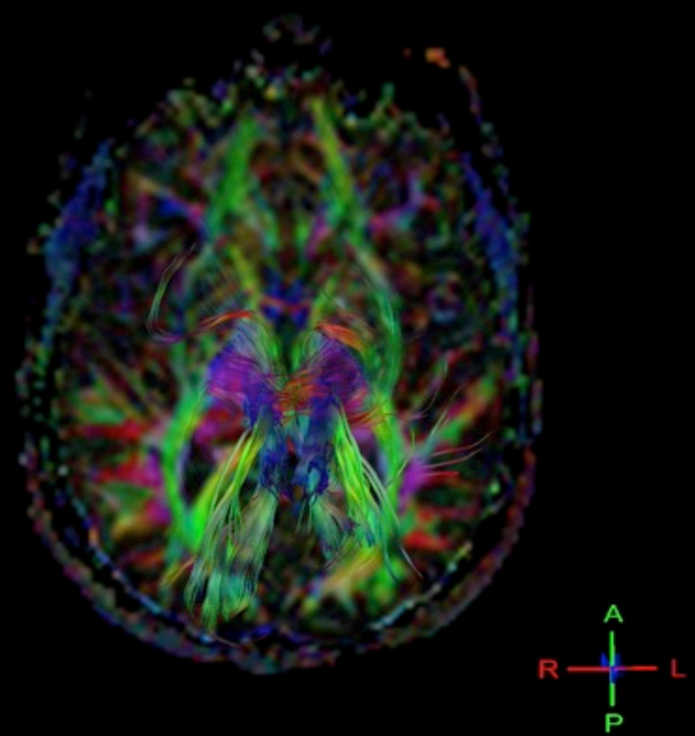
PET-CT

PET-MR

Brain study (Normal)

Pt. O.R. 25.06.1955

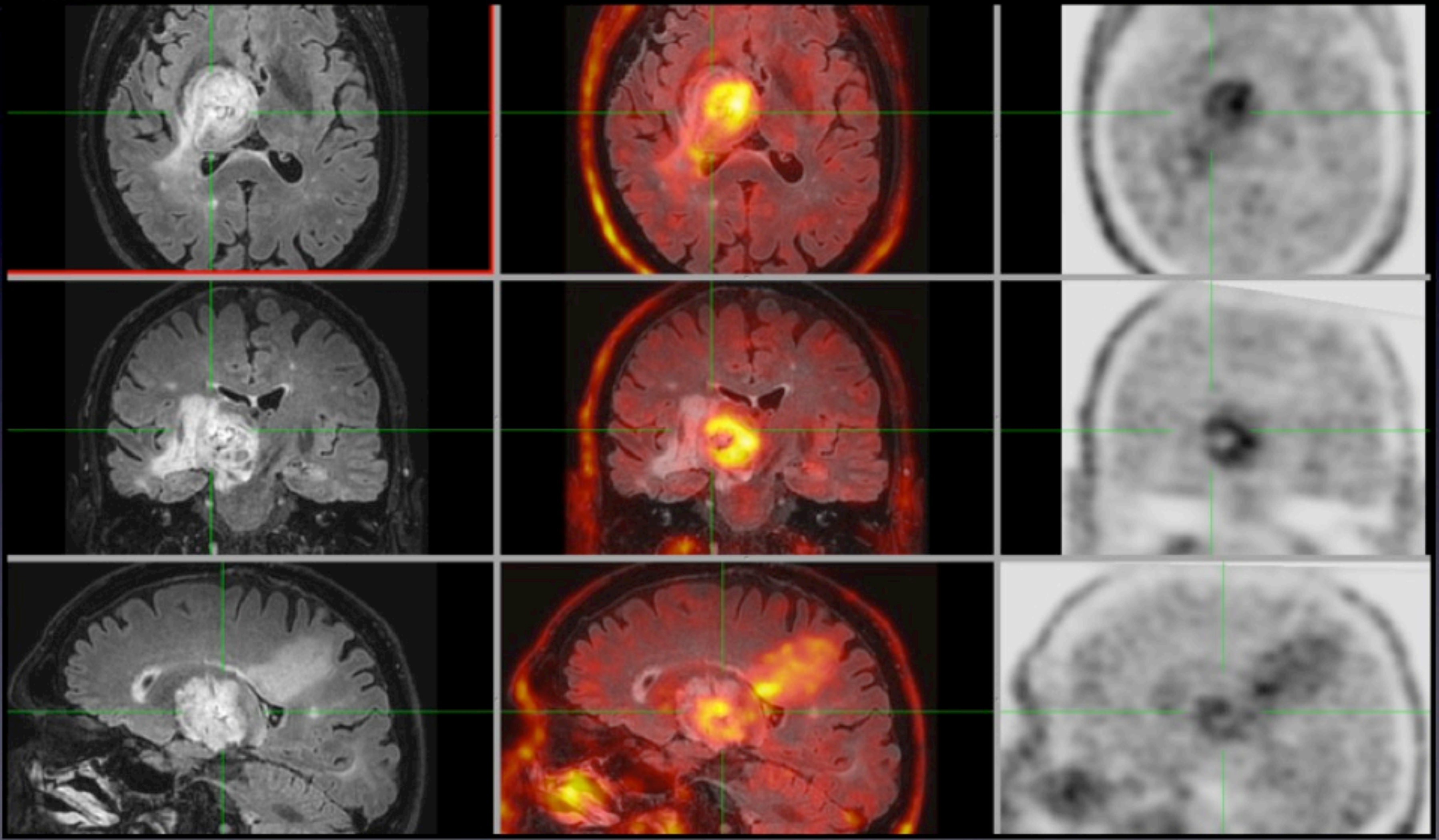




PET-MR (DTI)

Glyoblastoma (18F-Fluoroethyltyrosine)

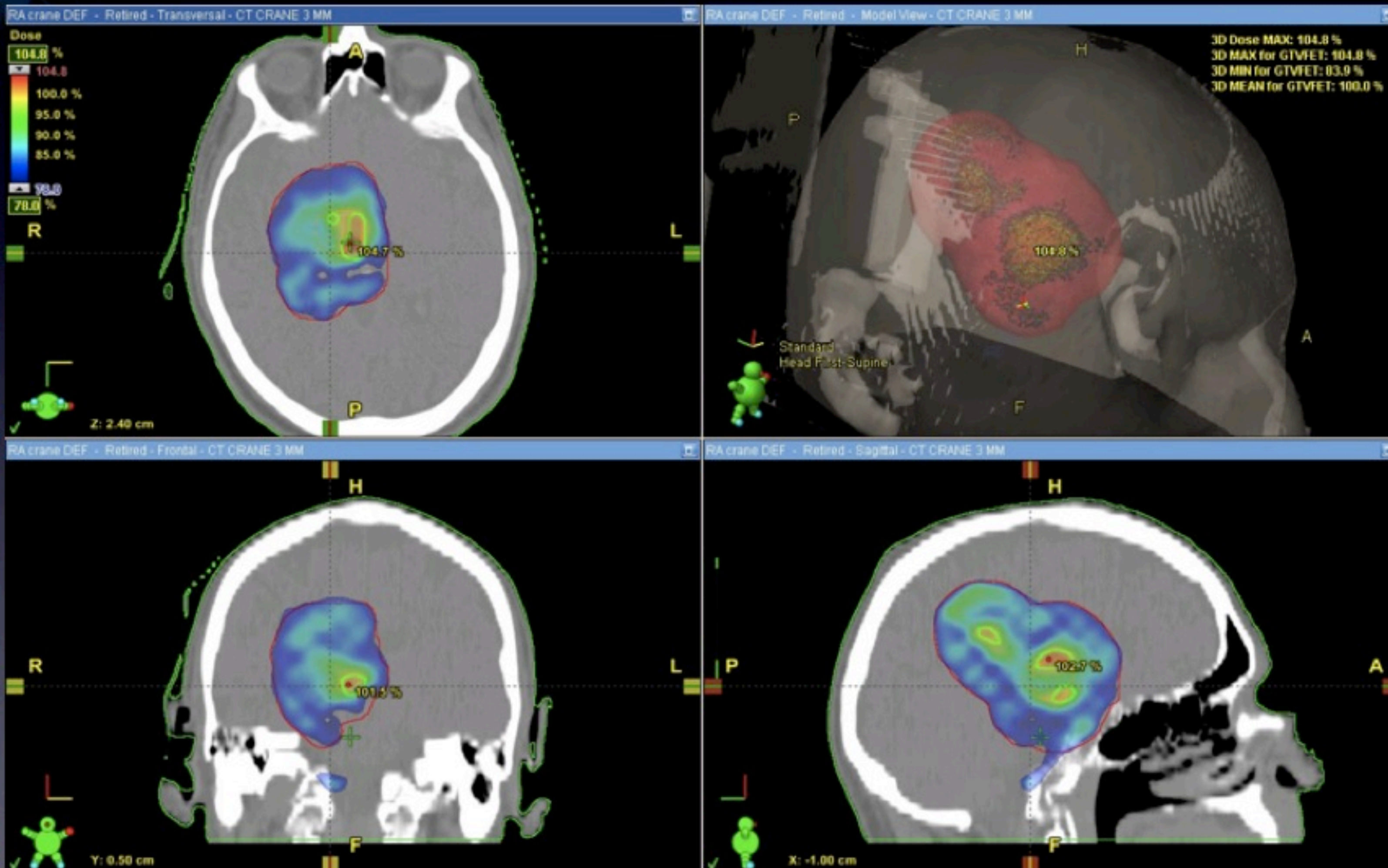
Pt. S.M. 12.07.1944



PET-MRI

Glyoblastoma (18F-Fluoroethyltyrosine)

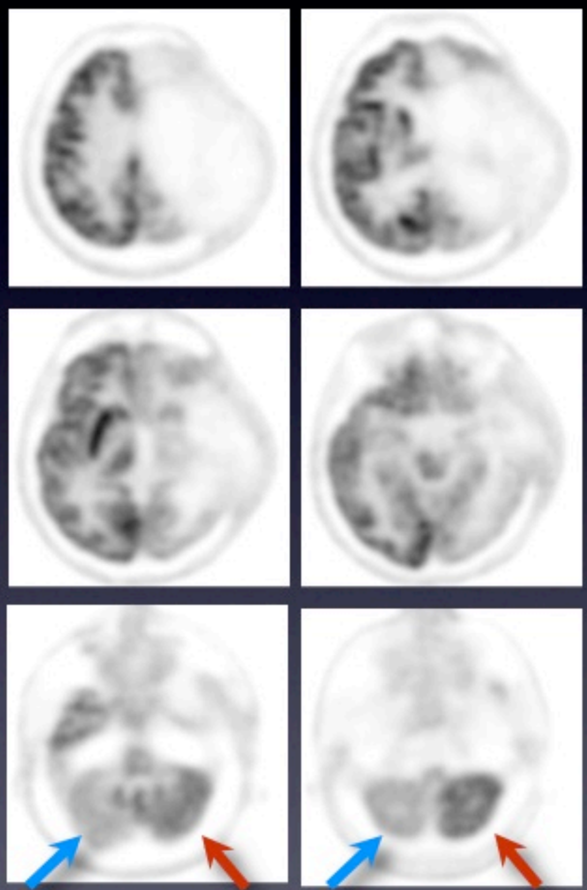
Pt. S.M. 12.07.1944



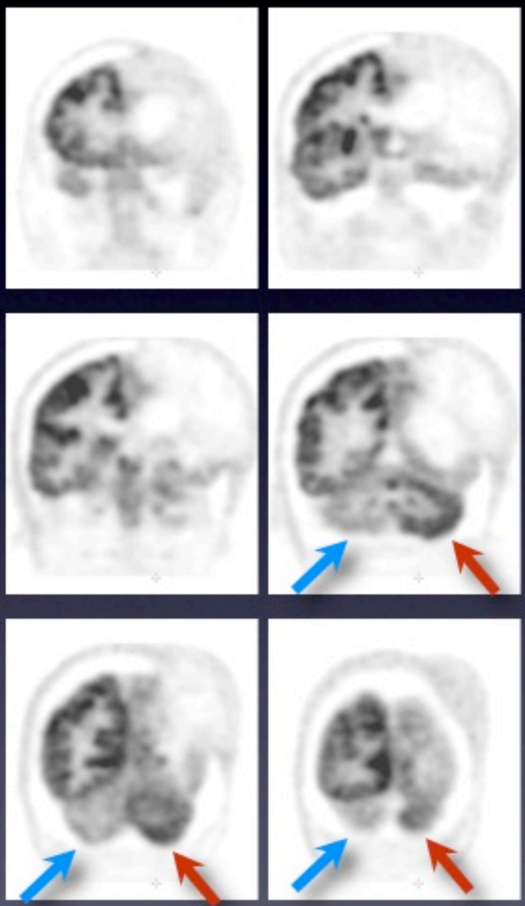
Radiotherapy treatment planning

Cortico-cerebellar diaschisis after stroke

Pt. F.A. 17.02.1964



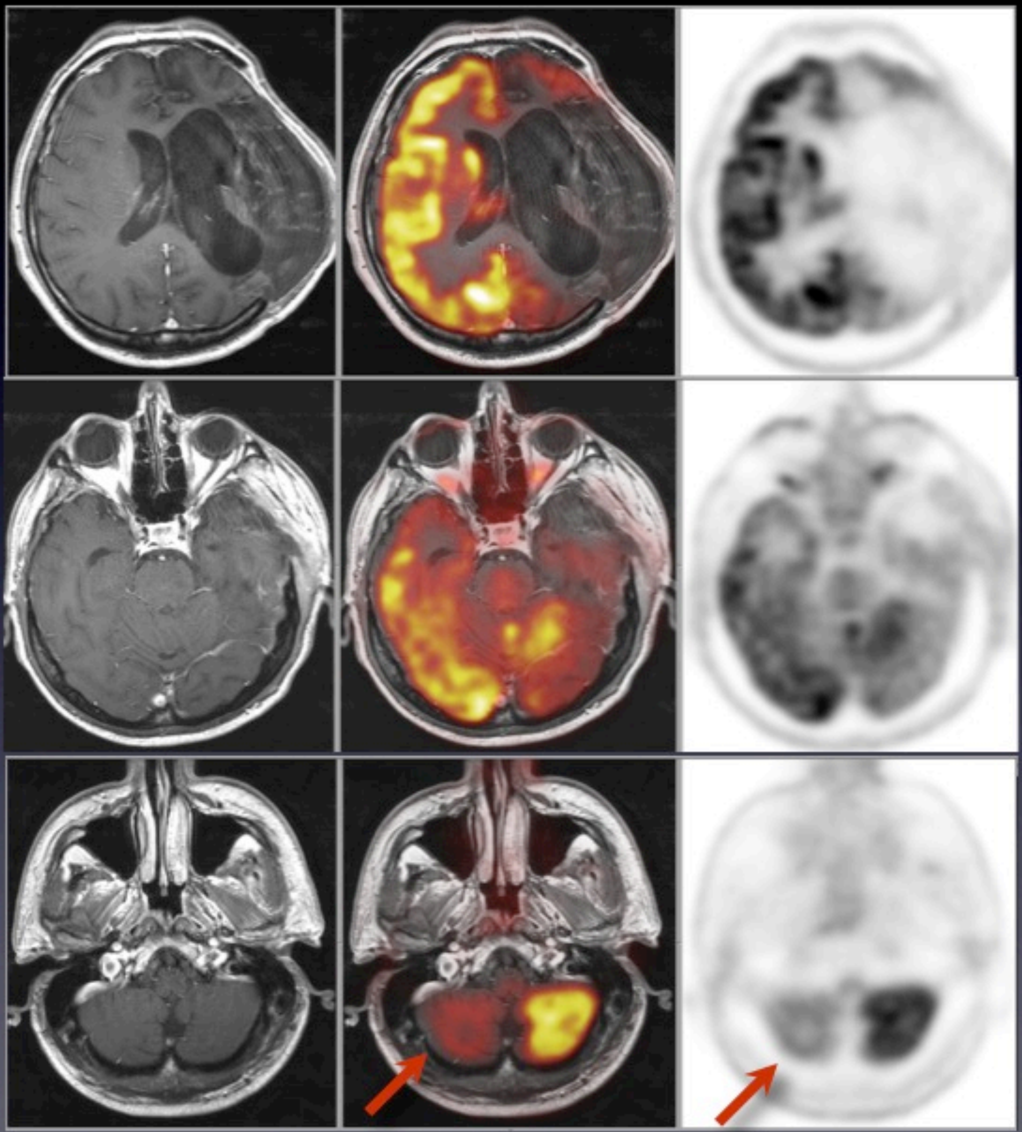
PET (axial)



PET (coronal)

Cortico-cerebellar diaschisis after stroke

Pt. F.A. 17.02.1964

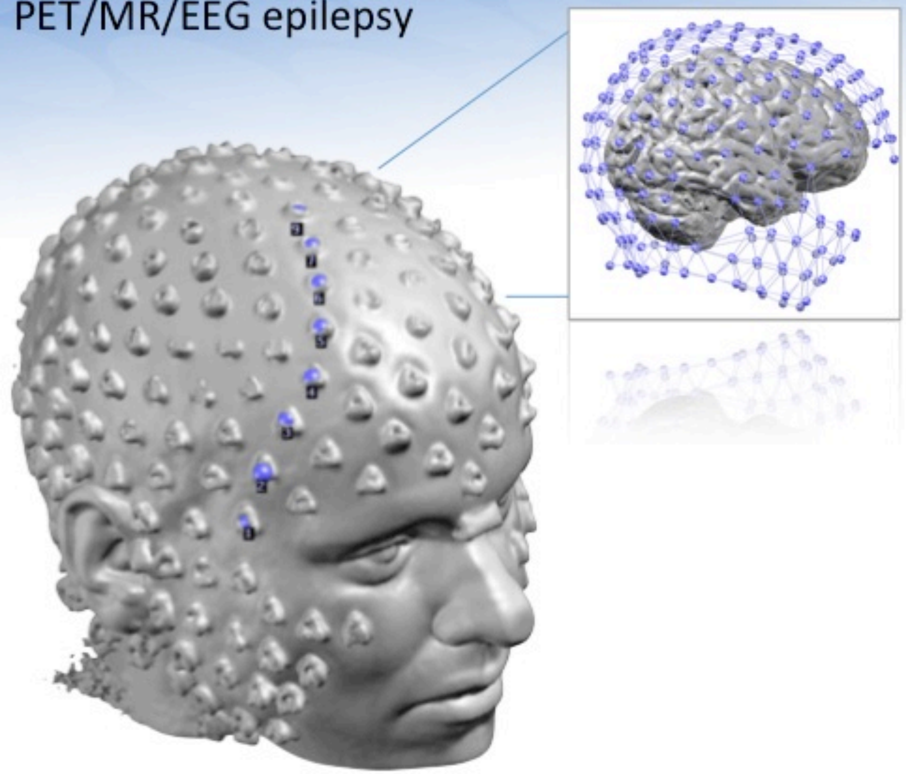


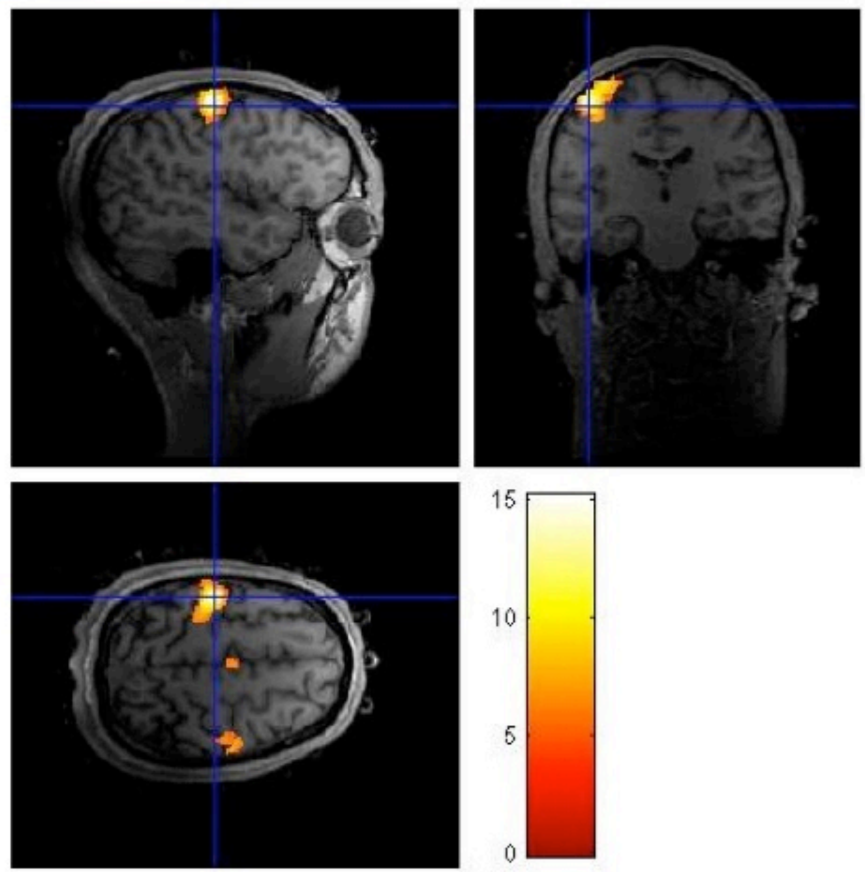
MRI PET/MR PET

Whole-body PET-MRI

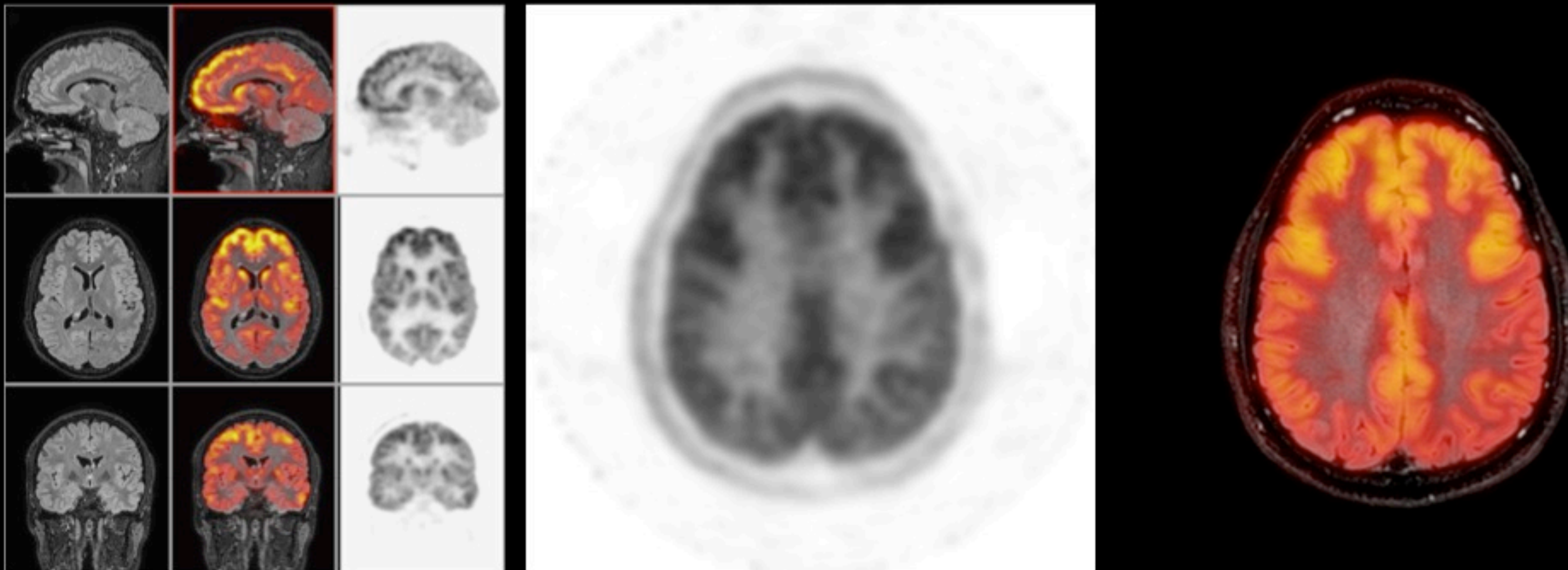
Clinical applications

PET/MR/EEG epilepsy





Courtesy of Dr. Laurent Spinelli, Dr. Serge Vuillemoz, Dr. Frédéric Grouiller, Prof. Margitta Seeck, Unité d'EEG et d'exploration de l'épilepsie, HUG



Epilepsy

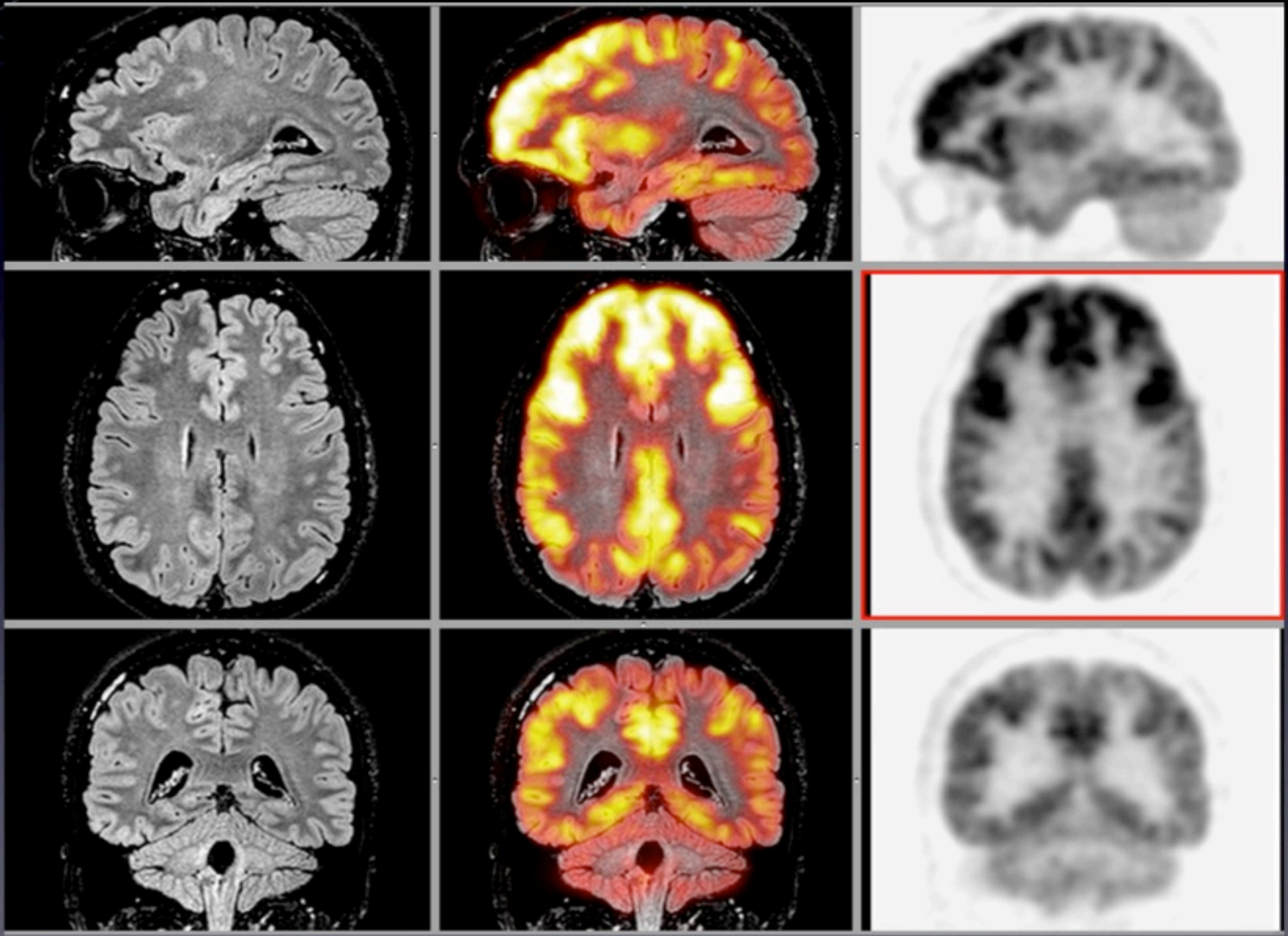
19 y/o M epilepsy suspected in left frontal cortex.

PET/MR shows no signs of sclerosis in hippocampus and no suspicious masses on ceMR (A). Mildly asymmetric metabolic activity in the temporal-parietal cortex (B,C) weighted towards the right side (BRASS analysis).

(A-C) 253 MBq 18F-FDG, 74 kg / 177 cm patient, 50 min uptake time, 2 beds x 1.3 min
(A,C) 3D FLAIR VISTA (act. TE 330, TR 8000, TI 2400, 1.04x1.09x1.16mm^3)
post 14mL Gadovist, SENSE Head-8 coil

Epilepsy

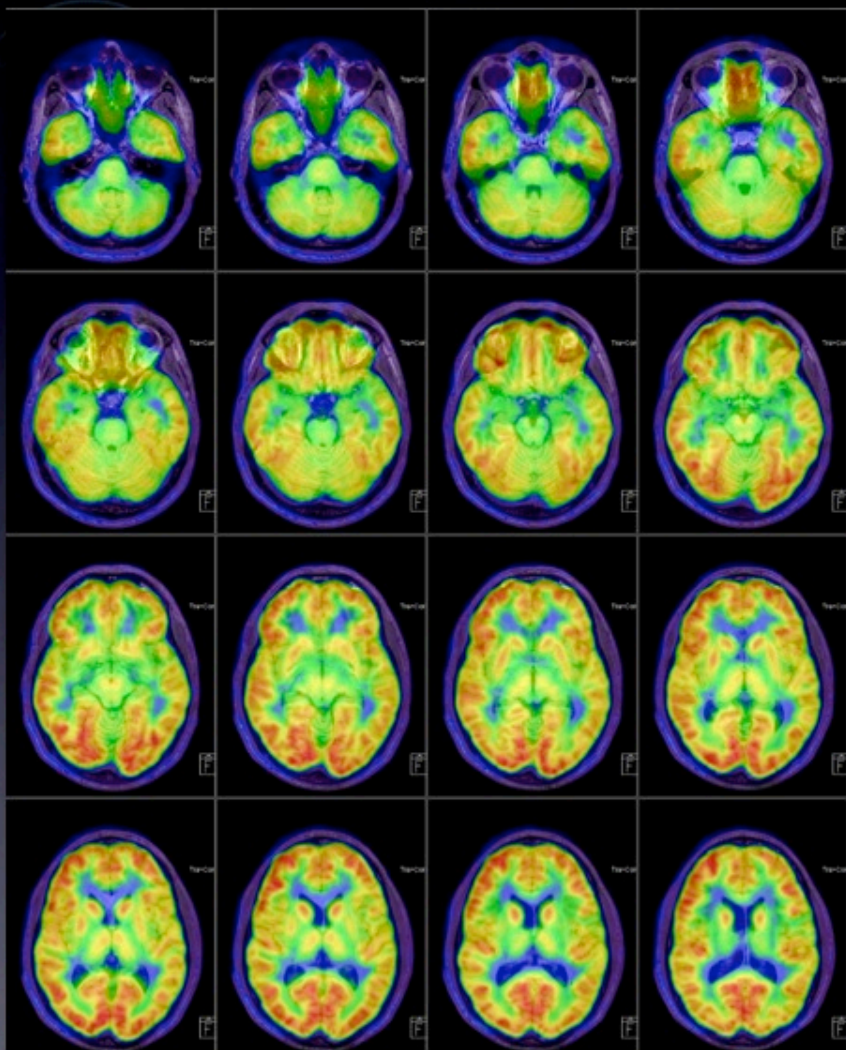
Pt. H.R. 1991



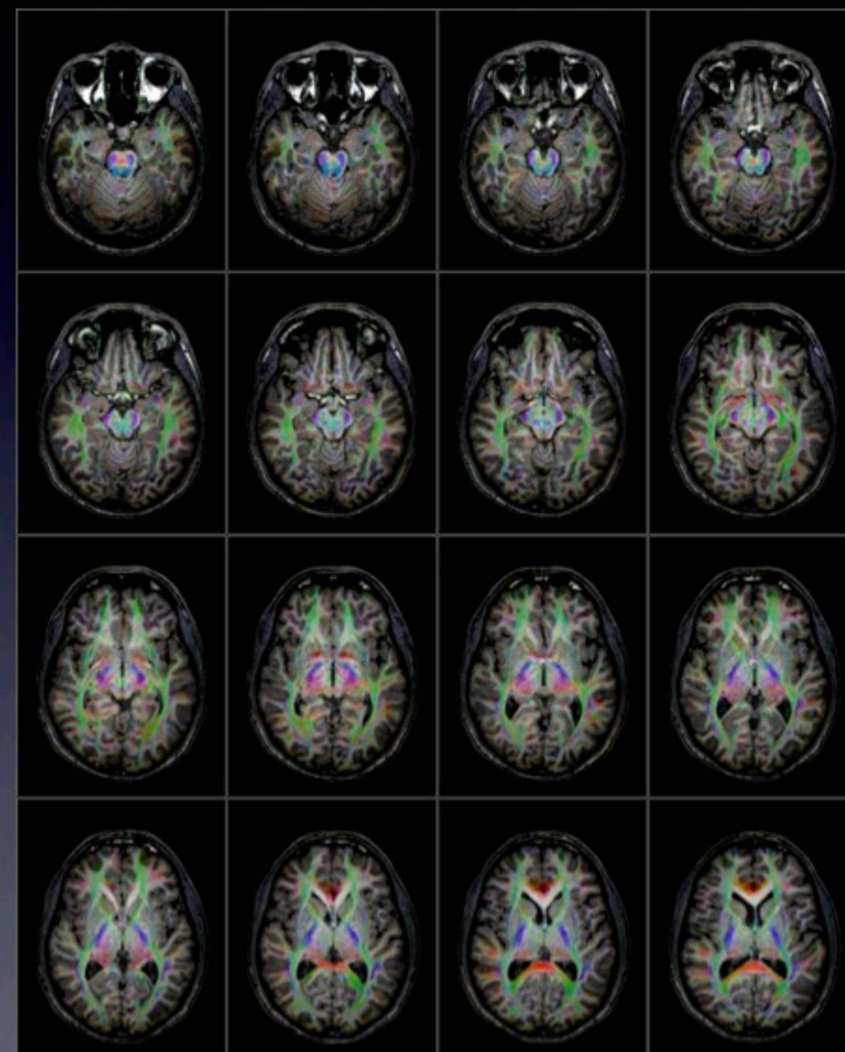
PET-MR

Epilepsy

Pt. H.R. 1991



PET-MR fusion (FDG)



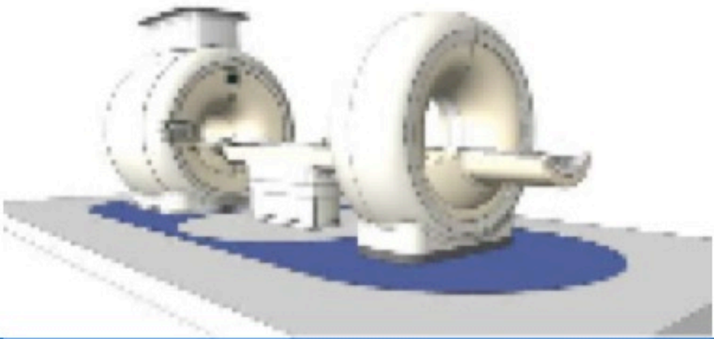
(Functional) MRI - DTI

PET-MR

Emerging clinical applications

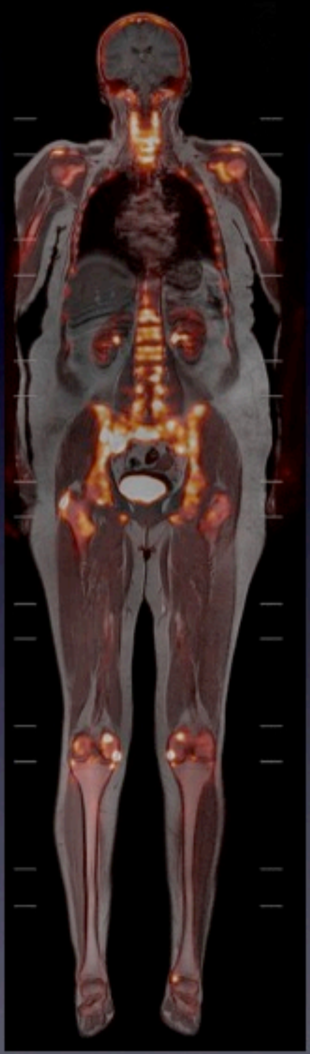
- Oncology investigation that require already a diagnostic MRI in addition to PET-CT:
  - **Head & Neck cancer (pre and post-op)**
  - **Prostate cancers**
  - **Breast imaging**
  - **Pediatric oncology**

- New emerging clinical applications:
  - **Cardiac imaging (viability, ischemia?)**
  - **Gynecological cancers**
  - **Brain imaging**
  - **Bone metastases (F^{18}-NaF)**



BONE METASTASES

F-18 NaF PET-MRI



Courtesy: Prof. Jörg van den Hoff and Dr. Ivan Platzek, Helmholtz-Zentrum Dresden-Rossendorf

Work in progress

Focus on clinically relevant improvements

1. **Improve and optimize MRI protocols**
   - **Better whole body scans**
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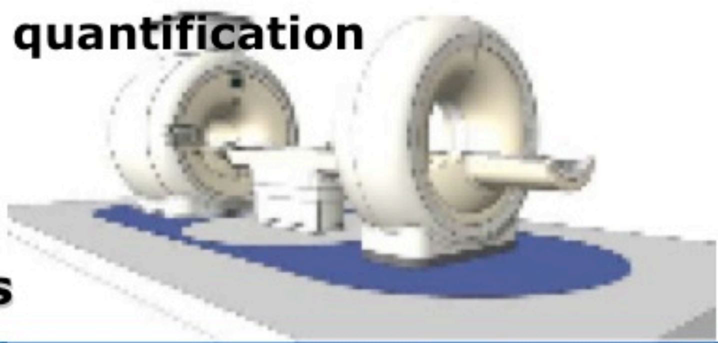
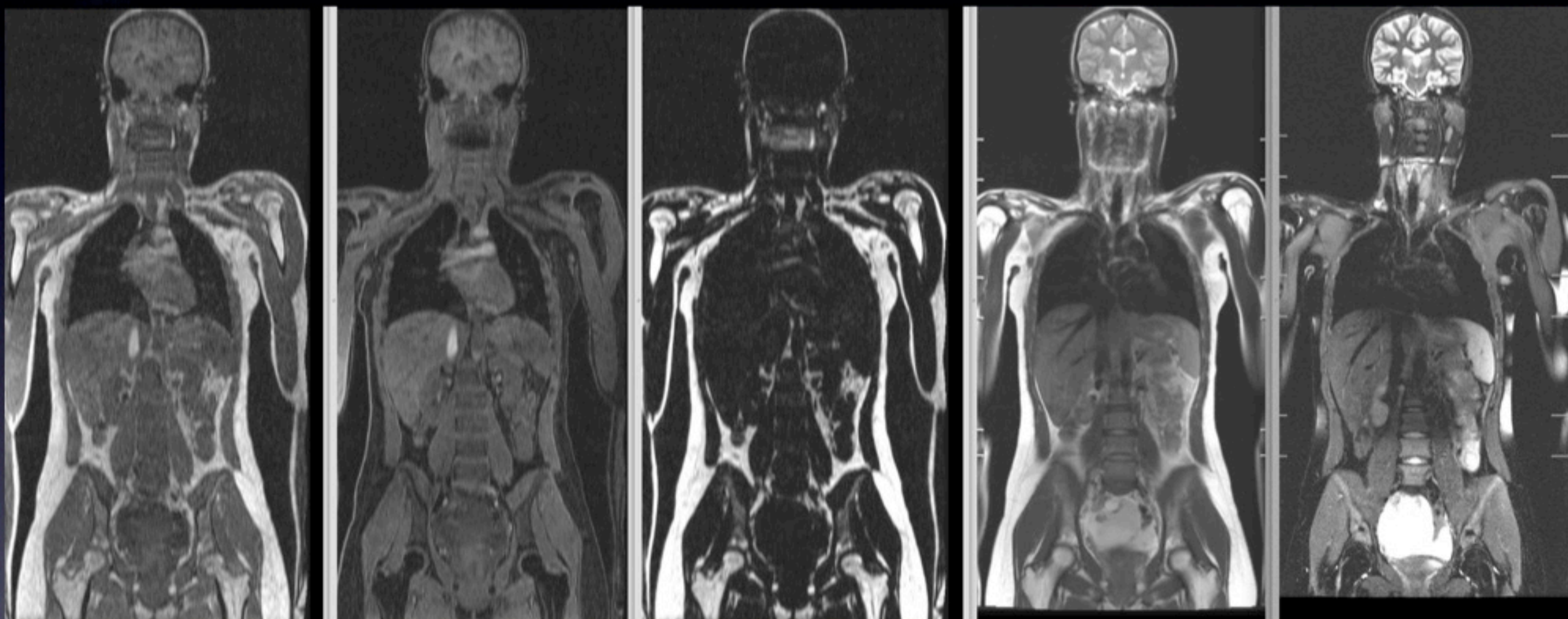


Whole body MRI

Work in progress

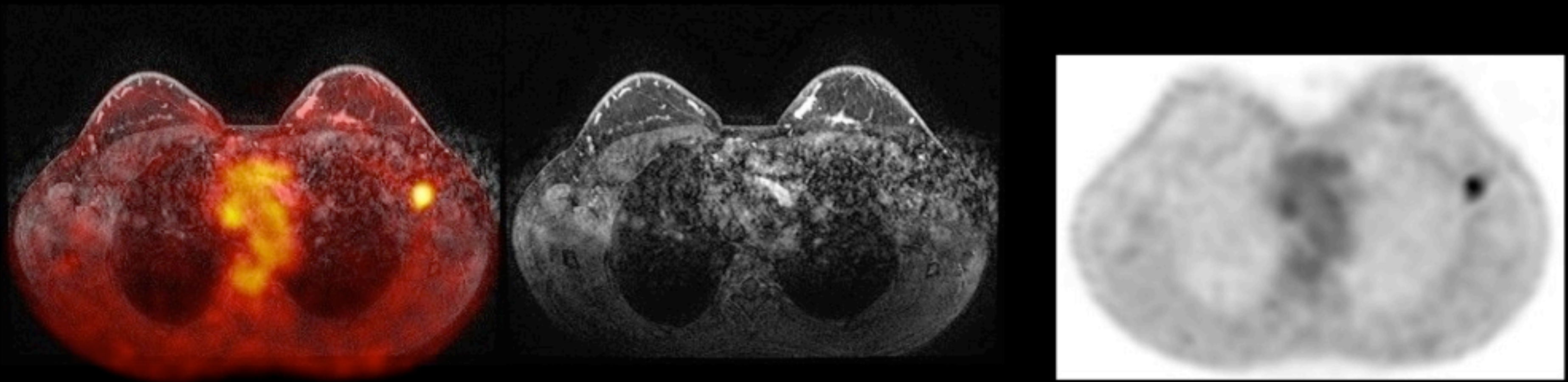


Dixon IP | Dixon water | Dixon fat | T2TSE | STIR

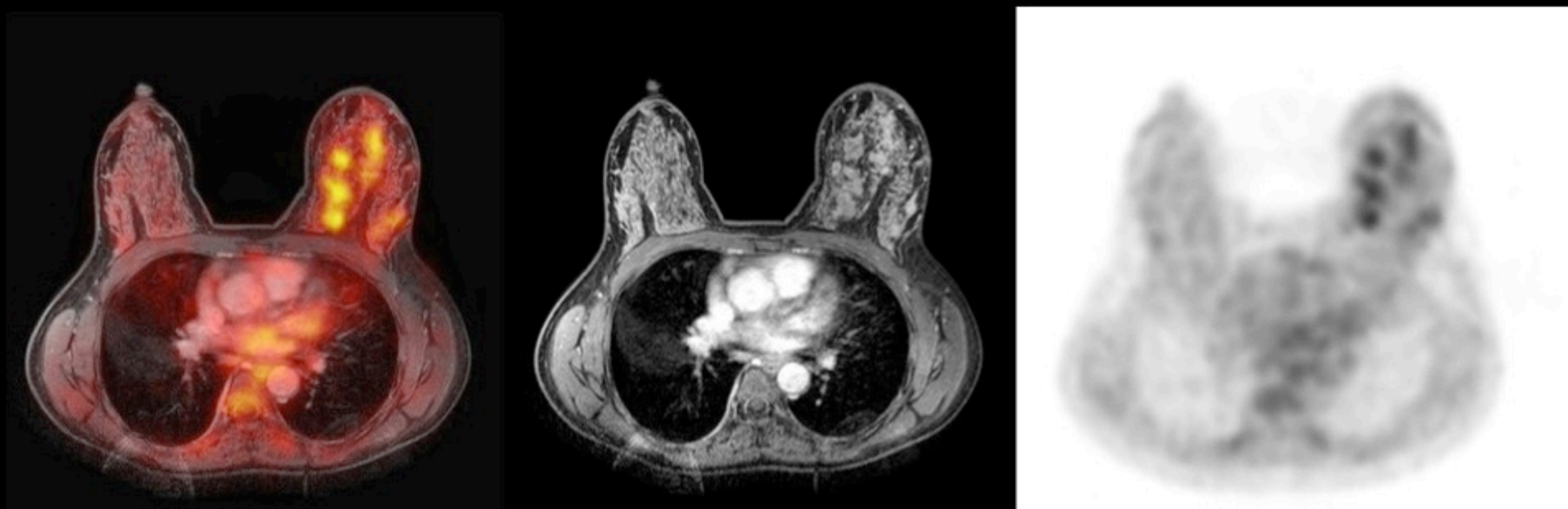
~ 5 min | ~ 7-10 min | ~ 10-15 min

Standard Quality: eThrive: Analysis in Breast Region possible

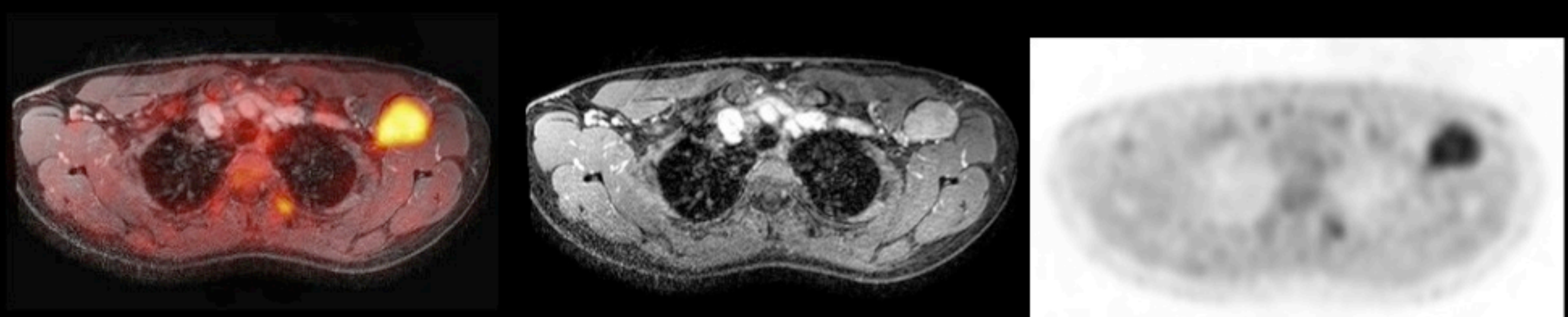
Standard Quality: eThrive: Axillary Lymph Node Involvement NOT visible



Courtesy: Susanne Heinzer, Harry Friel, Philips Healthcare and Michael Wyss, Institute for Biomedical Engineering, ETH Zurich, Enhanced Image Quality: Dixon: Analysis in Breast Region possible



Enhanced Image Quality: Dixon: Axillary Lymph Node Involvement WELL visible



Courtesy: Susanne Heinzer, Harry Friel, Philips Healthcare and Michael Wyss, Institute for Biomedical Engineering, ETH Zurich,

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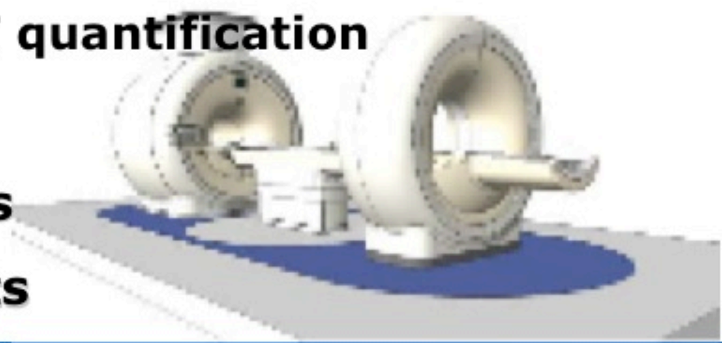
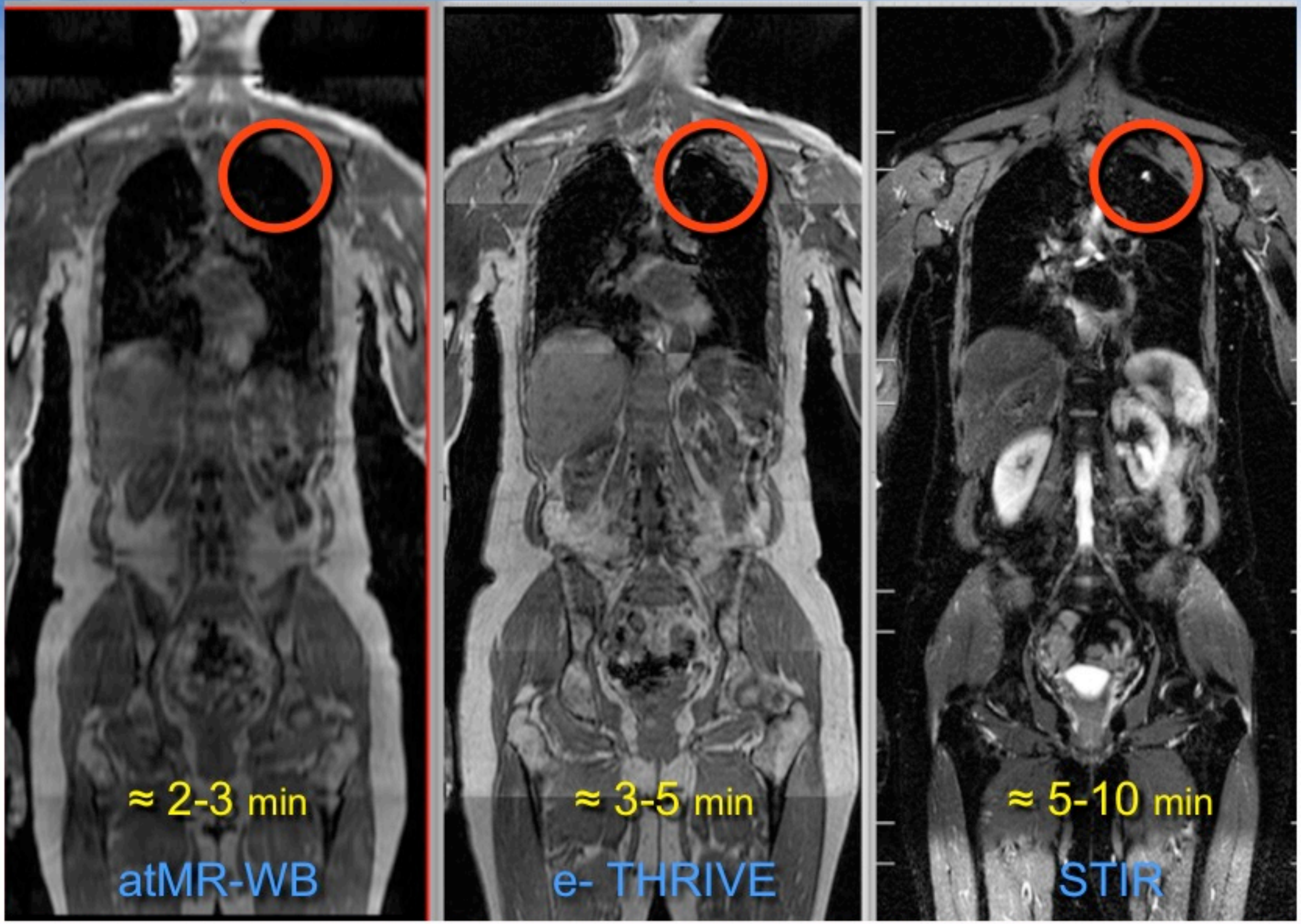


PET-MRI in Geneva

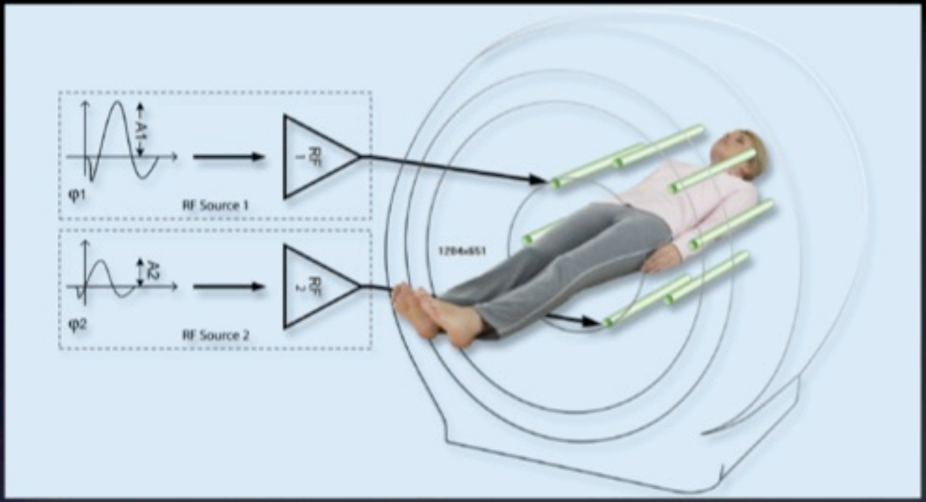
Improvement of whole body scan



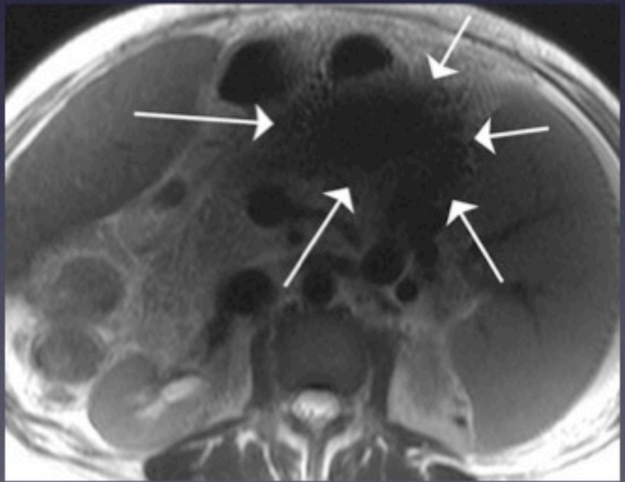
Multi-transmit image acquisition technology

Achieva 3.0T TX with
MultiTransmit parallel RF transmission

- **MultiTransmit RF technology addresses remaining 3T challenges at the source**
  - **Dielectric shading**
  - **Local SAR**
- **Patient-adaptive RF system**
  - **Two completetly independent RF amplifiers**
  - **RF-shimming per patient (and anatomy)**
- **Leads to enhanced**
  - **consistency, patient after patient**
  - **image and contrast uniformity**
  - **speed, up to 40% faster**
  - **diagnostic confidence**



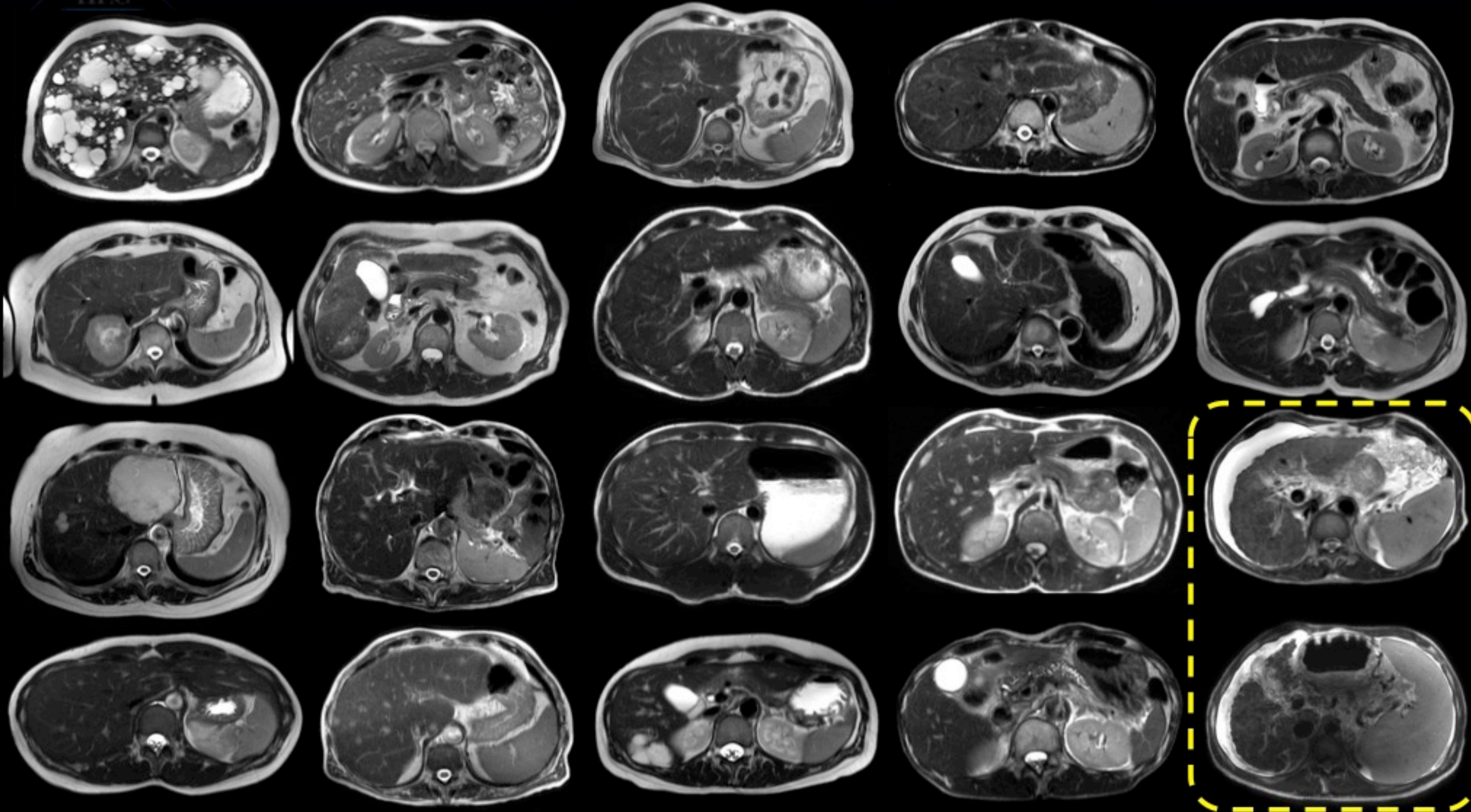
Correct the dielectric effect of field inhomogeneity



Source: Merkle, E. M. et al. Am. J. Roentgenol.2006;186:1524-1532

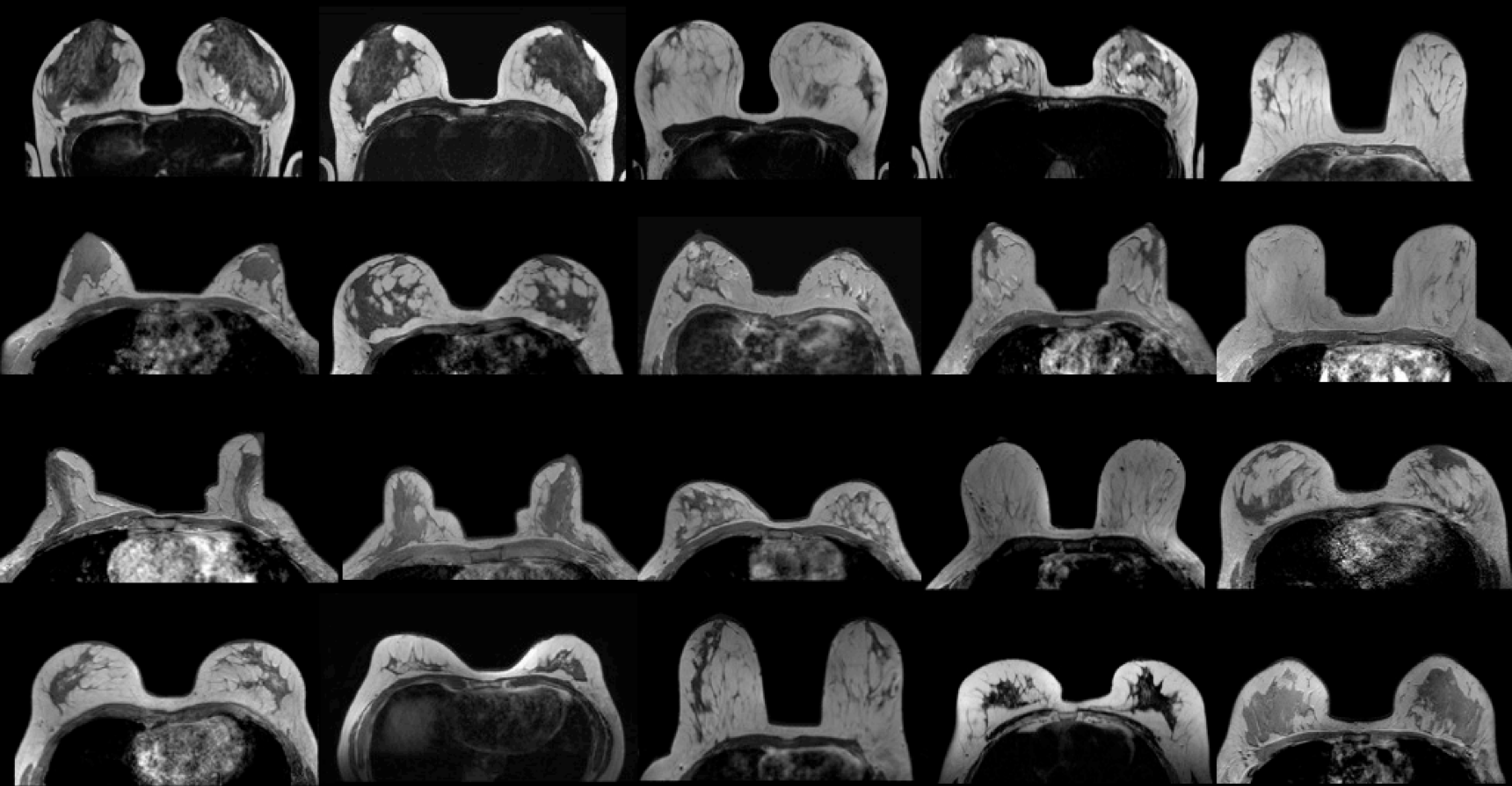
Courtesy: Peter Sundic, Susanne Heinzer, Philips Healthcare

Enhanced contrast and consistency



Courtesy: Peter Sundic, Susanne Heinzer, Philips Healthcare

using patient-adaptive MultiTransmit



Courtesy: *Peter Sundic, Susanne Heinzer, Philips Healthcare*

using MultiTransmit

Up to 40% increase in speed

Single transmit / conventional

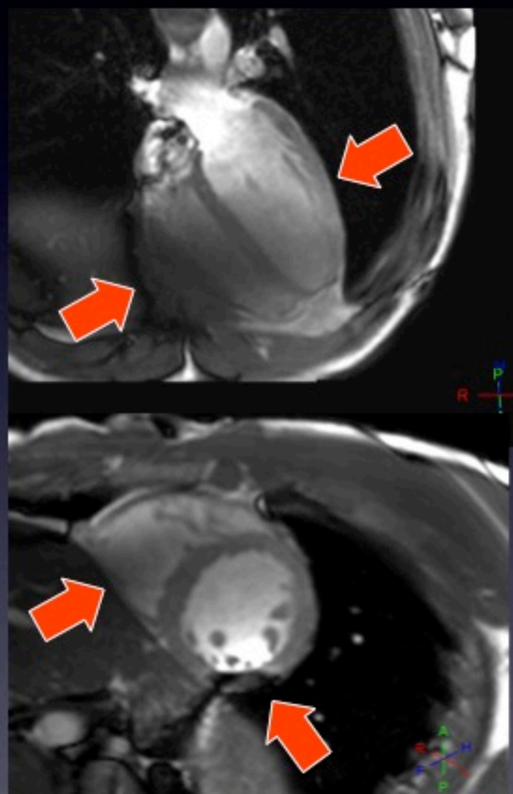
4 min 25

MultiTransmit

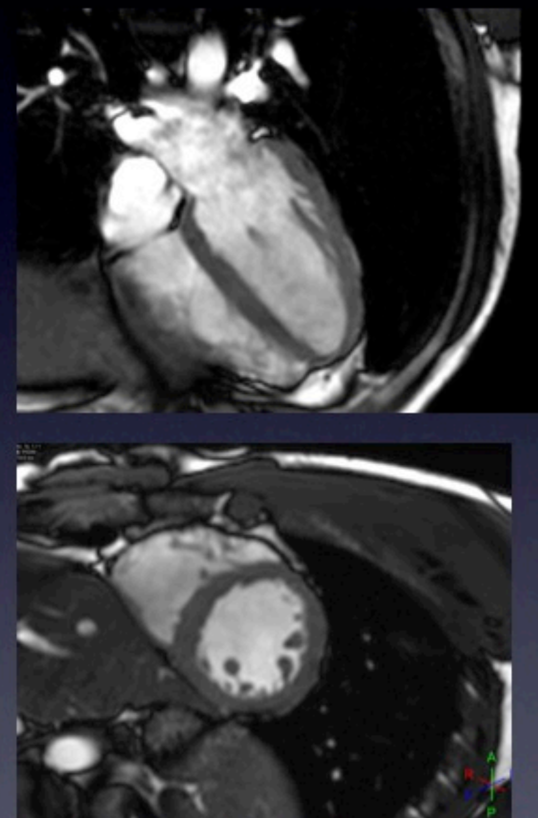
2 min 23

Courtesy: Bonn University Hospital, Germany

Cardiac with MultiTransmit *



Conventional



MultiTransmit

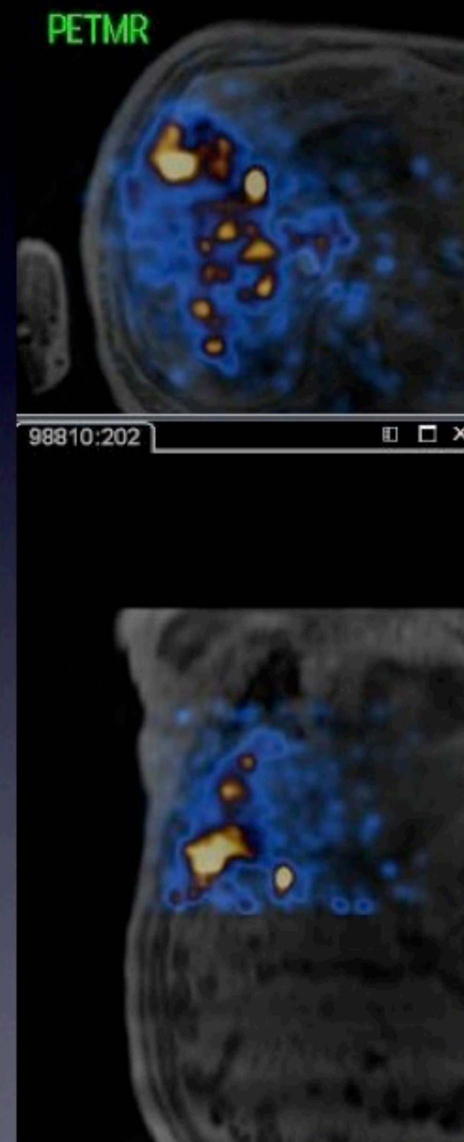
Cine B-TFE with optimized real-time RF shimming

Courtesy: King's College London, UK

PET-MR control of Y90 microspheres

Pt. A.D. 24.05.44

SPECT-CT



PET-MR

Work in progress

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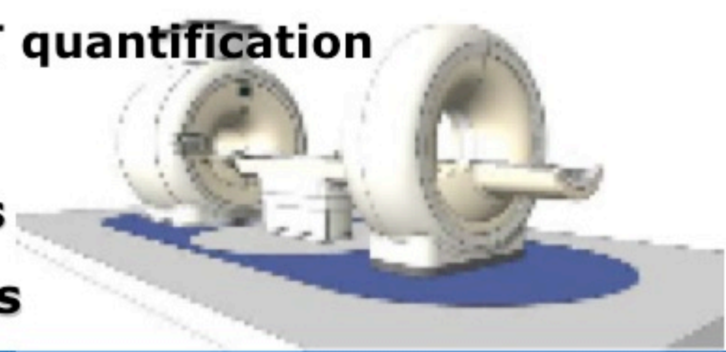
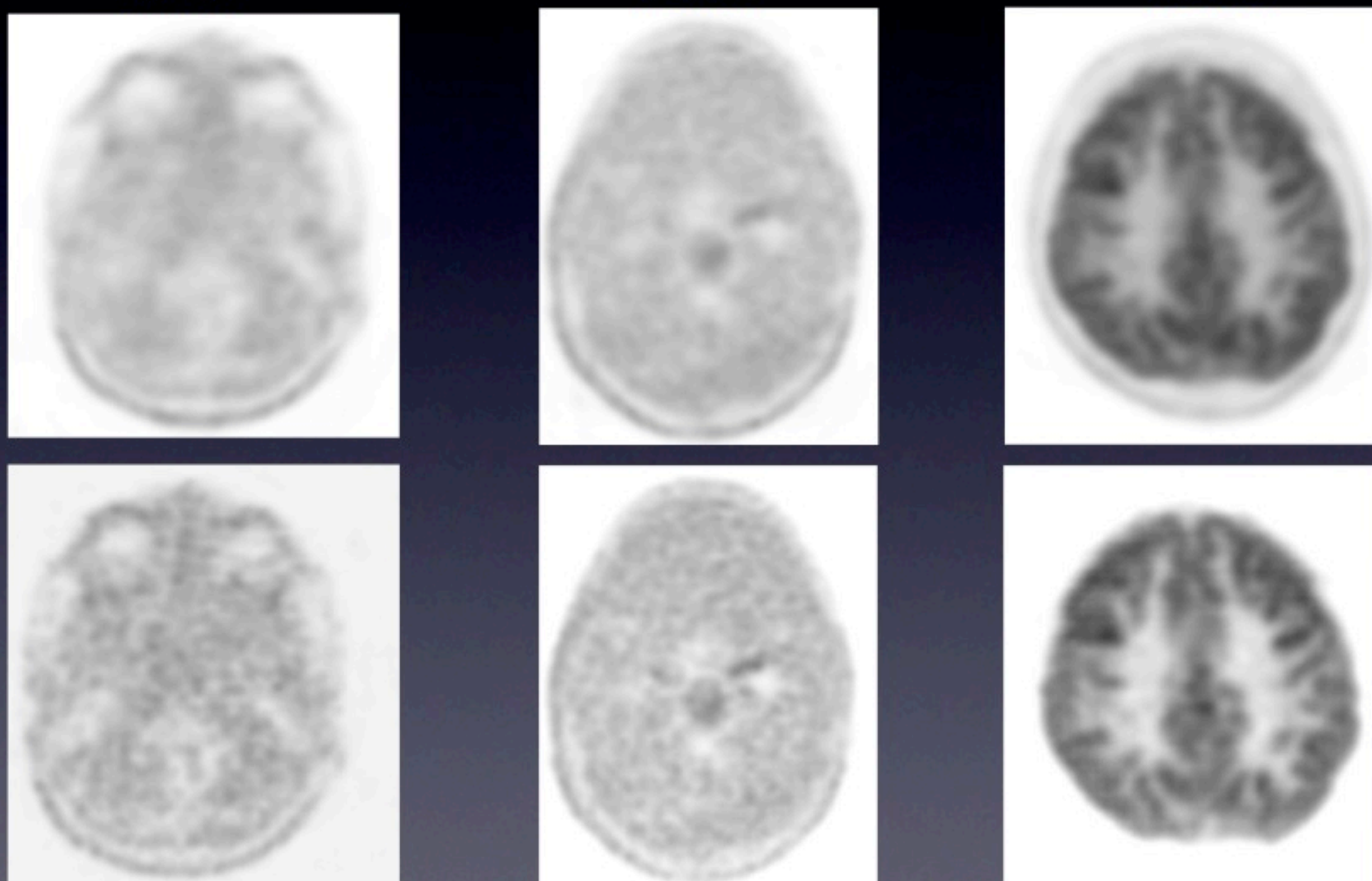


Work in progress

Better PET reconstruction



Optimization of BLOB parameters by Manoj Narayanan, Susanne Heinzer

Work in progress

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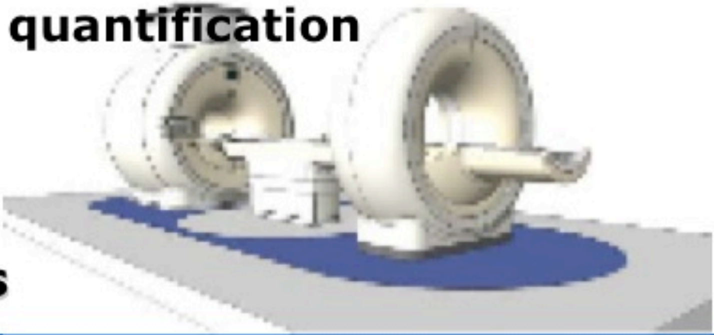
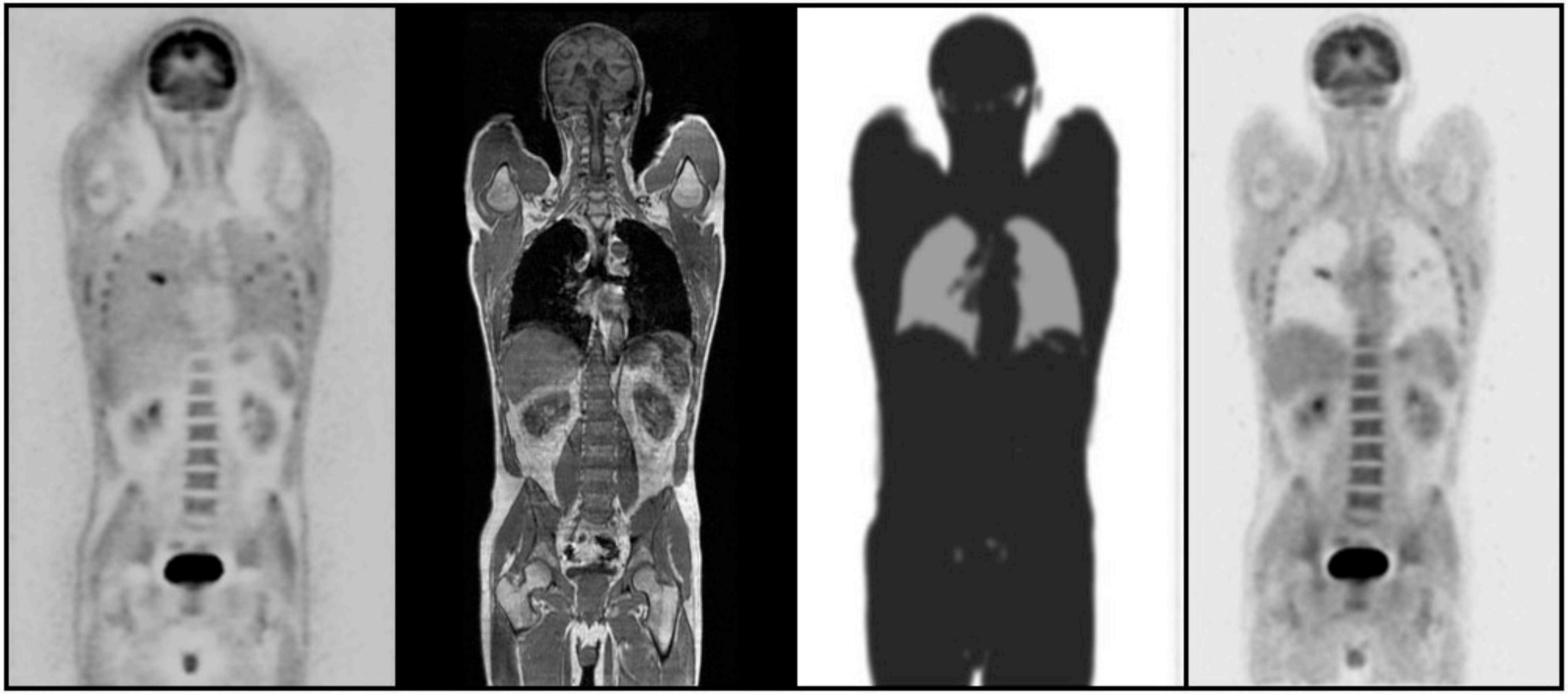


Work in progress

Better attenuation correction

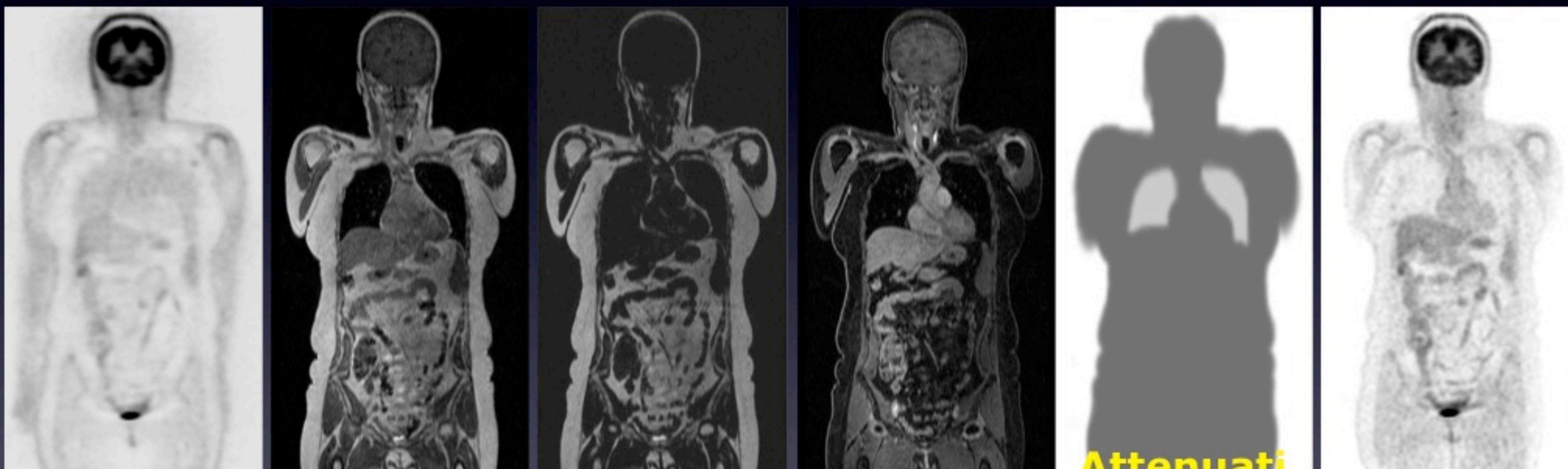


Uncorrected PET | Whole body MRI | Attenuation Mask | Corrected PET

Courtesy Susanne Heinzer

Work in progress

Better attenuation correction



Uncorrected

DIXON in phase

DIXON fat

DIXON water

Attenuation map

Corrected

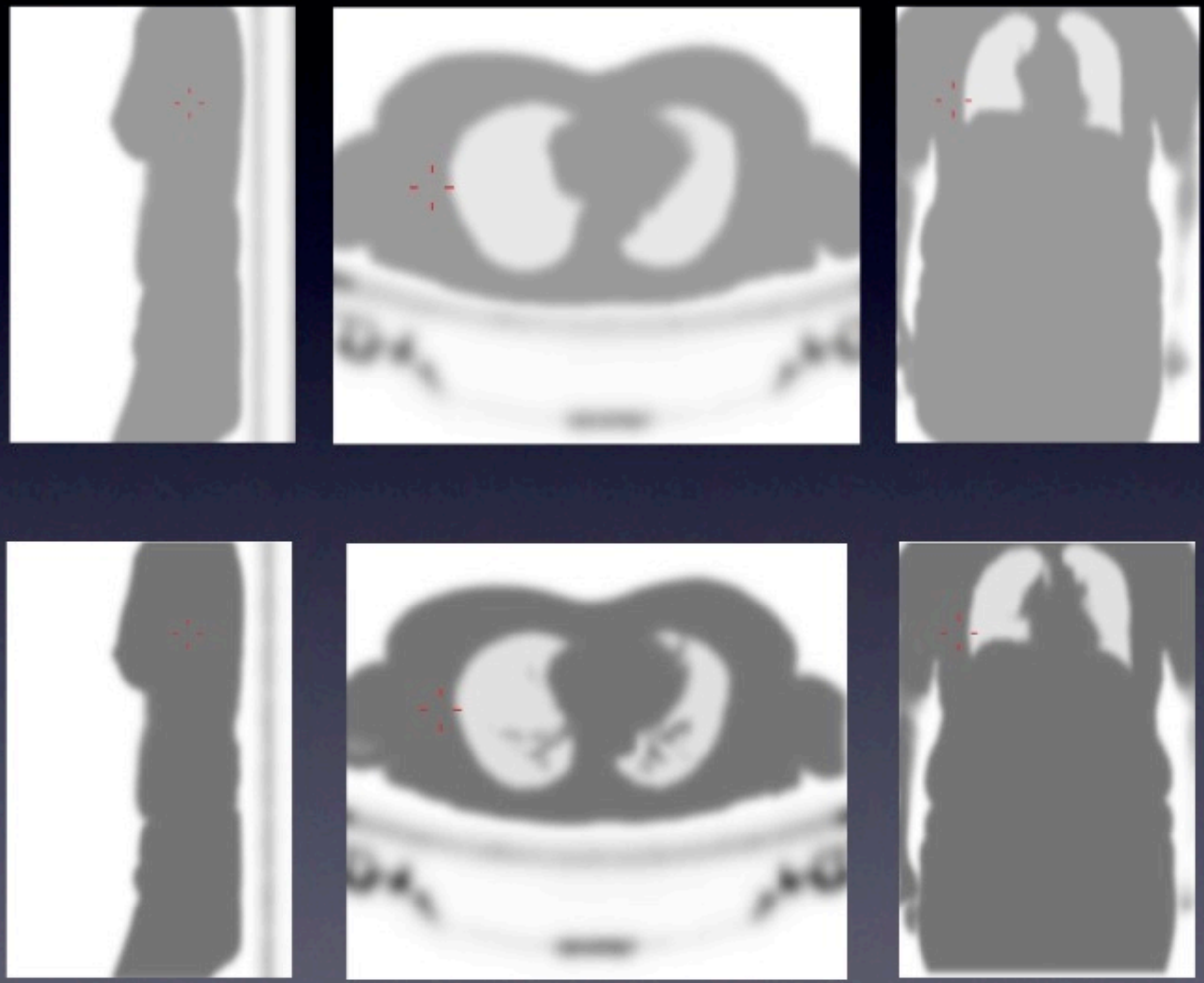
Courtesy Susanne Heinzer

Work in progress

Better attenuation correction

Standard MRAC:

Dixon:



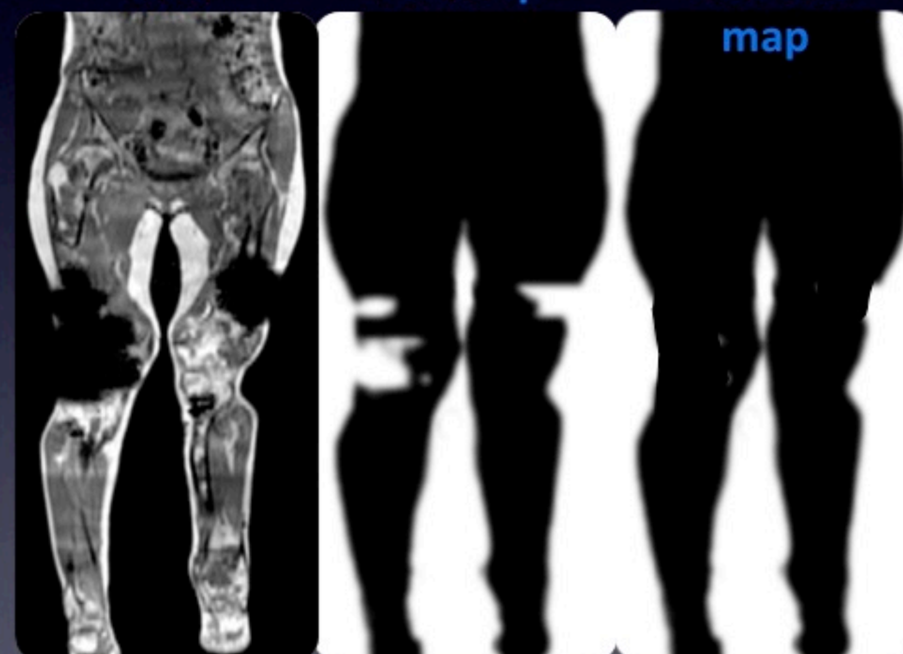
Courtesy Susanne Heinzer

Work in progress

Better attenuation correction

Corr truncation

MR | Att map | Corr Att map



Courtesy Susanne Heinzer

HUG

Conclusion

Clinical applications of hybrid PET-MR

Conclusion

Clinical applications of hybrid PET-MR

- **No killer application** where PET-MR can provide solution that cannot be obtained today with PET-CT and MRI performed separately
- Some routine clinical aplications slowly adopt **PET-MR when patients need both PET-CT and MR** and CT does not add any relevant information
- **Dose reduction** of PET-MR is important but may not be sufficient to justify PET-MR replacing PET-CT in all cases
- Clinical acceptability of PET-MR depends highly on the **quality and performance of the MR component**
- PET-MR will **NOT** replace PET-CT in **all** applications
- The **adoption rate** of PET-MR seems to grow faster than initial adoption of PET-CT when it was first introduced

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+consider costs, work flow, etc...