POSITRON EMISSION TOMOGRAPHY

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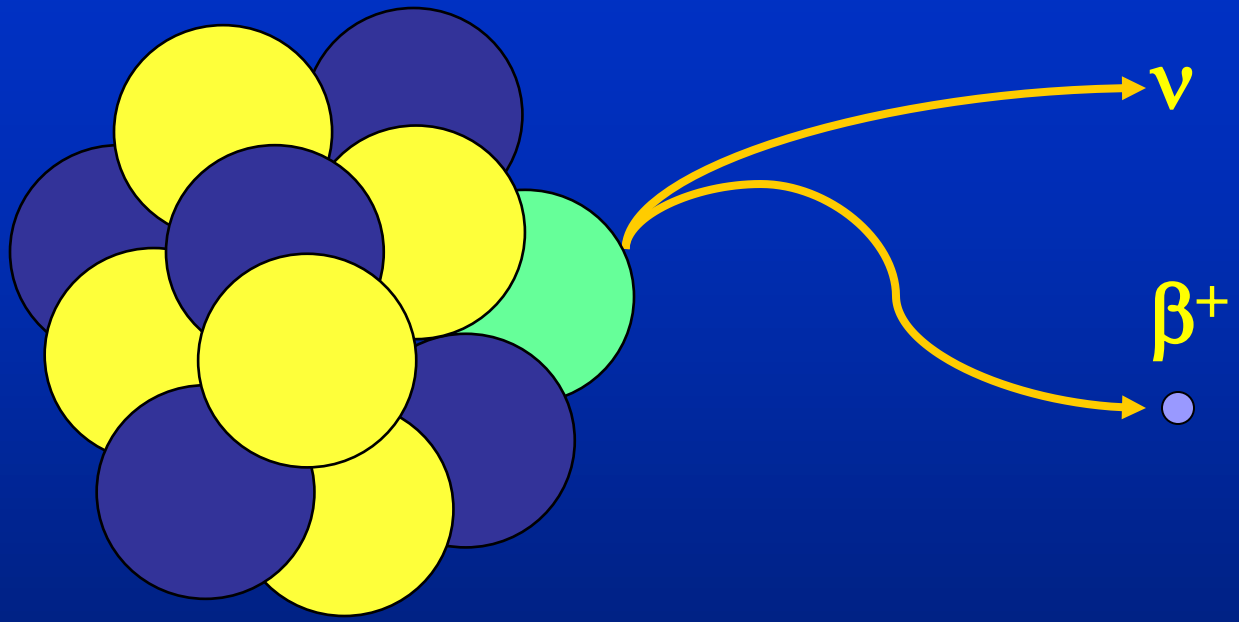
History of PET

- 1952 - first PET system - Brownell, Aronow
- 1962 – firts more-detectors system
- 1968 - first PET tomography system (PC I)
- 1971-6 first PET commercial system (PC II)
- 2001 first commercial PET/CT scanner
- 2010 first commercial PET/MRI scanner

Princip Of PET

β + emission

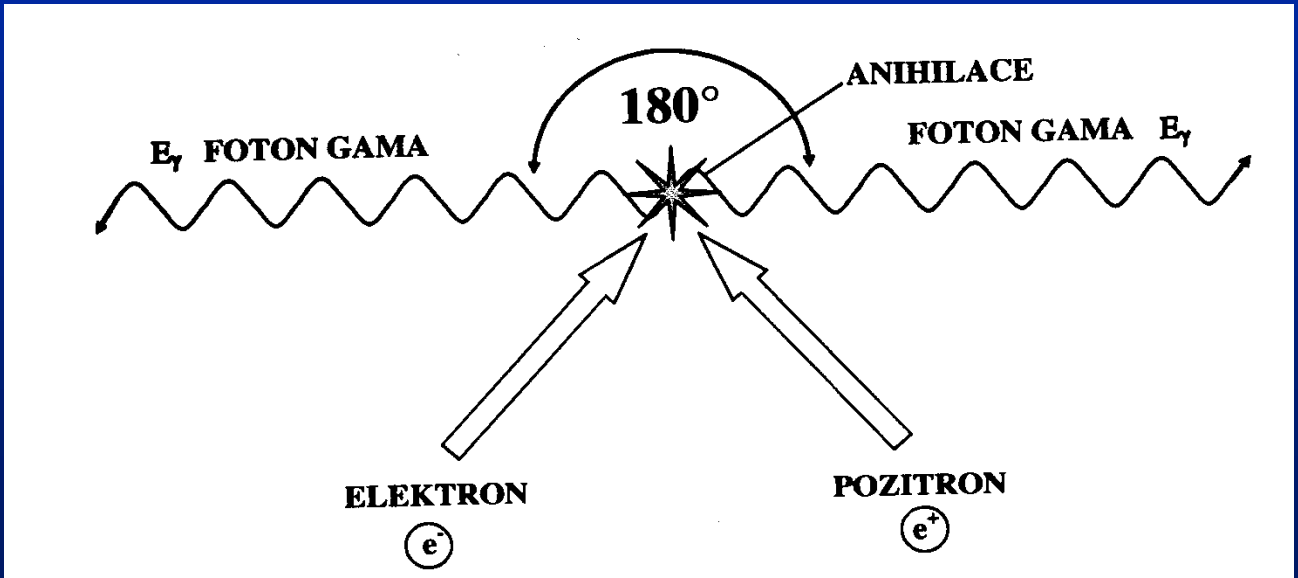


$^{11}C \rightarrow {}^{11}B$

Proton ⟶ neutron + positron (β^+) + neutrino(ν)

Beta emission

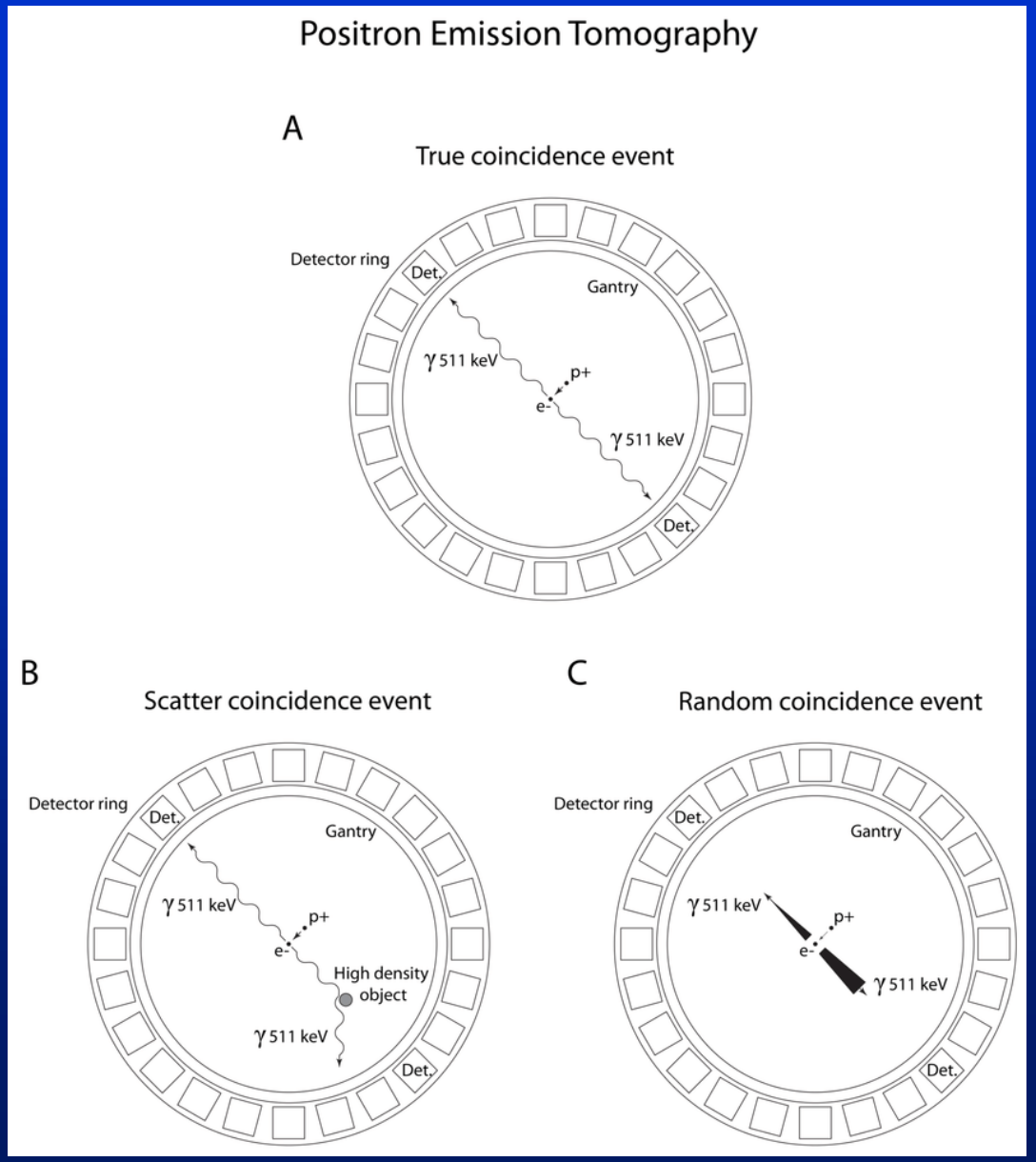
Beta^{+} - reaction positron with electron – positron annihilation – two amounts of gama radiation (energy 511 keV)



Positron emission tomography – PET camera

- Imaging: two detector elements on opposite sides of the subject are used to detect paired annihilation photons(gama radiation)
- 20 000 detectors in ring, 30 rings
- Detector materials: BGO (bismuth germanate) or LSO (luteciumortosilicate), APD –avalanche photodiode detector
- Electronic collimation – opposite coincidence window 10 nanosec.
- Superior sensitivity and spacial resolution that SPECT – 3D scintigraphy

PET possible types of detection



Radiopharmaceuticals

radionuclide – ^{11}C (half time -20 min) ,^{68}Ga (67 min), ^{15}O (123 sec), ^{18}F (110 min)

Ligand – body substances, most common FDG (fluorodeoxyglucose)

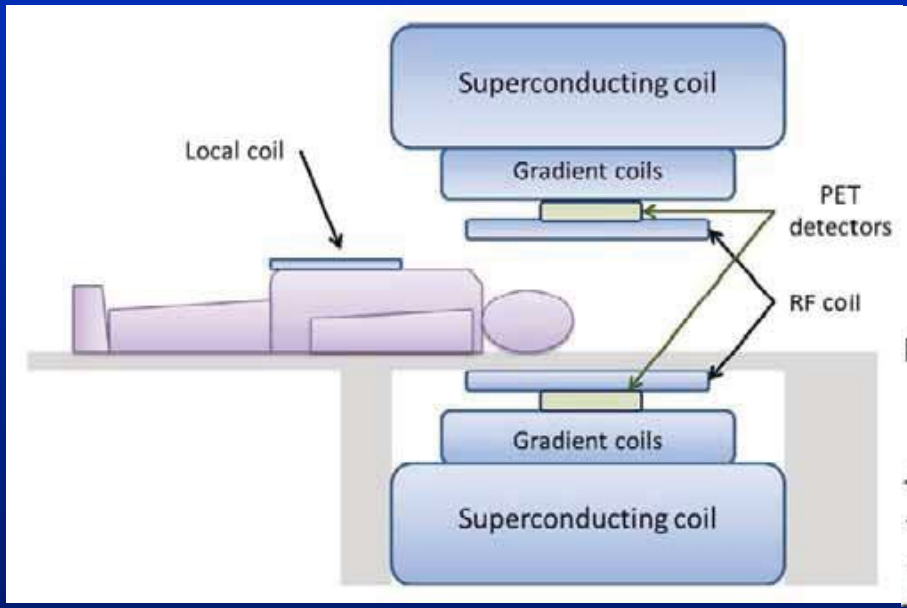
- 18FDG – aerobic glycolysis
- 18FLT – fluorothymidin - – cell proliferation
- Na18F - fluorid sodný – bone renewal
- 18Fcholin, 18F Fluciklovin, 68GA PSMA – Prostatic cancer
- 18FDOPA, 68Ga DOTA – NET
- 18Fflutemetamol – Alzheimer disease

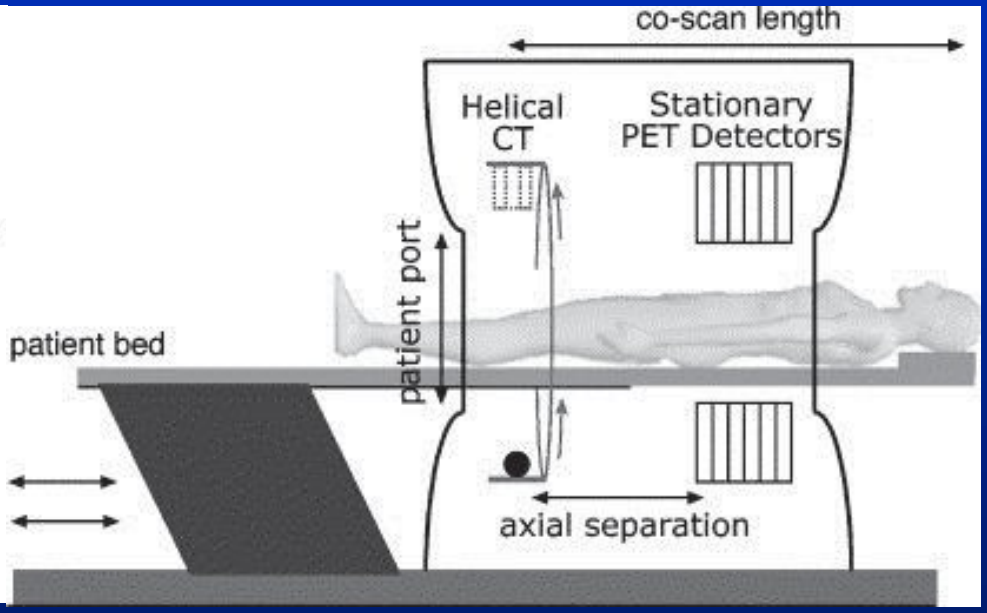
Hybrid systems

- Camera system piles from two independent systems – scintigraphy camera and CT or MRI scanner

- Fusin pictures from both systems – information on function organ gained scintigraphy methods are inosculation with anatomical photos from CT or MRI

PET/MR/CT





PET/MR

PET/CT

Imaging protocol PET/CTx PET/MRI

Patient

- Fast 4 hrs prior to exam
- Inject tracer
- Start scan 60 min later

PET/CT - 20min

PET

- Brain (10 min)
- Heart (10 min)
- Body (20 min)

CT

- Topogram (scout)
- CT scan (1 min)

PET/MRI – 40 – 60 min

PET

- 15 min

MRI

- First part simultaneously during PET scanning (T1, T2 and DWI)

- second part after PET scanning – other needed sequences (25-40 mins)

ADVANTAGES PET

- Skull to mid thigh in 15 mins.
- Functional imaging
- High sensitivity
- No adverse reaction in last 30 years

PETxSPECT

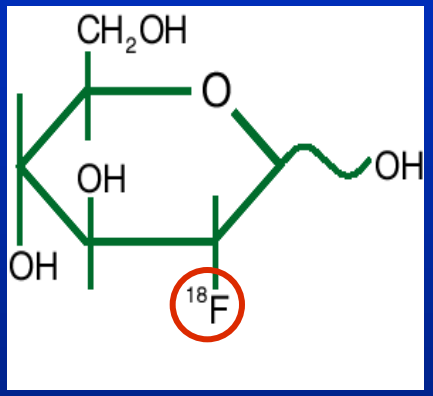
- As well three-dimensional vision as with SPECT – 3D scintigraphy
- 30x higher sensitivity than SPECT
- Better resolution than SPECT
- Possibility of quantification of radiofarmaceutical

Advantages and disadvatages PETMR x PETCT

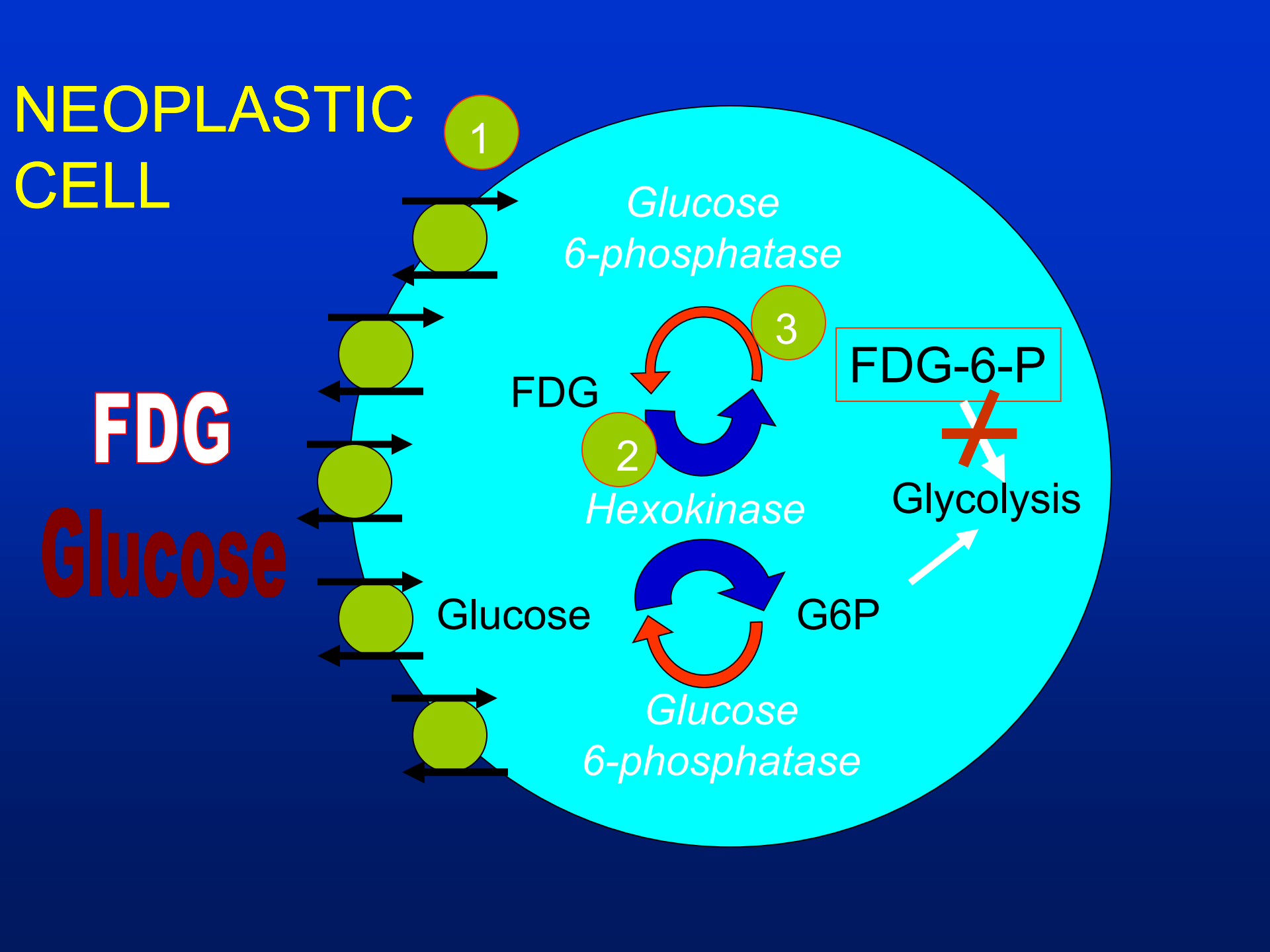
- Advantages:
  - No radiation load x CT
  - PETCT – mean dose 5 - 23 mSv, PET 3-5 mSv
  - Excellent tissue contrast MR
  - Possibility to combine with more advanced techniques such as perfusion, DWI, angiography, spectroscophy

- Disadvantage:
  - the length of the examination
  - basic MRI contraindications

Most common PET Tracer: FDG



18F-fluorodeoxyglucose (FDG) is taken up by cells proportionate to their metabolic rates


NEOPLASTIC CELL
FDG
Glucose
1
Glucose 6-phosphatase
3
FDG
FDG-6-P
2
Hexokinase
Glycolysis
Glucose
G6P
Glucose 6-phosphatase

Indication

- Oncology (staging, control of treatment effectiveness, monitoring after treatment)
- Inflammation (investigation of inflammation origin, vasculitis, sarcoidosis, inflammation of the heart, suspected inflammatory changes around implanted foreign materials
- Rheumatology (eg polymyalgia)
- Cardiology - myocardial viability
- Endocrinology (detection of hyperfunctional parathyroid glands)
- Non-tumorous pathology of CNS (Neurodegenerative diseases)

Problems and Pitfalls

- False negative findings

  Tumor histology(renal carcionoma)

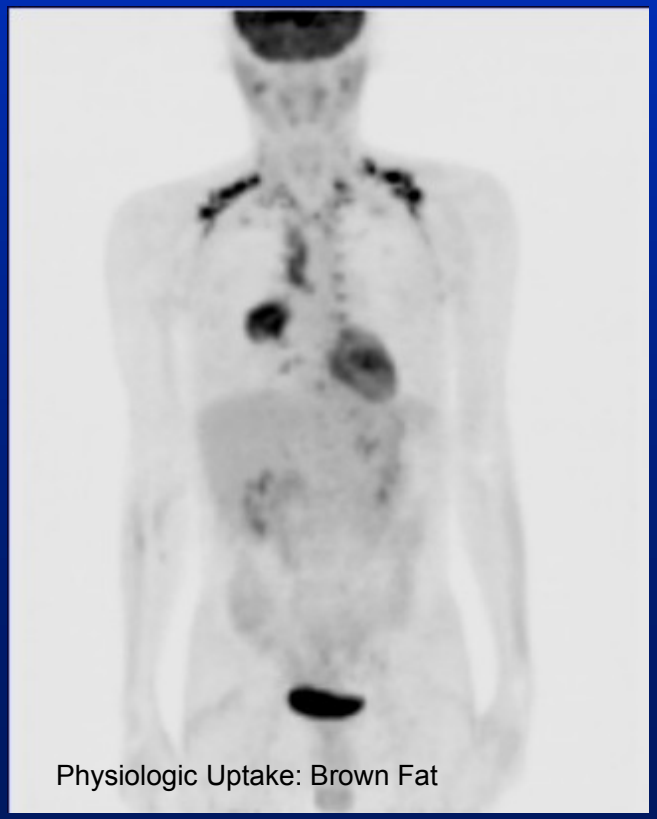
  Lesions smaller than 6-8 mm

  Diabetes/Non-fasting patients

- False positive findings

  Normal physiology

  Granulomas and other infections



Physiologic Uptake: Brown Fat

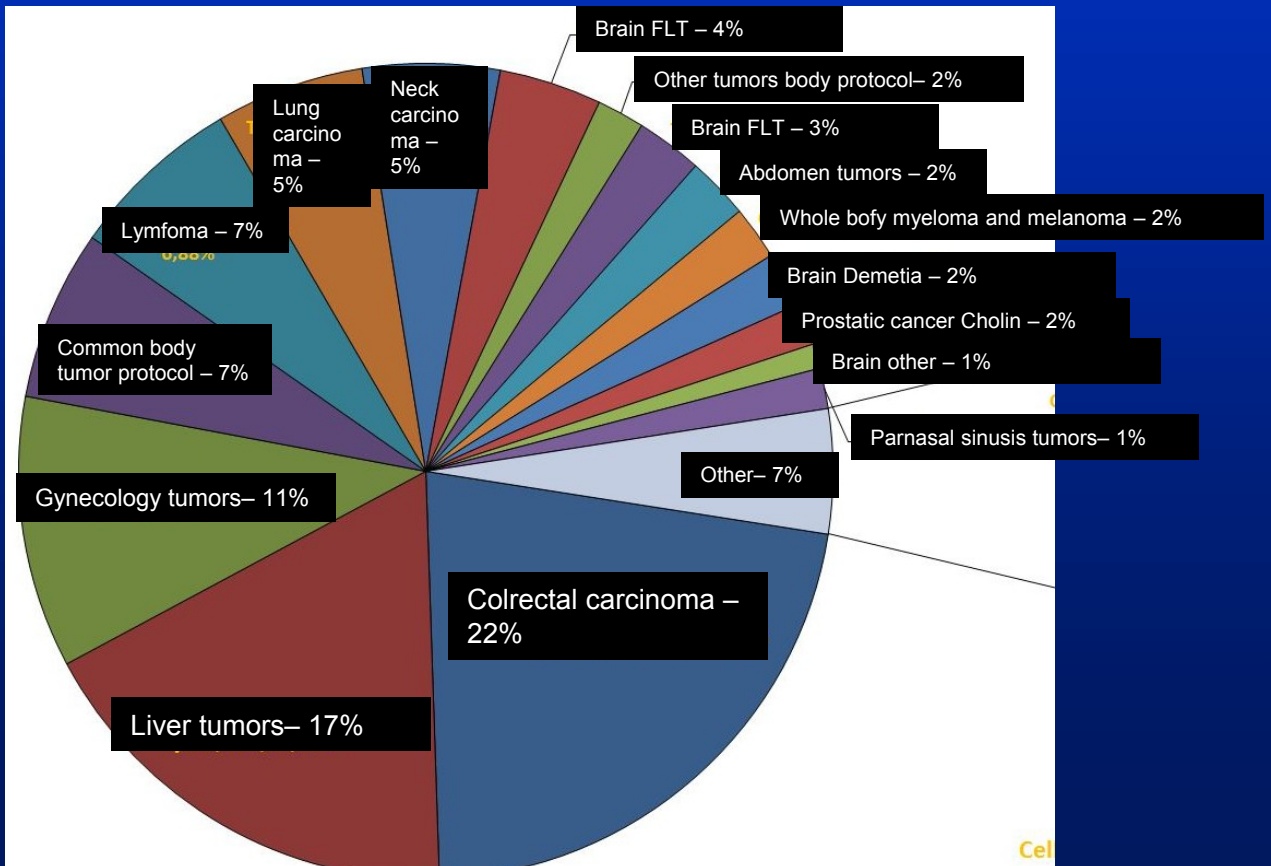
- Effective chemotherapy decreases FDG accumulation in tumor cells.
- The longer time distance PET / CT examinations from CHT - the higher the sensitivity of the method (recommended at least two weeks)
- Evaluation of FDG-PET in the irradiated area can be exacerbated by several months (the gap is suitable PET / CT examination by RT 3 months)

PET/MR on our department

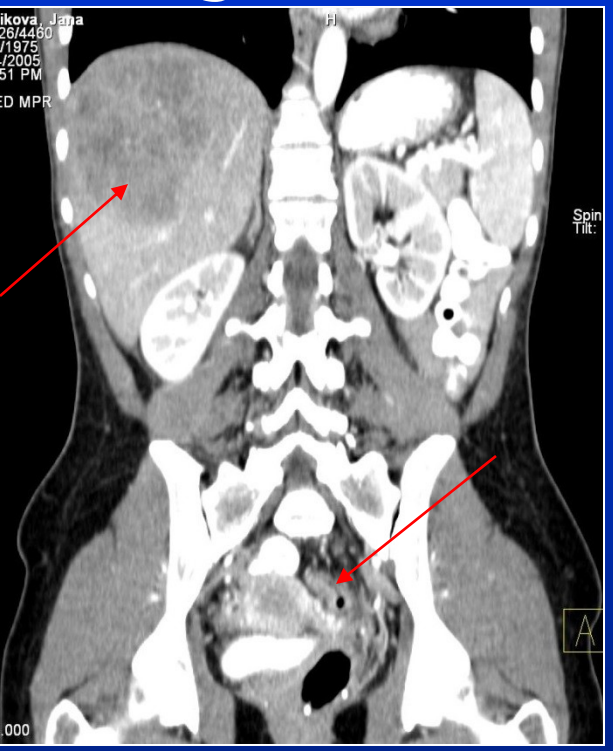
- Instalation: June 2016

  2016 – 111 patients 2017 – 858 patients

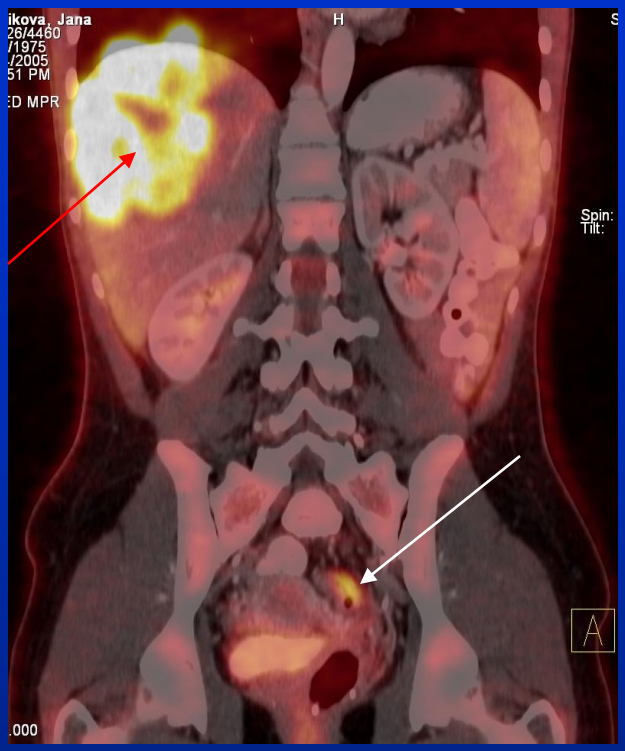
  2018 – 1389 patients



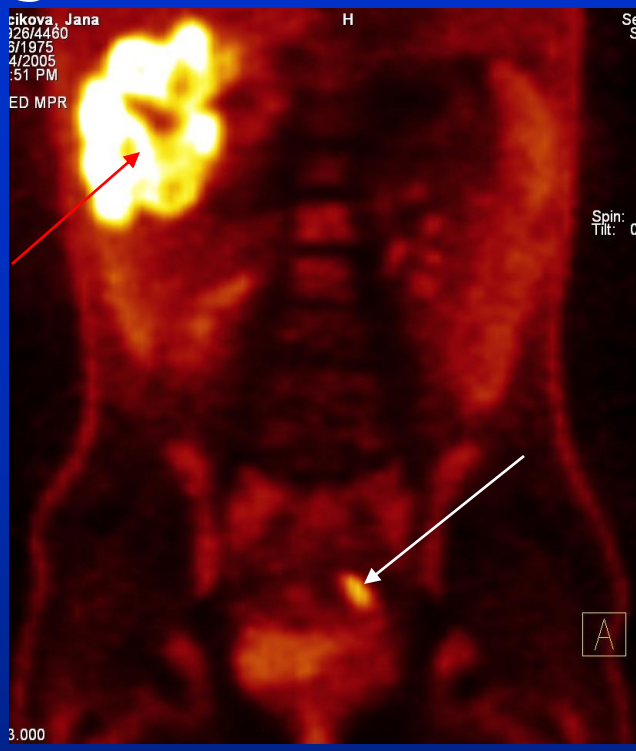
Big metastasis in liver, unknown origin



CT



PET/CT

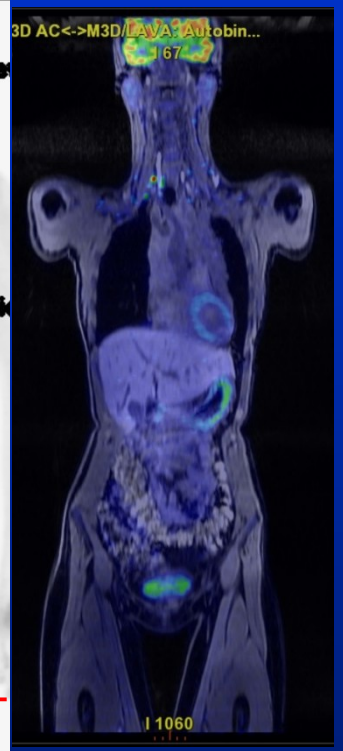


PET

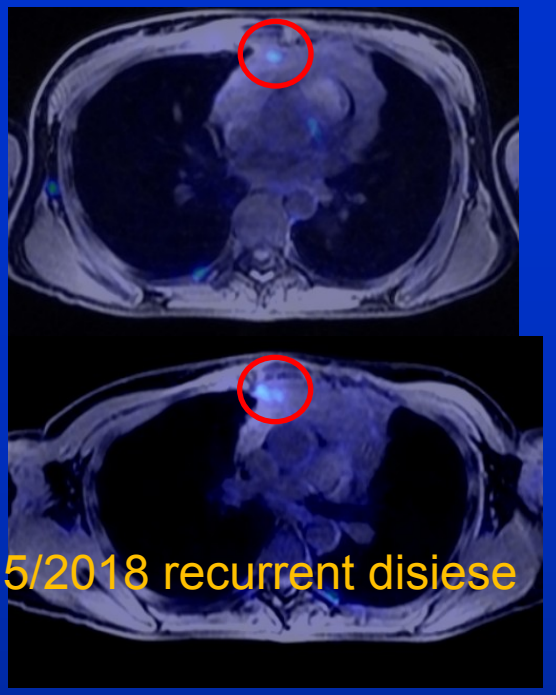
PET/CT – origin tumor Of colon

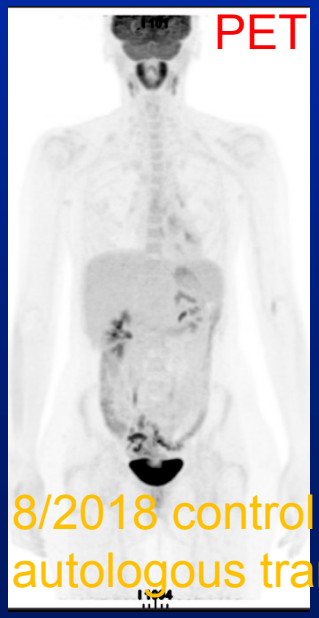
88* female

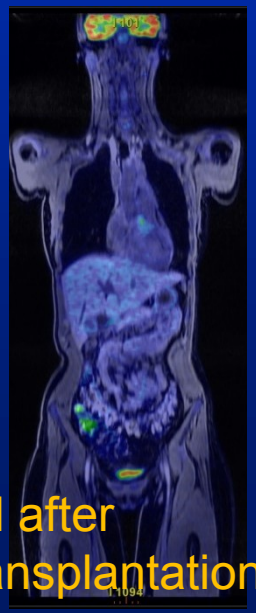
- non hodgkin lymphoma



3/2018 after treatment
- Complete regresion



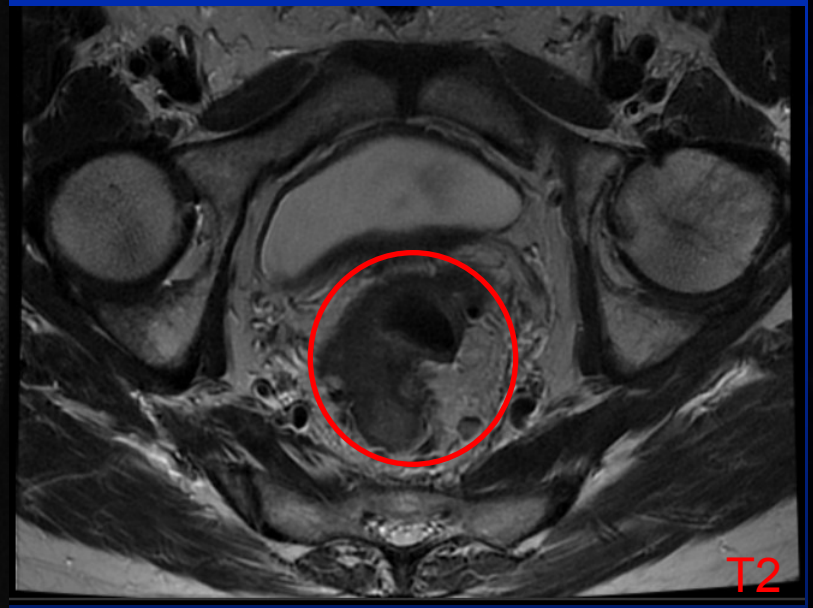


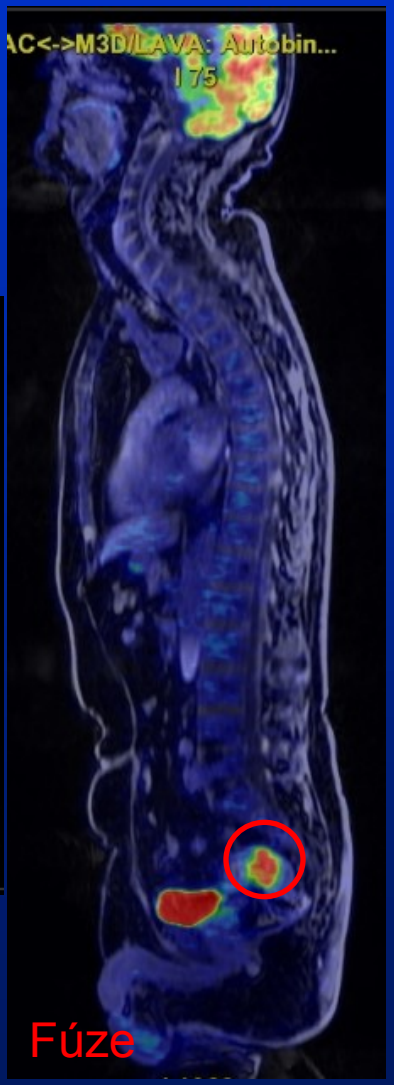


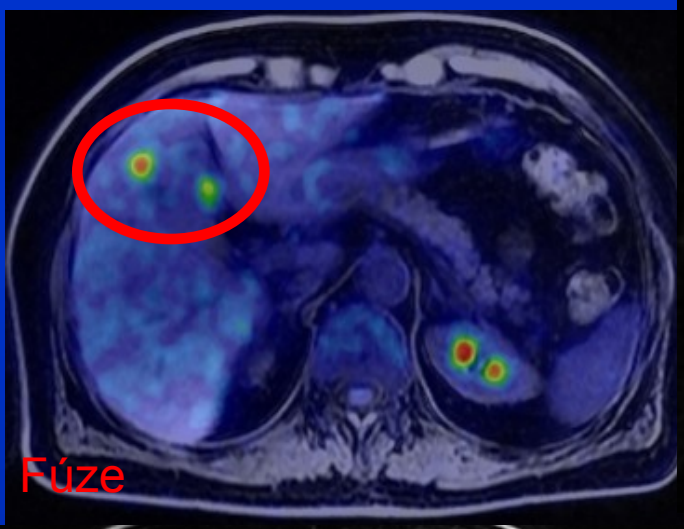
8/2018 control after autologous transplantation

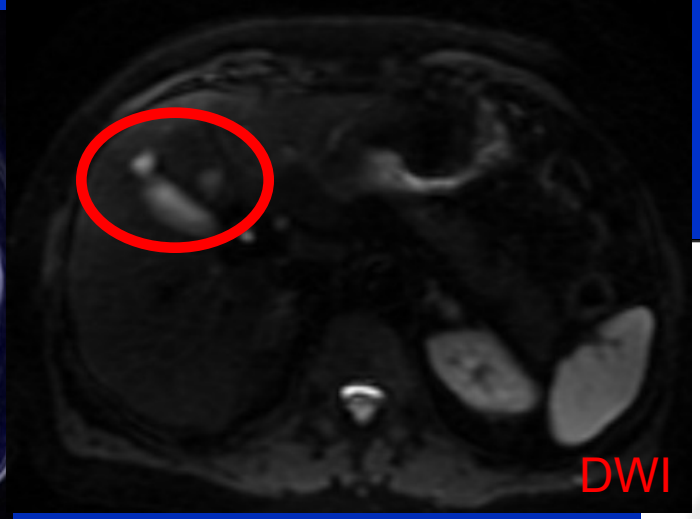
54* male

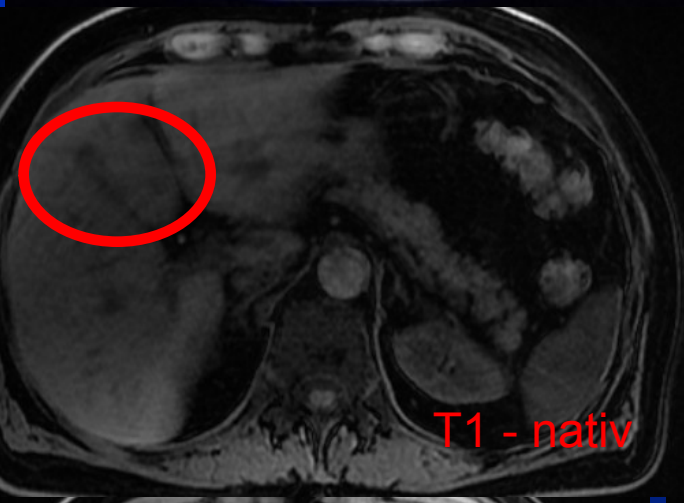
- Difficulty with emptying
- rectoscopically in 12 cm tumor infiltration

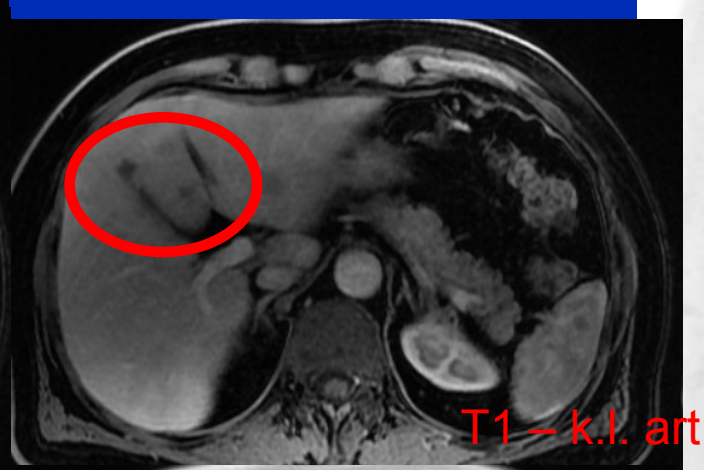




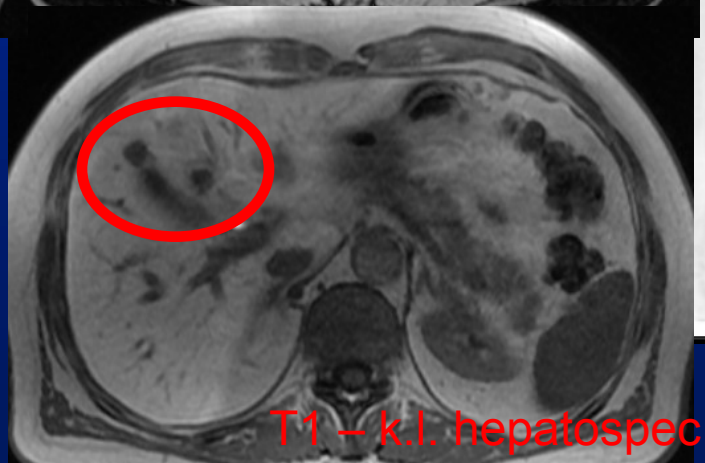

Fúze

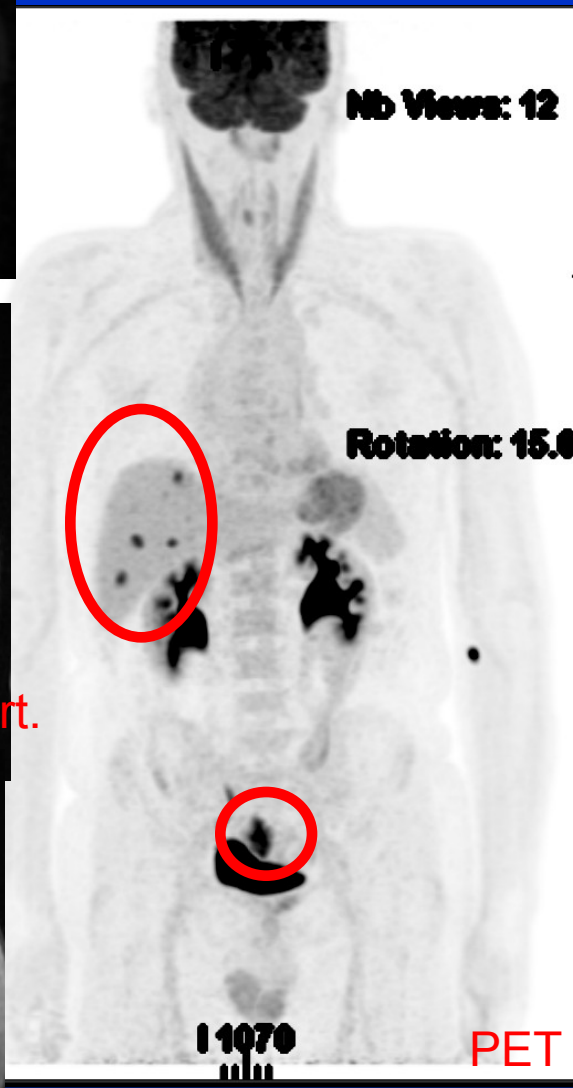

DWI


T1 - nativ


T1 – k.l. art.

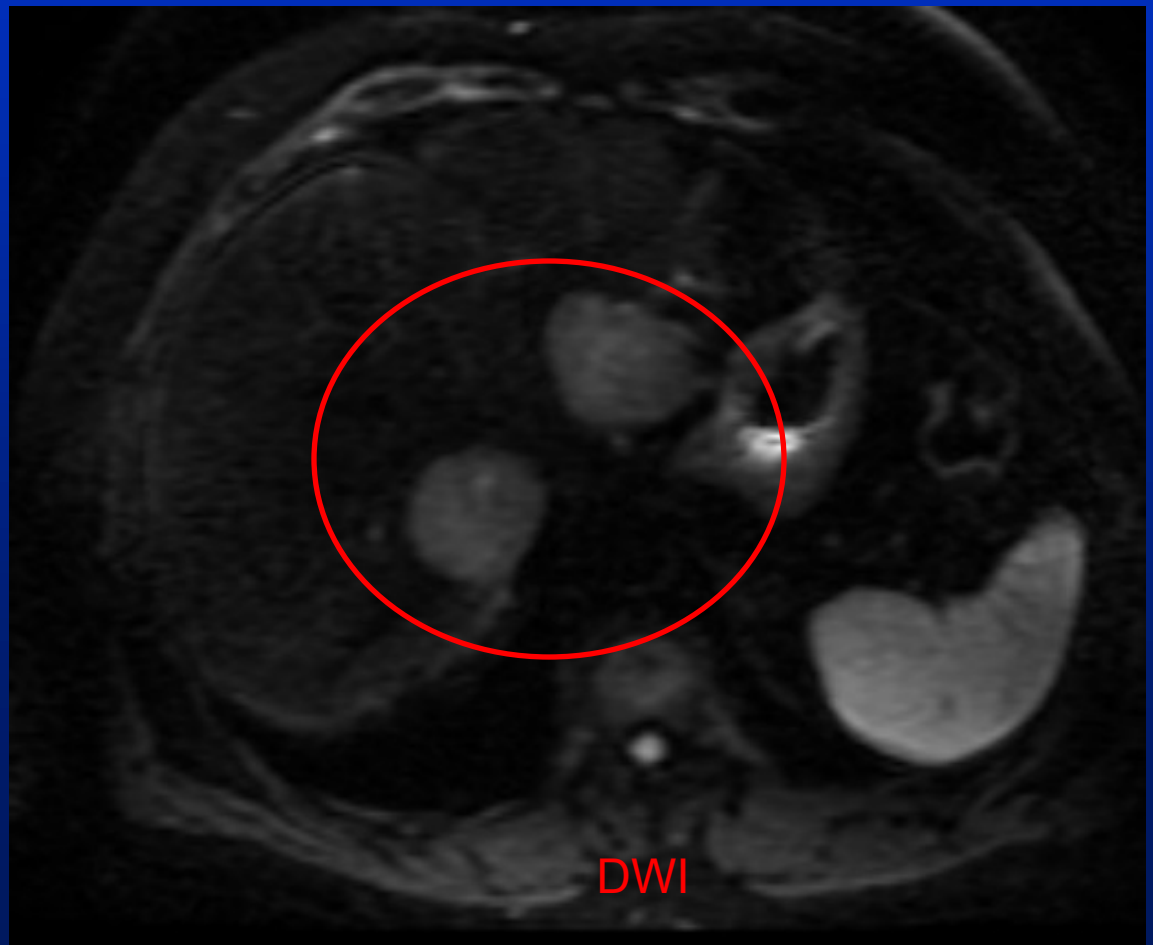

T1 – k.l. PV

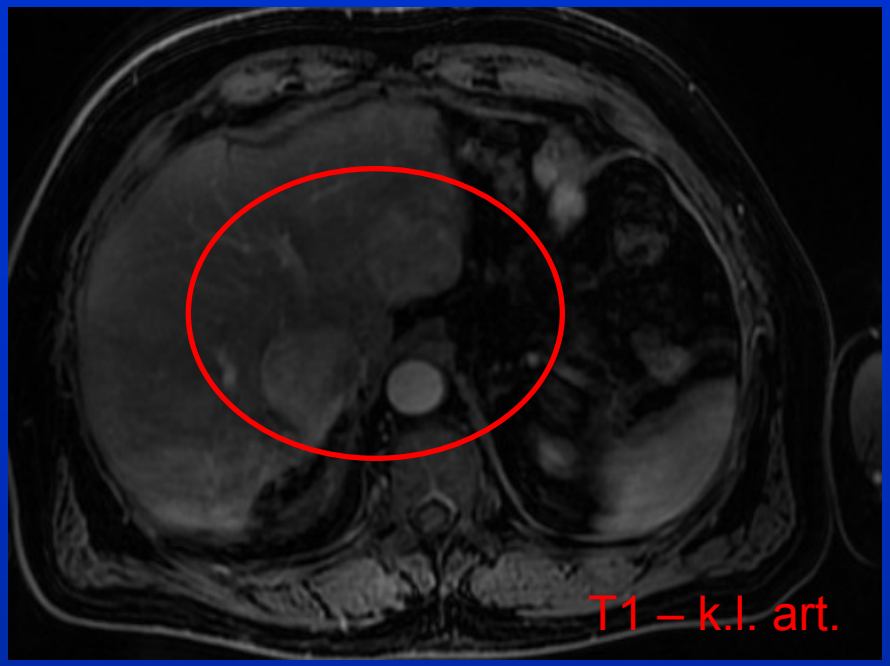

T1 – k.l. hepatospec.

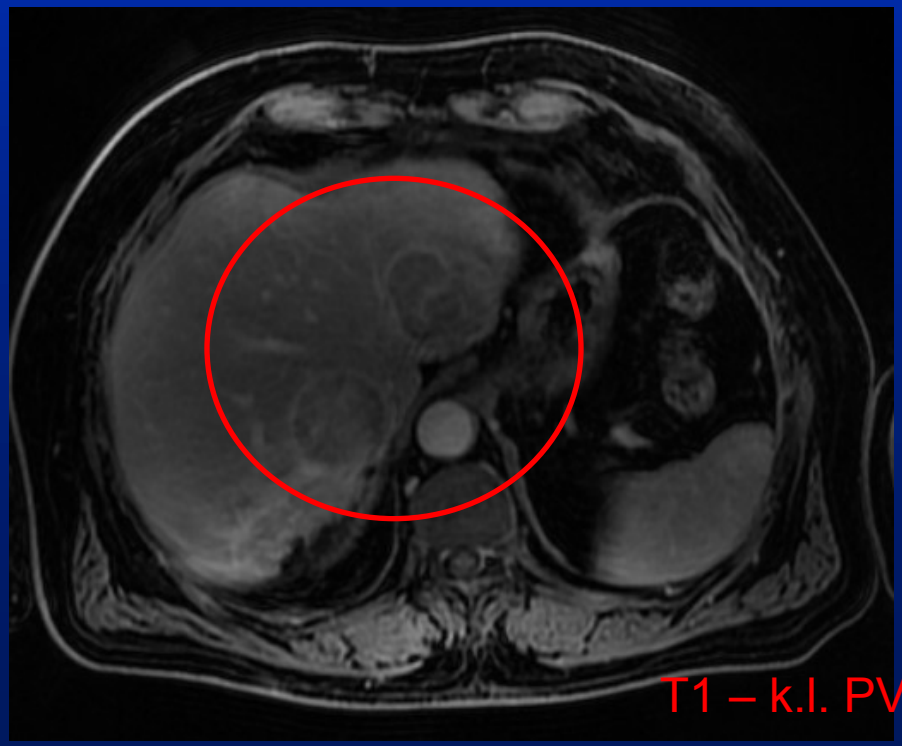

Nb Views: 12
Rotation: 15.0
I 1070
PET

48* male 18F Cholin

- Hepatocelular carcinoma – grade 1



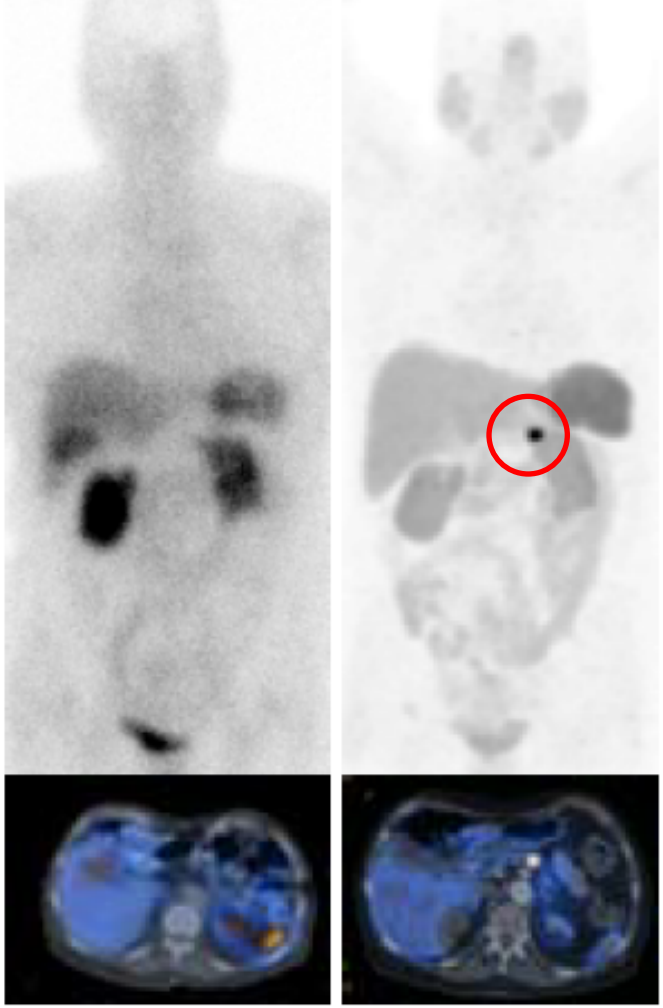

T1 – k.l. art.


T1 – k.l. PV


PET

Octreo-SPECT vs Ga68 DOTATOC

SPECT - Octreotid PET – 68GA DOTA

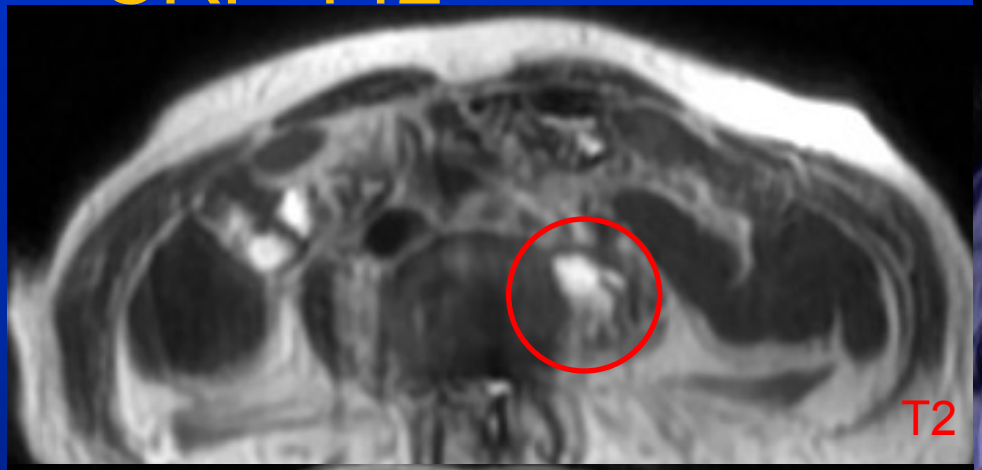


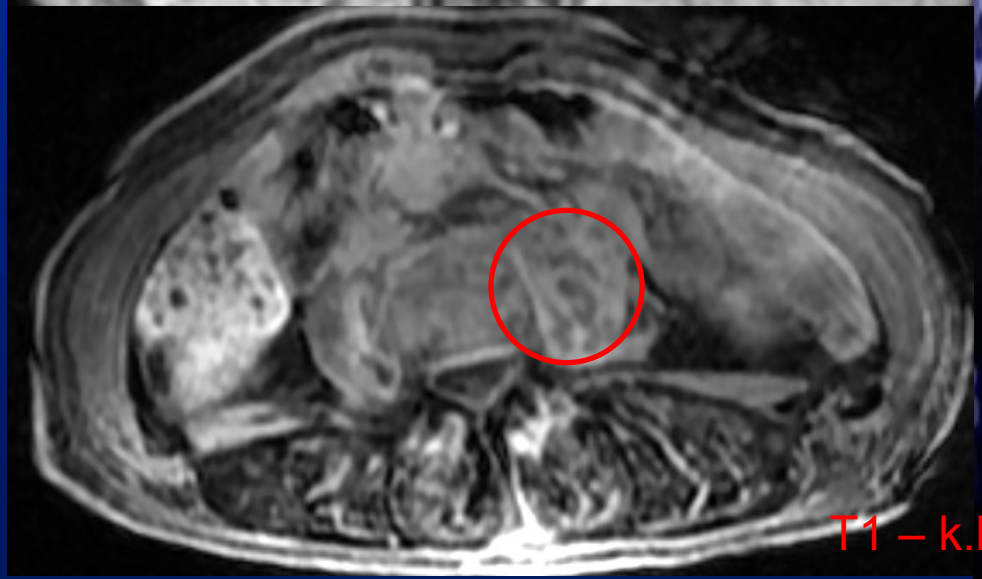
Parameter	PET (%)	SPECT (%)	CT (%)
Sensitivity	97 (69/71)	52 (37/71)	61 (41/67)
Specificity	92 (12/13)	92 (12/13)	71 (12/17)
Accuracy	96 (81/84)	58 (49/84)	63 (53/84)

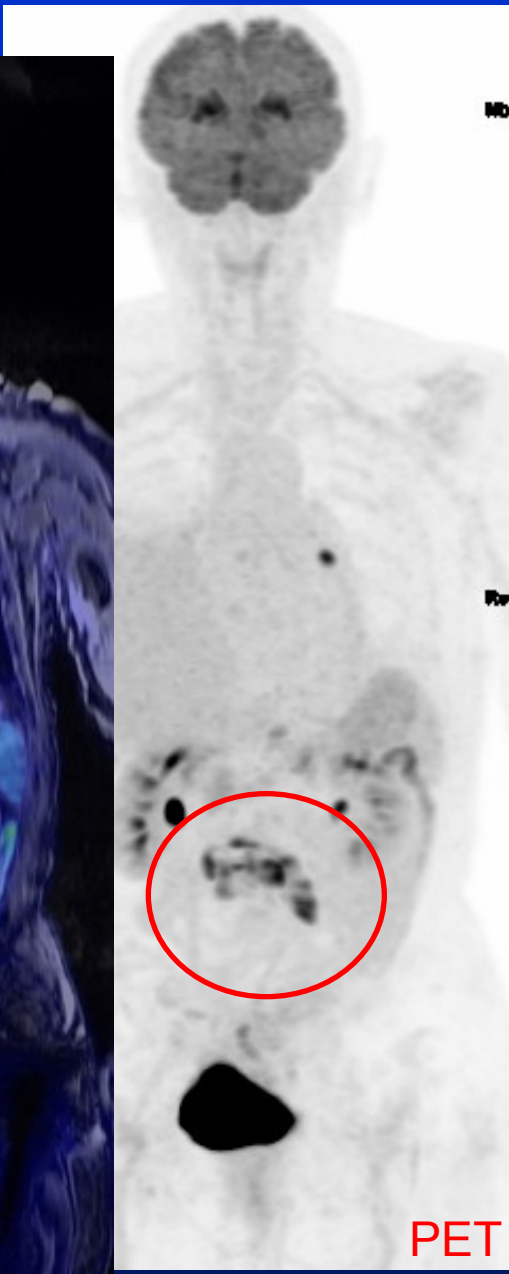
Gabriel et al. 68Ga-DOTA-Tyr3-Octreotide PET in Neuroendocrine Tumors: Comparison with Somatostatin Receptor Scintigraphy and CT. JNM 2007

female 40*

- Febrile state of unclear etiology
- CRP 142

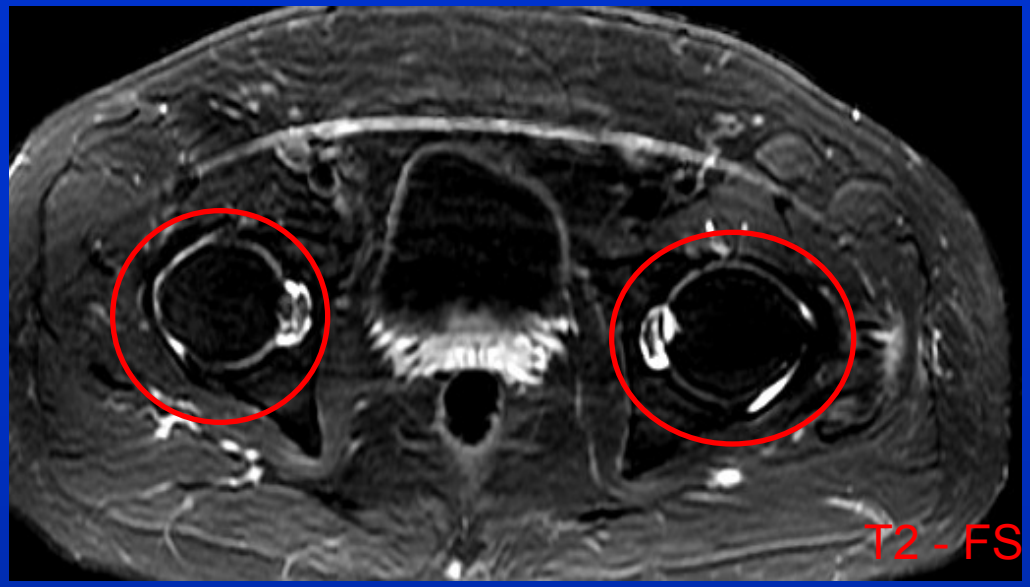


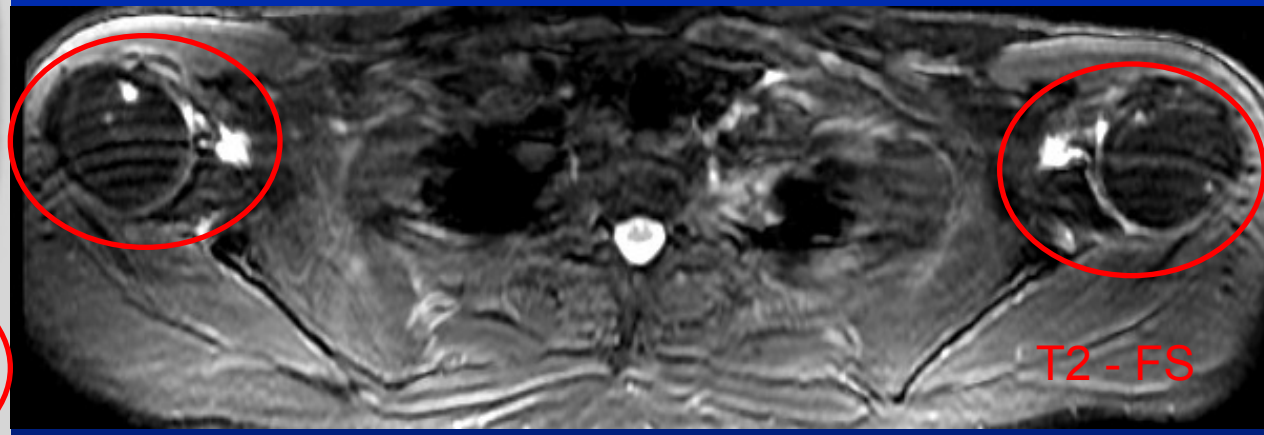




64* - muž

- Prolonged myalgia
- Swelling and stiffness of tiny joints of the hand
- CRP elevation
- polymyalgia rheumatica x vasculitis

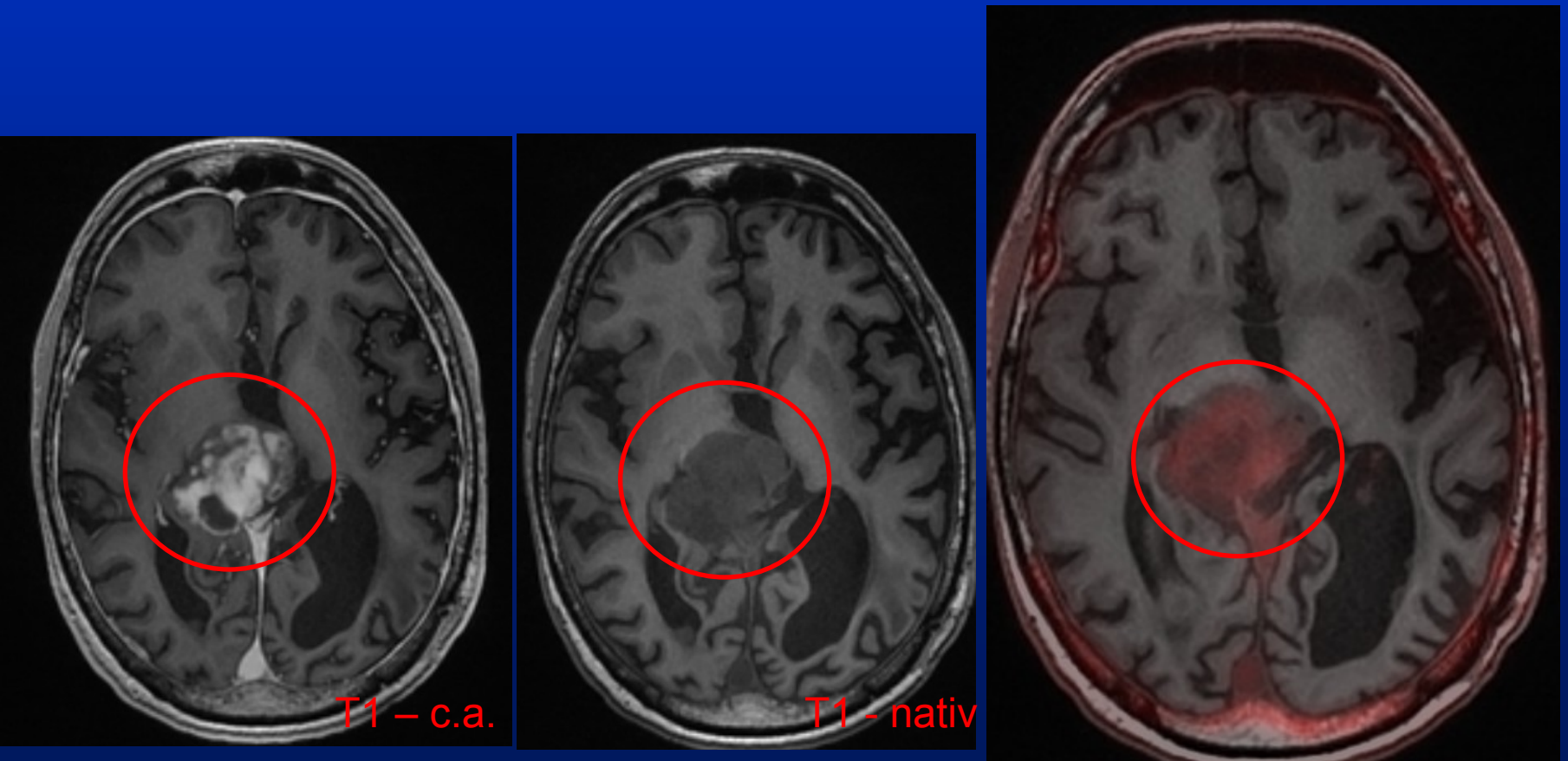




- Two-sided symmetric picture of inflammatory changes of joints and muscle insertions (metabolic activity in the area of the joint capsule + intraarticular effusion

18FLT – male 99*

- Pilocytic astrocytoma of mesencephalon



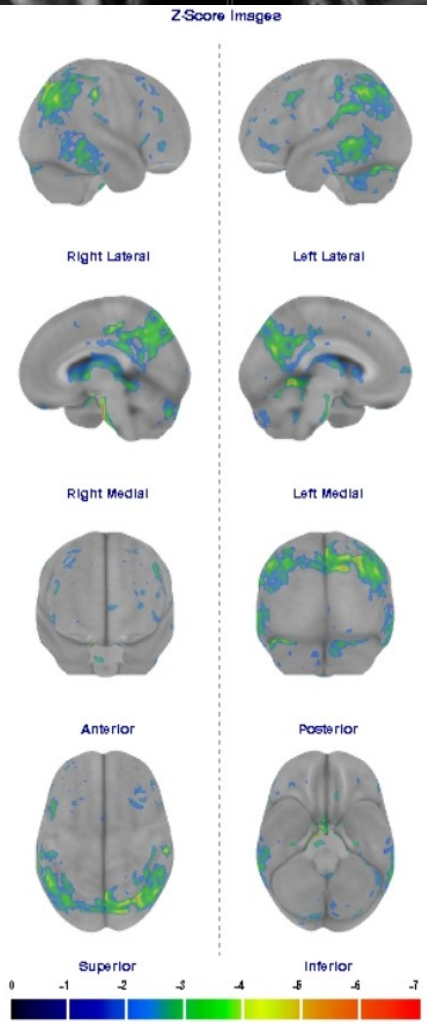
Typical PET / MR image of Alzheimer's dementia

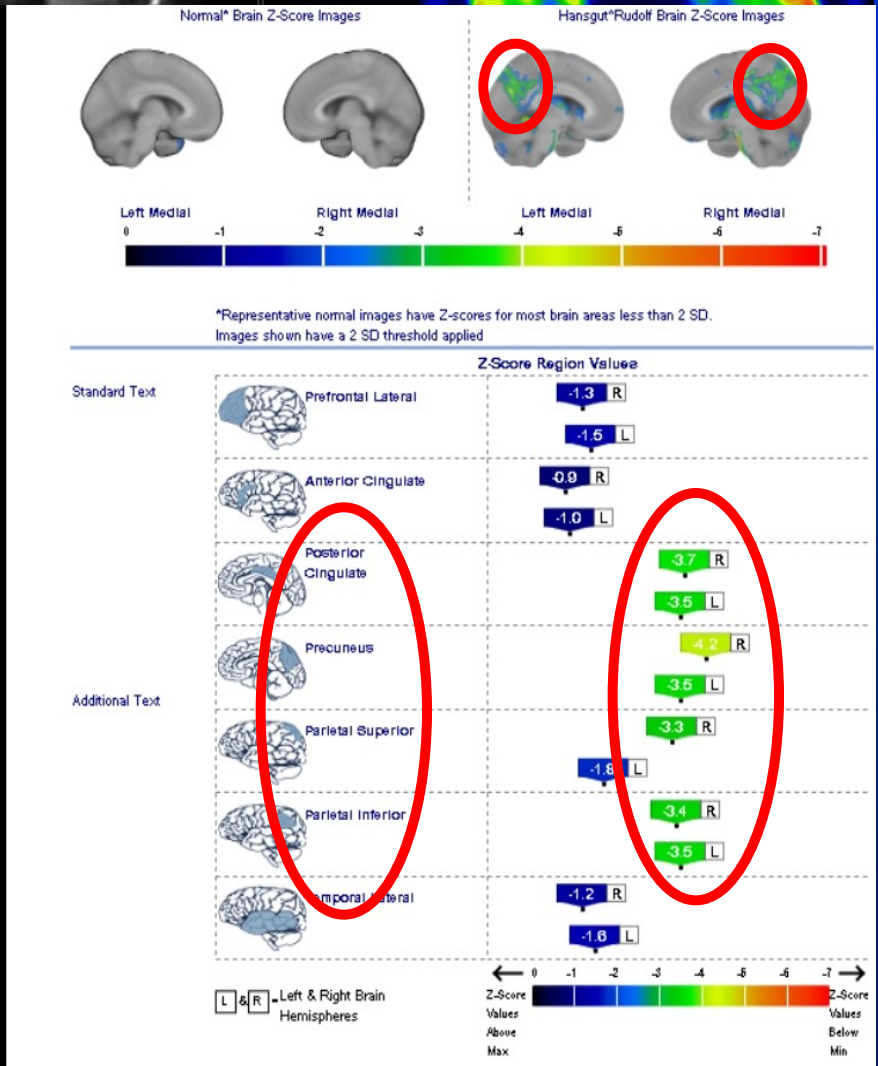
Mutually symmetric atrophy and hypometabolism of parietal lobes (especially precuneus)

Later bilateral mediotemporal atrophy and hypometabolism

There is no reduction in metabolism in the basal ganglia

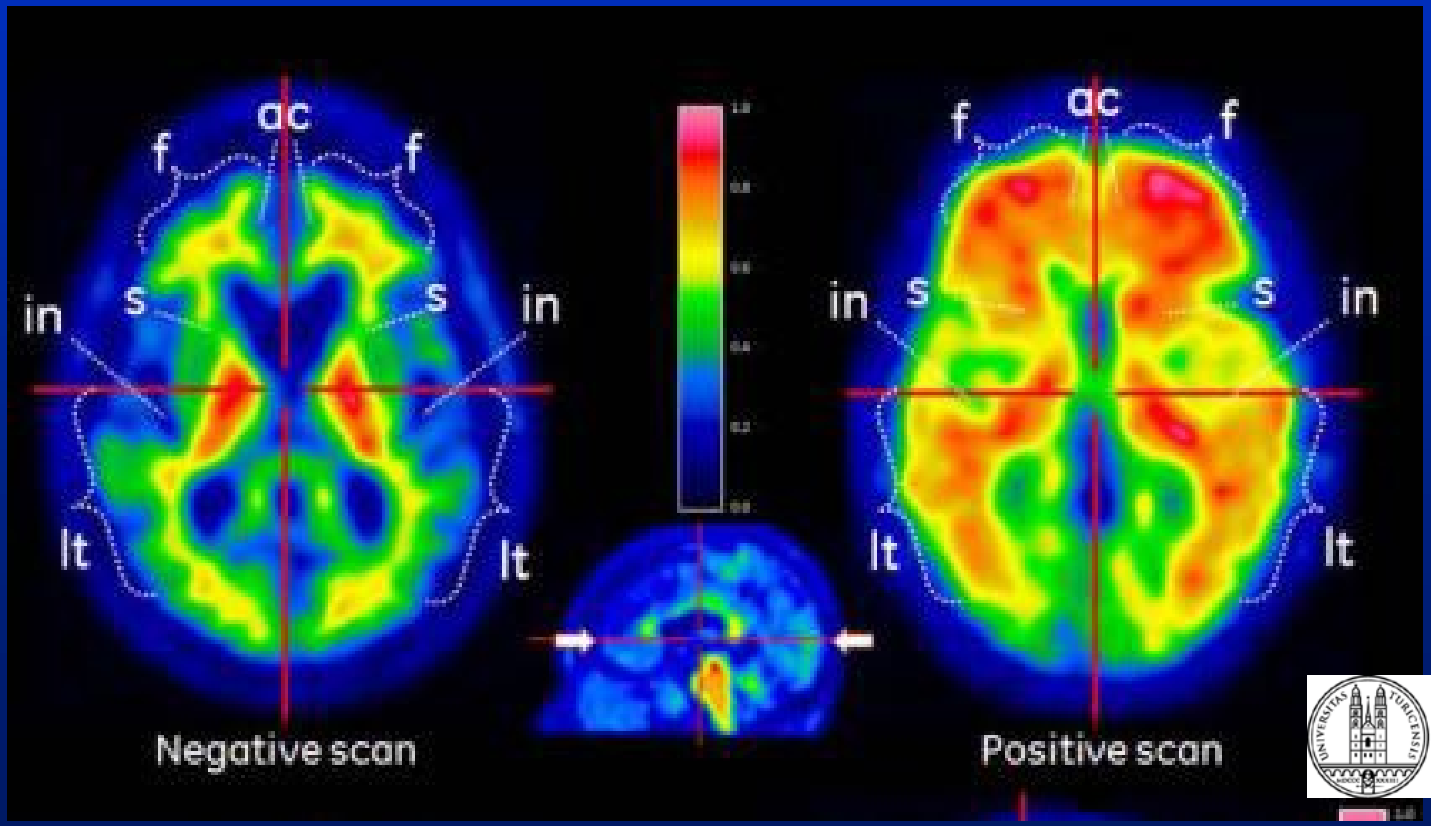
Region	Uptake Ratio	Z-Score
Prefrontal Lateral R	1.33	-1.29
Prefrontal Lateral L	1.29	-1.49
Prefrontal Medial R	1.32	-0.37
Prefrontal Medial L	1.26	-1.00
Sensorimotor R	1.48	0.38
Sensorimotor L	1.47	0.14
Anterior Cingulate R	1.08	-0.85
Anterior Cingulate L	1.09	-0.99
Posterior Cingulate R	1.03	-3.66
Posterior Cingulate L	1.07	-3.51
Precuneus R	1.14	-4.15
Precuneus L	1.16	-3.52
Parietal Superior R	1.04	-3.31
Parietal Superior L	1.20	-1.79
Parietal Inferior R	1.05	-3.44
Parietal Inferior L	1.00	-3.53
Occipital Lateral R	1.27	-1.91
Occipital Lateral L	1.32	-1.55
Primary Visual R	1.56	-0.24
Primary Visual L	1.56	-0.32
Temporal Lateral R	1.19	-1.24
Temporal Lateral L	1.14	-1.55
Temporal Mesial R	0.91	-1.83
Temporal Mesial L	0.95	-1.41
Cerebellum Whole	1.14	-1.33
Pons	1.00	0.00
Reference Region: Pons		





18F Flutemetamol

- Detection of β amyloid deposits
- sensitivity 64% specificity 69% (1)
- A negative finding significantly reduces the likelihood that it is Alzhemer's disease or its preclinical stage (1)



(1)Marcus, Charles, Esther Mena, and Rathan M. Subramaniam. "Brain PET in the diagnosis of Alzheimer's disease." *Clinical nuclear medicine* 39.10 (2014): e413.
(2)Martinez, Gabriel, et al. "18F PET with flutemetamol for the early diagnosis of Alzheimer's disease dementia and other dementias in people with mild cognitive impairment (MCI)." *The Cochrane Library* (2017).

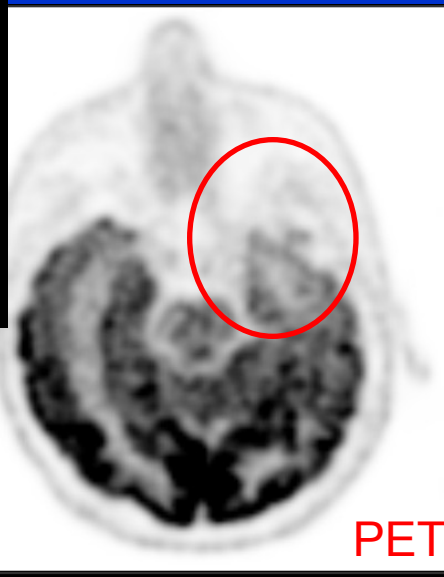
PET / MR image of semantic dementia

Atrophy affects the ventral portion of the temporal

Extension of the temporal corner of the lateral ventricle to the left

Asymmetric atrophy of the left hippocampus

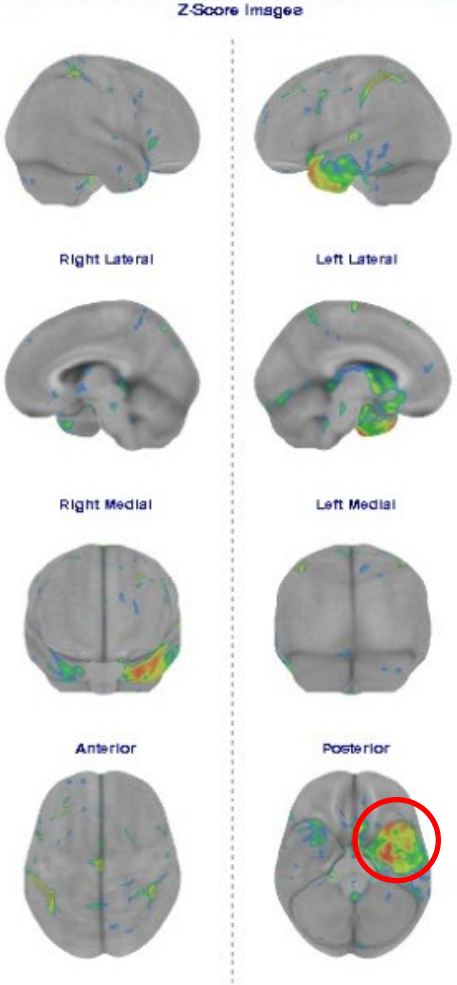
female 44*

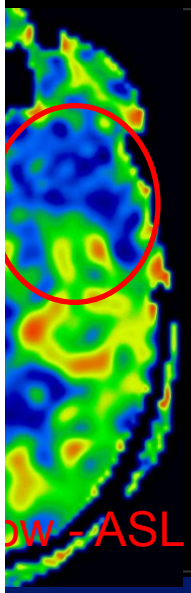


T1

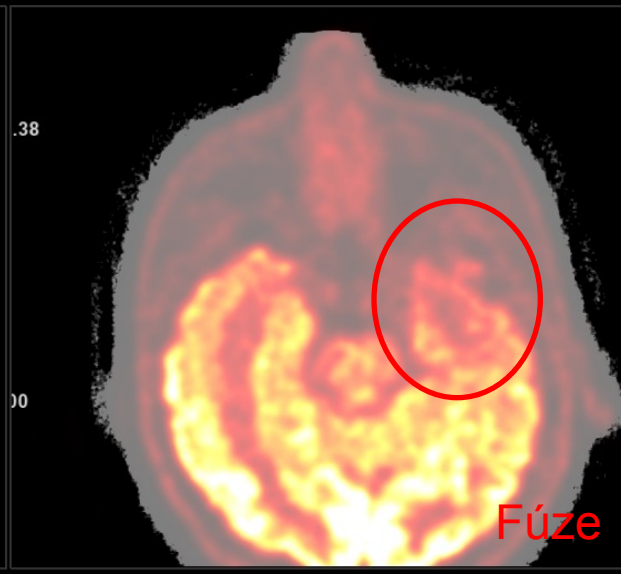
PET

Region	Uptake Ratio	Z-Score
Prefrontal Lateral R	1.43	-0.68
Prefrontal Lateral L	1.38	-1.07
Prefrontal Medial R	1.36	-0.36
Prefrontal Medial L	1.22	-1.67
Sensorimotor R	1.40	-0.62
Sensorimotor L	1.42	-0.49
Anterior Cingulate R	1.16	-0.77
Anterior Cingulate L	1.06	-1.56
Posterior Cingulate R	1.70	0.47
Posterior Cingulate L	1.63	-0.02
Precuneus R	1.56	-0.49
Precuneus L	1.56	-0.36
Parietal Superior R	1.26	-1.22
Parietal Superior L	1.27	-0.99
Parietal Inferior R	1.41	-0.45
Parietal Inferior L	1.22	-1.92
Occipital Lateral R	1.49	-0.41
Occipital Lateral L	1.55	0.13
Primary Visual R	1.82	0.90
Primary Visual L	1.82	0.97
Temporal Lateral R	1.26	-0.47
Temporal Lateral L	1.11	-2.22
Temporal Mesial R	1.00	-0.67
Temporal Mesial L	0.81	-3.33
Cerebellum Whole	1.18	-0.36
Pons	1.00	0.00





ow - ASL

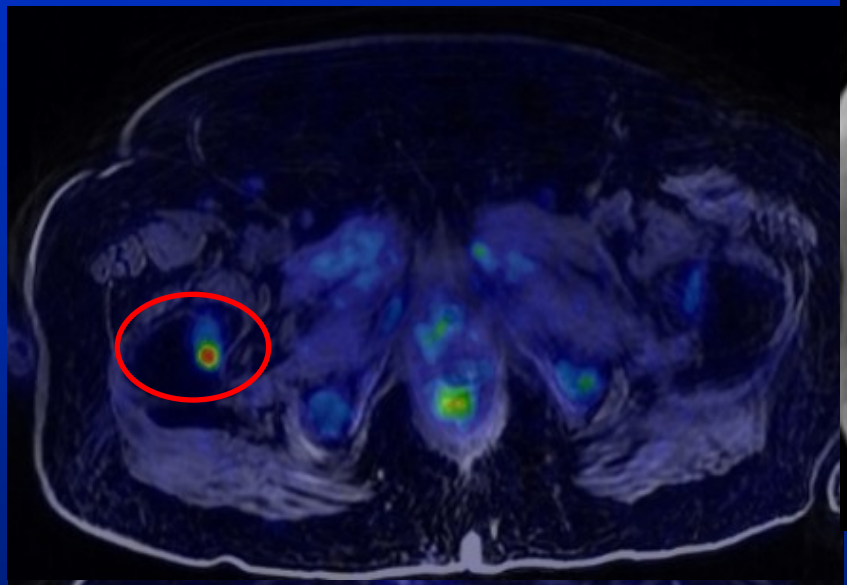


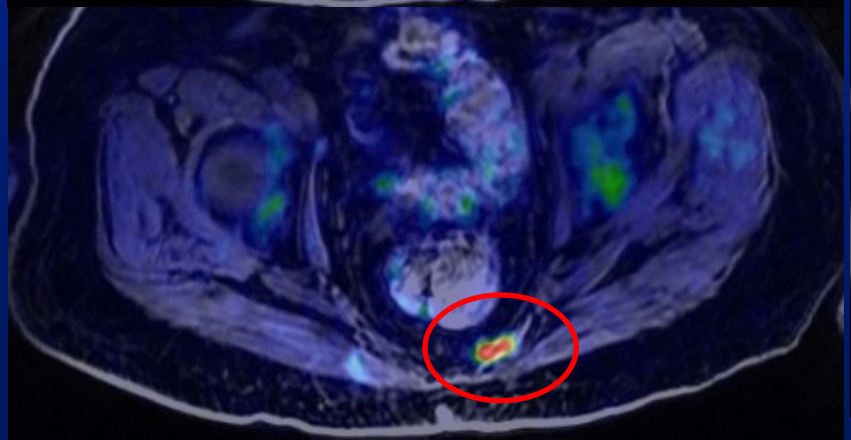
Fúze

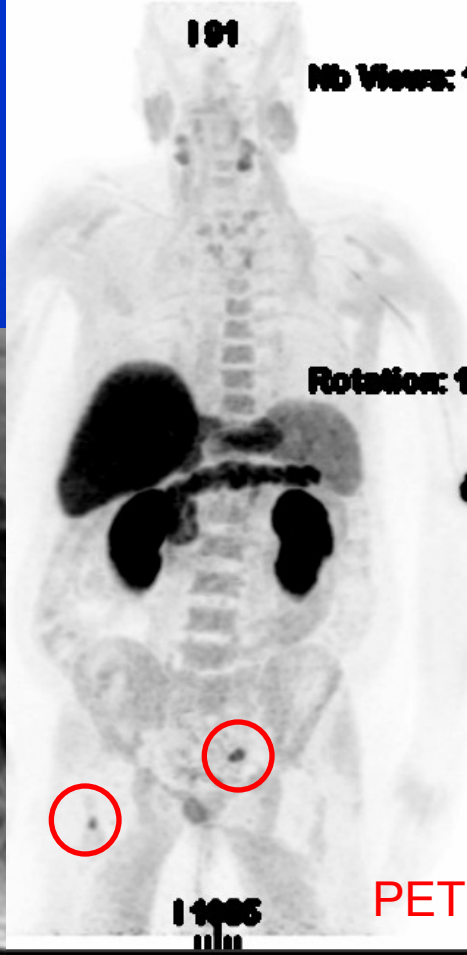
degree

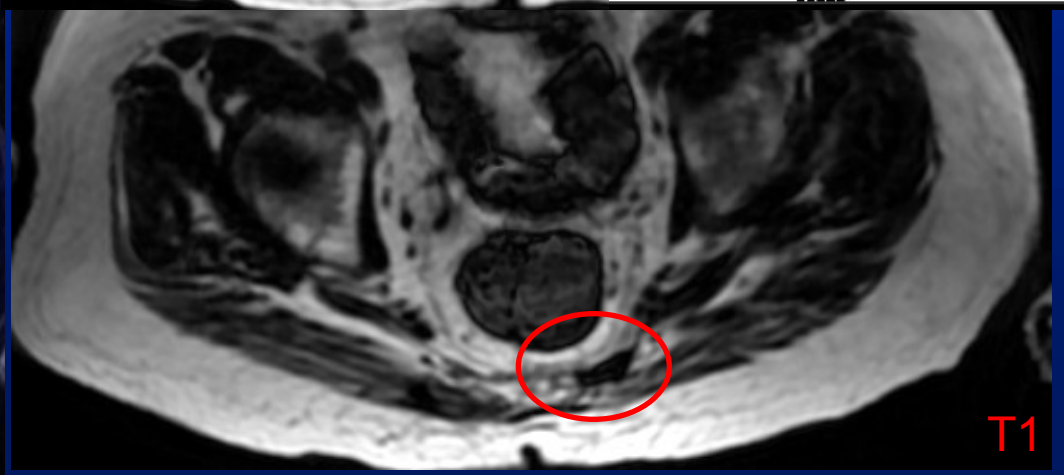
Cholin

- Adenokarcinoma of prostatic gland
- PSA 29,7 ng/mL



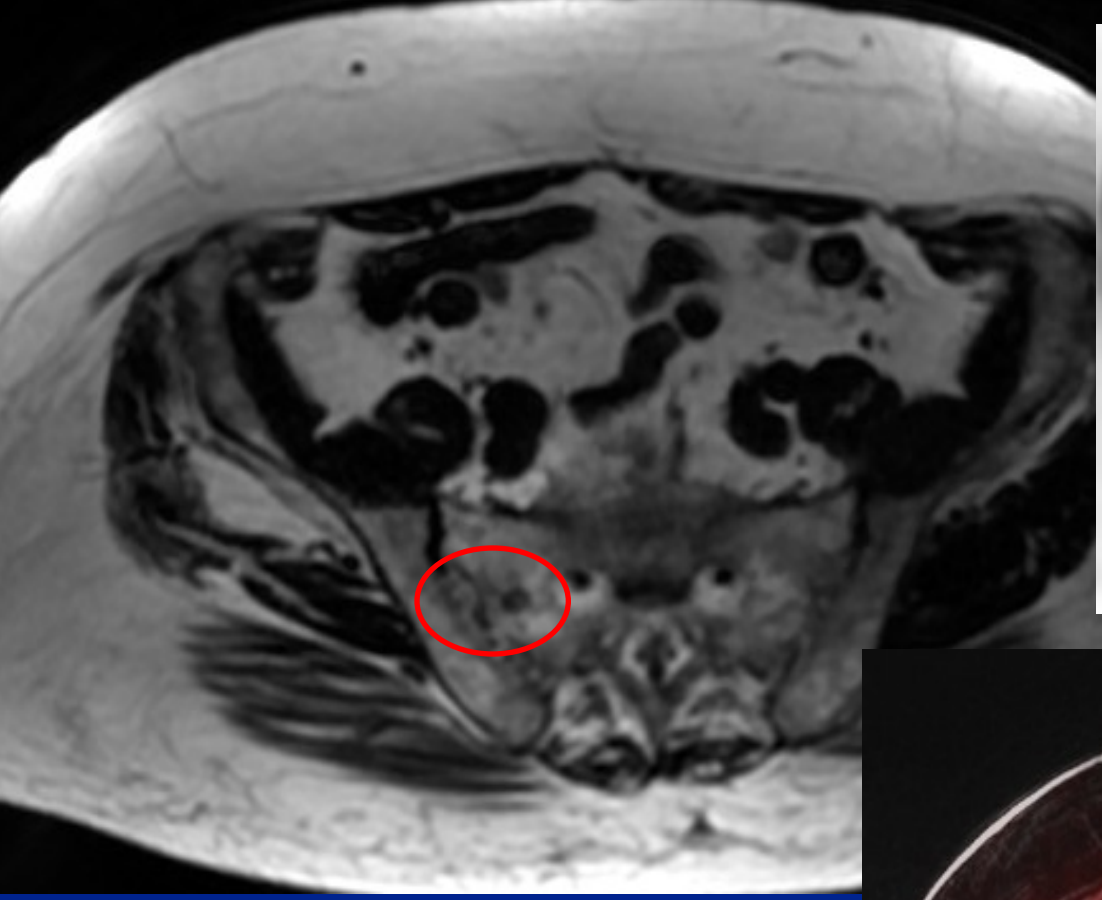


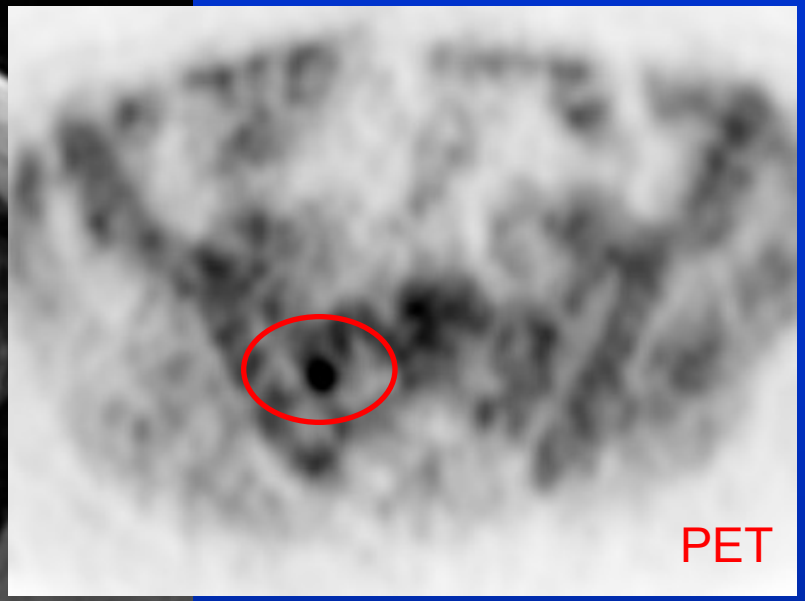


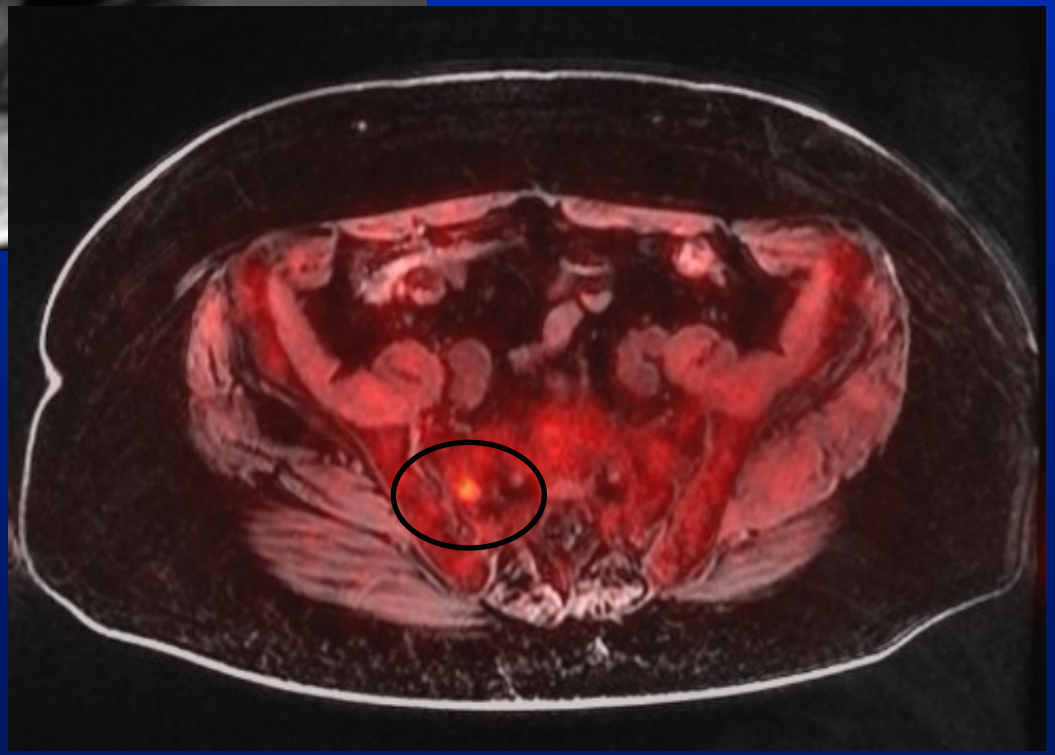


44* male - FLUCIKLOVIN 18F

- After prostatectomy for cancer
- biochemical relapse
- negative findindg on Cholin PET/CT

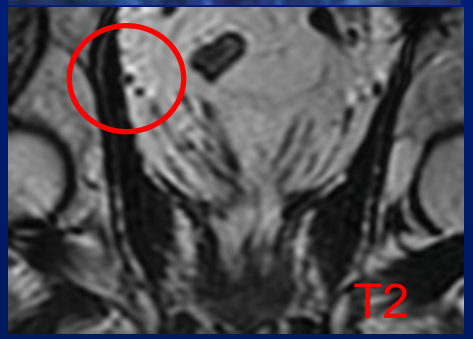


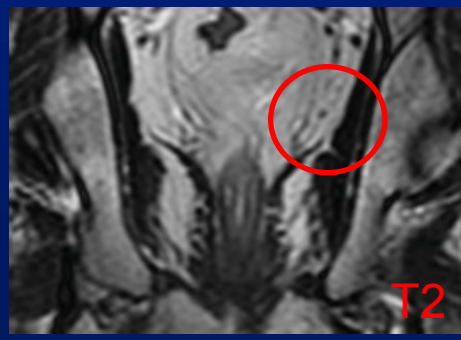

PET



Prostatic gland - PSMA 68Ga

Male 66 years after prostatectomy slow increase in PSA now 0.17 ng / ml, patient with negative finding on PET with Choline





Universität Zürich[UZH]

Hyperfunctional parathyroid glands

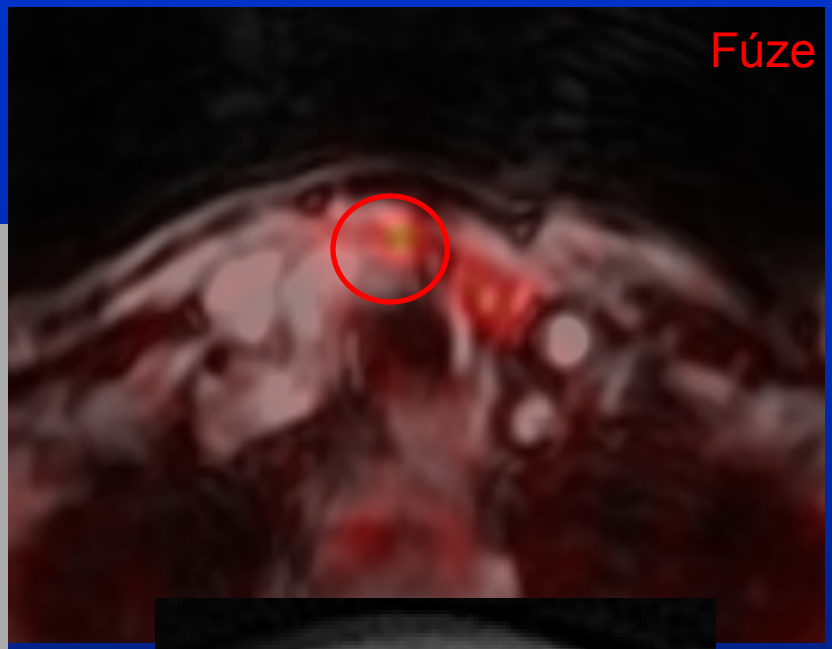
- PET cholin 18F - sensitivity 95%
  - *Treglia, Giorgio, et al. "Diagnostic performance of choline PET for detection of hyperfunctioning parathyroid glands in hyperparathyroidism: a systematic review and meta-analysis." European journal of nuclear medicine and molecular imaging (2018): 1-15.*

- ^{99m}Tc-MIBI SPECT – senzitivity 58 %
  - *Caldarella, Carmelo, et al. "Diagnostic performance of planar scintigraphy using 99m Tc-MIBI in patients with secondary hyperparathyroidism: a meta-analysis." Annals of nuclear medicine 26.10 (2012): 794-803.*

Female 55*

Primyry hyperparathyreosis

Negativ MIBI a US



Thanks for your attention