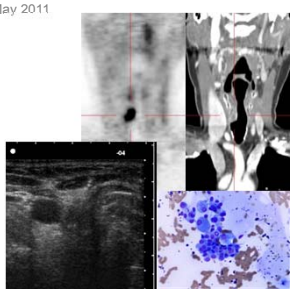
# PET – clinical applications

Cancer imaging with PET



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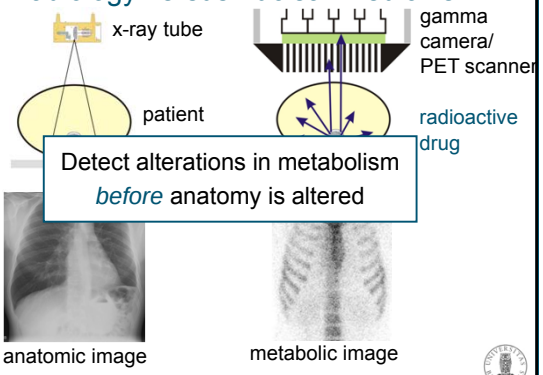
## Radiology versus nuclear medicine








## Nuclear medicine (incl. PET!)

is about

**contrast**

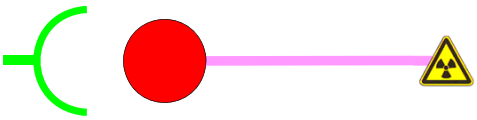
\+ whole body

information





## Molecular imaging



| Target | Carrier | Linker/Spacer | Signal |
|---|---|---|---|
| • cell membrane<br>• receptor<br>• transport system<br>• antigen<br>... | biologic tracer: molecule with suitable pharmaco-kinetics | • covalent binding<br>• complex binding<br>... | • gamma (NM)<br>• positron (PET)<br>• beta$^-$ (therapy)<br>• fluorescent dye |

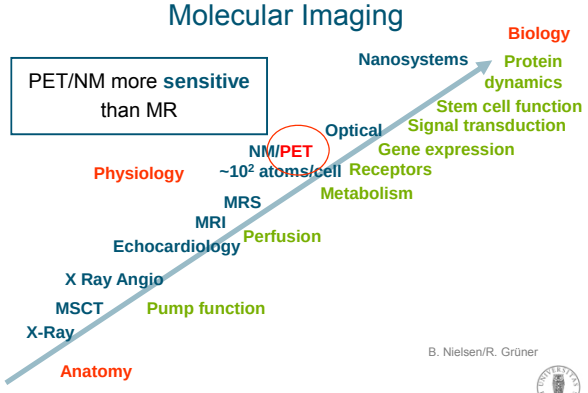
Carrier + linker + signal emitter can be 1 atom: F-18, I-131…





## Molecular Imaging

PET/NM more **sensitive** than MR




B. Nielsen/R. Grüner





## Nuclear medicine

2 sets of study protocols:

- Organ imaging:
  - Transport of a tracer by an organ/organ system
  - Positive (hot spots) or negative contrast (cold spots)
  - modelling
- Tumour imaging:
  - Tracer uptake in the tumour
  - Positive contrast (= hot spot imaging)

## Organ imaging

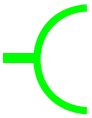
- Skeleton
- Thyroid
- Kidney
  - Renography (dynamisk)
- He
  - M
- Lu
  - Perfusion/ventilation
- Brain
  - Dopamine transport
  - Perfusion, metabolism

Tracer that is transported by the organ under study + modelling





## Tumour imaging: radioactive drugs



**Target**
- Cell membrane
- Transport system
- receptor
- antigen
- etc. …

- Mitochondria
  - Tc-99m-MIBI (parathyroid glands)
- Glucose (FDG), amino acids, iodine, stress hormone, choline…
  - FDG-PET, I-131, MIBG, choline…
- Somatostatin (a peptide hormone)
  - In-111-octreotide, Ga-58-DOTATOC
- Prostate-specific antigen, CEA…
  - Poor contrast, obsolete
- Mineralization (skeleton, osteosarcoma)
  - Tc-99m-MDP, F-18-fluoride

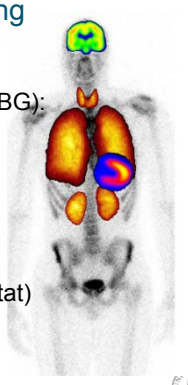




Tumour spesificity

## Tumour imaging

- Iodine transport (I-131, I-124)
  - Thyroid cancer
- Stress hormone-reuptake (MIBG):
  - Pheochromocytoma…
- Somatostatin receptors
  - Neuroendocrine tumours
- FDG-PET (glucose):
  - Many solid cancers
- Choline transport (cholin/actetat)
  - Prostate cancer
- Mitochondria (Tc-99m-MIBI)
  - Parathyroid scintigraphy







## Image acquisition

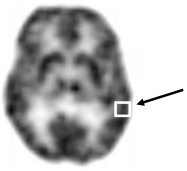
- Conventional (gamma imaging):
  - Whole body scintigraphy ant. + post. (planar, 2 D)
  - SPECT (-CT) of selected regions:
    - If WB images show likely pathology
    - Routinely in "difficult" body regions:
      e.g. SPECT abdomen at somatostatin receptor scintigraphy
    - Some times several volumes:
      SPECT thorax, SPECT abdomen
- PET (positron imaging):
  - "Whole body" = torso: base of skull to thigh
  - Sometimes dedicated series,
    e. g. PET-CT neck with i. v. contrast
  - Sometimes PET of lower extremites

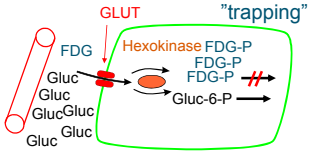




## F-18-fluorodeoksyglukose (FDG)

- Glucose labelled with radioactive fluor-18 (F-18)
- Glucose metabolism is universal:
  - normal: brain, heart, muscle
  - pathologic: many solid tumours → cancer diagnostics !!
    leukocytes → inflammation









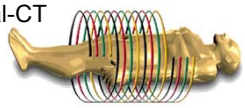

## Indications for F18-FDG in oncology

- Head and neck cancer[1,2]
- Thyroid cancer[1]
- Oesophagus cancer[1,2]
- Lung cancer (non-small-cell) [1,2]
- Colorectal cancer[1,2]
- Lymfoma[1,2]
- Melanoma[1,2]
- others:
  seminoma, osteosarcoma…

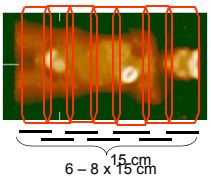
[1]Reske (2001) Eur J Nucl Med 28:1707-23
[2]http://www.cms.hhs.gov

## PET-CT study

- Low-dose whole body spiral-CT
  < 1 min



- PET helkropp
  ca. 25 min = 6-8 x ca. 3 min
  - CT for attenuation correction: saves time compared to transmission scanning with line sources
- Diagnostic CT with contrast




A. Skretting, Oslo





## FDG-PET: malignant melanoma (MM)

- n = 156 pts. with MM & suspected recurrence
- FDG-PET + body CT

| | Modality | Sensitivity | Spesificity |
|---|---|---|---|
| Total | PET | 74 % | 86 % |
| | CT | 58 % | 45 % |
| Lymph nodes | PET | 88 % | 95 % |
| | CT | 56 % | 81% |
| | | 57 % | 92 % |
| | | 93 % | 70 % |

PET more sensitive & specific than CT
(except lungs)

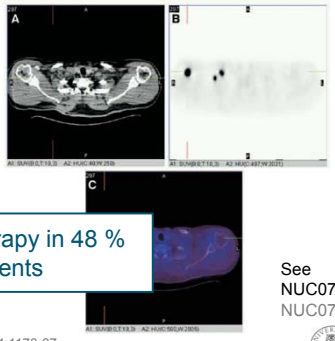
Fuster (2004) J Nucl Med 45:1323-7





## PET-CT with malignt melanoma

- n = 250 patients
- PET/CT
- Sensitivity:
  PET/CT 99 %
  PET 89 %
  CT 70 %




Change in therapy in 48 % of patients

See NUC071 NUC070

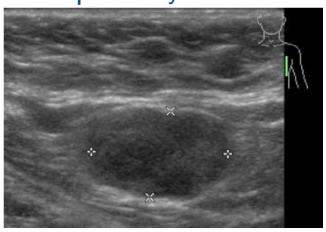
Reinhardt (2006) J Clin Oncol 24:1178-87





## Nodule in left armpit f. 51 yrs.

- Malignant melanoma
  in the back
  OP 8/2006
- Histology:
  MM (nodular type)
  Breslow 3.6 mm
  Clarks level 4
  1 mikrosatelite
  R0 (0.9 mm)



US L armpit

- 2009: nodule in left armpit
  US: 1.8 x 1.2 cm
  cytology positive

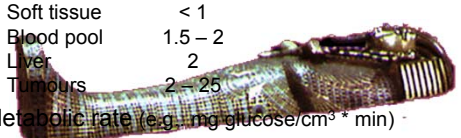
See NUC071





## Quantification

- Standardized uptake value (SUV):
  - Fill a whole body phantom (70 kg) with F-18-FDG (400 MBq), wait 1 h, and measure the activity concentration with your PET scanner: SUV = 1
  - Soft tissue < 1
    Blood pool 1.5 – 2
    Liver 2
    Tumours 2 – 25
- Metabolic rate (e.g. mg glucose/cm³ * min)
  - Measure radioactivity in blood ("input function") + mathematical modeling



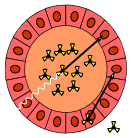




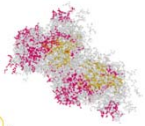
## Differentiated thyroid cancer (DTC)

Thyroid hormone production:

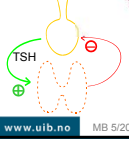
- active iodine uptake
  → radioiodine for diagnosis & therapy



- synthesis of thyroglobulin
  → serum hTg as tumor marker



- control by hypophysis (TSH)
  → *suppress* TSH
  to retard tumor growth
  → *stimulate* TSH
  for I-131 and hTg



## FDG for suspected recurrent thyroid cancer

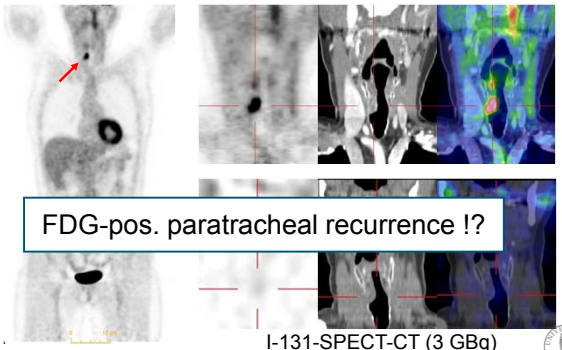
- 30 pas. HUS 6/2009 – 1/2011
- Change in therayp in 37 % (11/30) of patients:
  Don't re-operate without FDG-PET!
- 20 % false positive FDG-foci:
  - Inflammatory lymph nodes: FNB !
  - Pulmonary infiltrates
  - Physiological/reactive uptake in laryngeal muscle
  Ultrasound-guided fine needle biopsy!
- Pre-PET ultrasound + biopsy important for optimal selection of patients for FDG-PET

Biermann... Brauckhoff (2010) Eur J Nucl Med 37 (Suppl. 2):S291 (2011) Soc. for Nuclear Medicine (oral presentation)





## F-18-FDG-PET f. 50 yrs. PTC pT4a ↑hTg



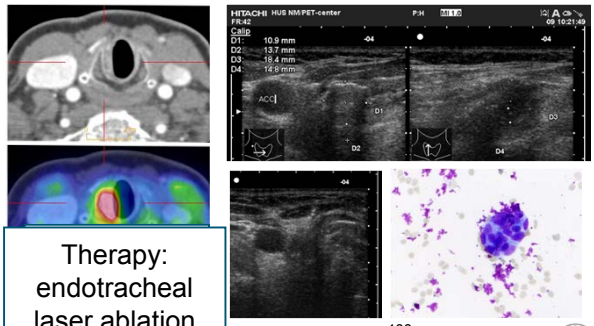
FDG-pos. paratracheal recurrence !?

I-131-SPECT-CT (3 GBq)





## F-18-FDG-PET f. 50 yrs. PTC pT4a ↑hTg



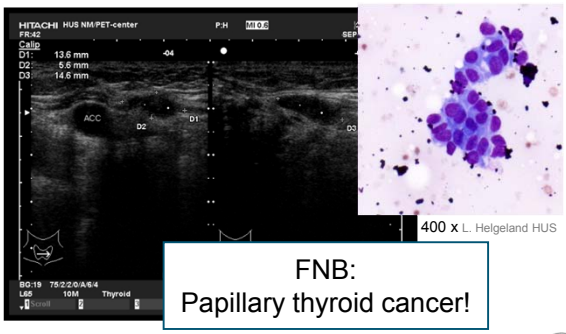
Therapy: endotracheal laser ablation

400 x L. Helgeland HUS





## Ultrasound f. 55 yrs. PTC OP 2006 ↑↑Tg-AB



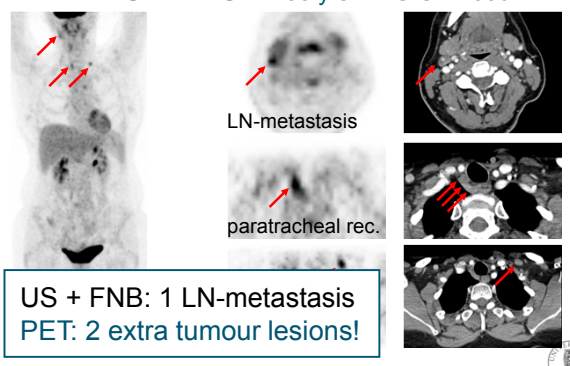
400 x L. Helgeland HUS

FNB: Papillary thyroid cancer!





## FDG-PET-CT f. 55 yrs. PTC OP 2006



LN-metastasis

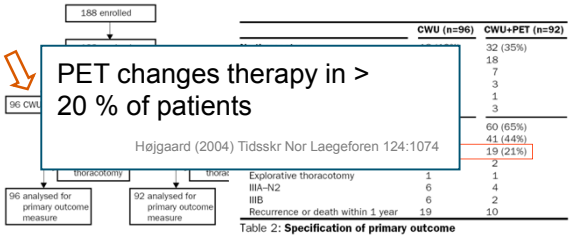
paratracheal rec.

US + FNB: 1 LN-metastasis
PET: 2 extra tumour lesions!





## PET & thoracic surgery for lung cancer




| | CWU (n=96) | CWU+PET (n=92) |
|---|---|---|
| | | 32 (35%) |
| | | 18 |
| | | 7 |
| | | 3 |
| | | 1 |
| | | 3 |
| | | 60 (65%) |
| | | 41 (44%) |
| | | 19 (21%) |
| | | 2 |
| Explorative thoracotomy | 1 | 1 |
| IIIA–N2 | 6 | 4 |
| IIIB | 6 | 2 |
| Recurrence or death within 1 year | 19 | 10 |

Table 2: **Specification of primary outcome**

PET changes therapy in > 20 % of patients

Højgaard (2004) Tidsskr Nor Laegeforen 124:1074

- prospektive randomized trial at Univ. of Amsterdam
- non-small lung cancer
- PET (Siemens Exact HR+)

van Tinteren (2002) Lancet 359:1388-93

NUC087

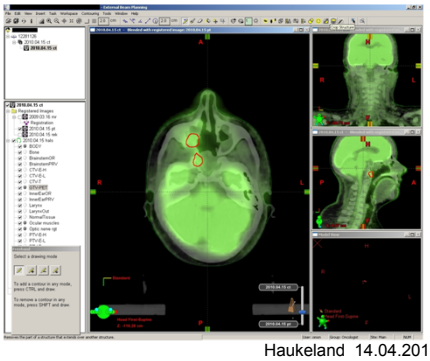
## The future

- RTx dose planning with PET-CT
- New PET-tracers:
  - C-11-choline/acetate — prostate cancer
  - Ga-68-DOTATOC — nevroendocrine tumours
  - F18-FDOPA — medullary thyreoidea cancer
  - C-11-5-HTP — nevroendokrine tumours
  - F-deoksytymidin (FLT) — brain tumours
  - C-11-HED — sympathetic nervous system
  - C-11-metionin — brain tumours, parathyreoid
  - …
- Combination of tracers/modaliteties





## Dose planning for RTx with PET-CT

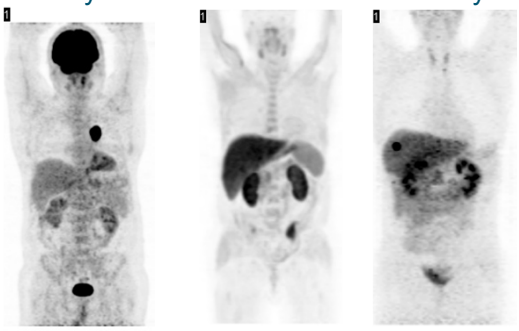


Haukeland 14.04.2010





## Every PET tracer is its own modality…



F-18-FDG C-11-choline Ga-68-DOTATOC





## Clinical PET

F-18-FDG = workhorse:

- Cancer imaging (> 90 %):
  - head/neck cancer, lung, colon…
  - Pre-therapy, therapy-control, dose planning…
- Sensitive but UNspecific!
  - Inflammation!
  - Best if combined with other modalities: contrast-CT, MR, ultrasound, biopsies
- Changes treatment in > 20 – 40 % of patients
- New tracers:
  - C-11-acetate (prostate)
  - Ga-58-DOTATOC (neuroendocrine tumours)





## Bergen PET centre


HELSE BERGEN