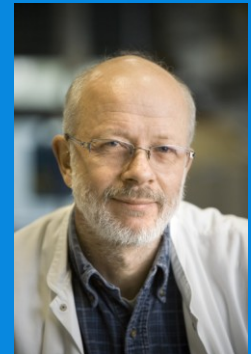


Radiation doses 2001-2010 to staff working in a large PET and PET/CT department



Søren Holm, Susanne Svalling, Thomas L Klausen, Annika Loft

Copenhagen, Denmark

Rigshospitalet – Copenhagen University Hospital

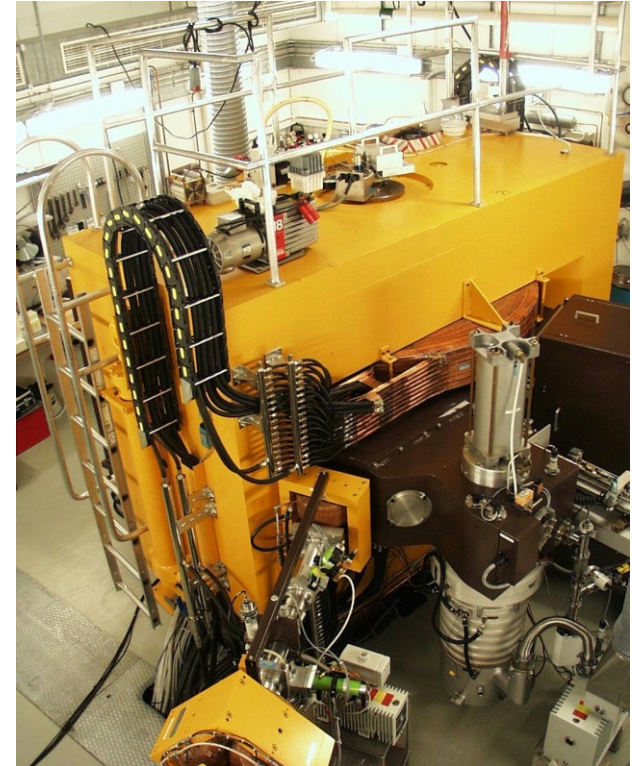


PET & Cyclotron
(and Radiotherapy)

- Hospital for patients who need highly specialized treatment and care
- 1400 scientific papers (2009)
- 8000 employed
- Budget 5 G-DKK (700 M€)

PET and Cyclotron Unit, Rigshospitalet

- Cyclotrons:
 - Scanditronix 32 MeV (1991-
 - CTI Eclipse 11 MeV (2005-
- PET scanners
 - GE 4096+ (1991-2006)
 - GE Advance (1993-2009)
 - Siemens HRRT (2008-
- PET/CT scanners
 - GE Discovery LS (2001-11)
 - Siemens Biograph 16 (2005-10)
 - Siemens Biograph 40 (2007-
 - Siemens Biograph 64 (2009-
 - Siemens mCT (2010-
 - Siemens mCT (2011-



All equipment – except 2 Biographs - was donated by the John and Birthe Meyer Foundation



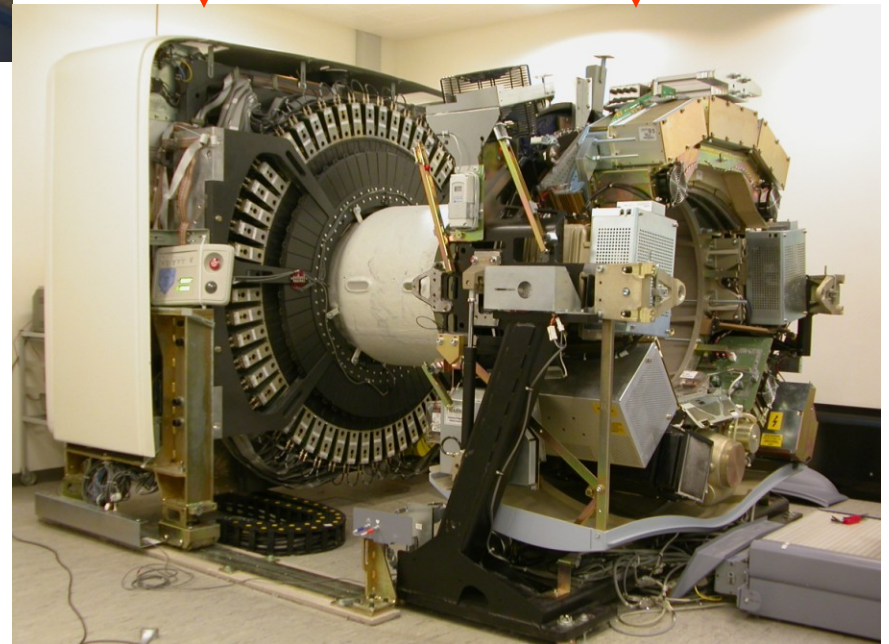
Discovery LS 2001

PET/CT

PET



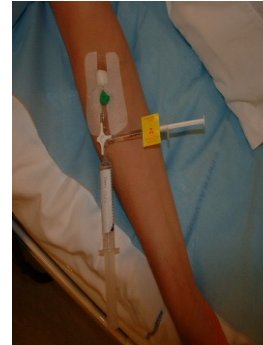
CT



Sequence of events for a PET scan



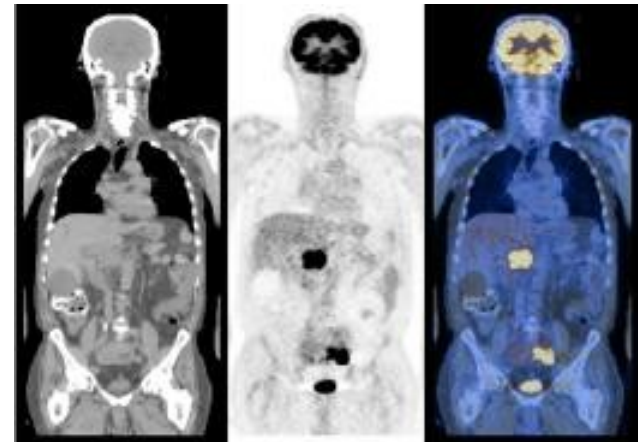
Cyclotron
Isotope production



Injection
...waiting...



PET/CT scanning



Results



Radiochemistry



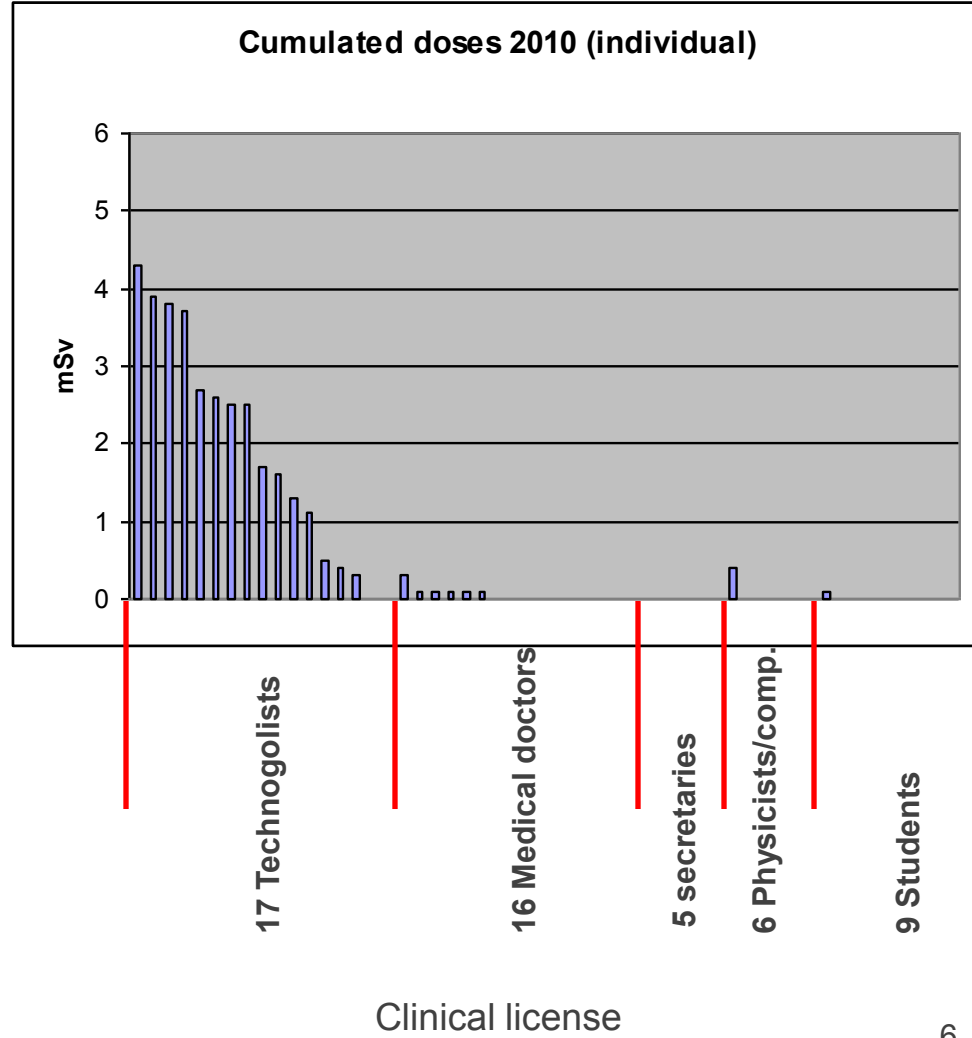
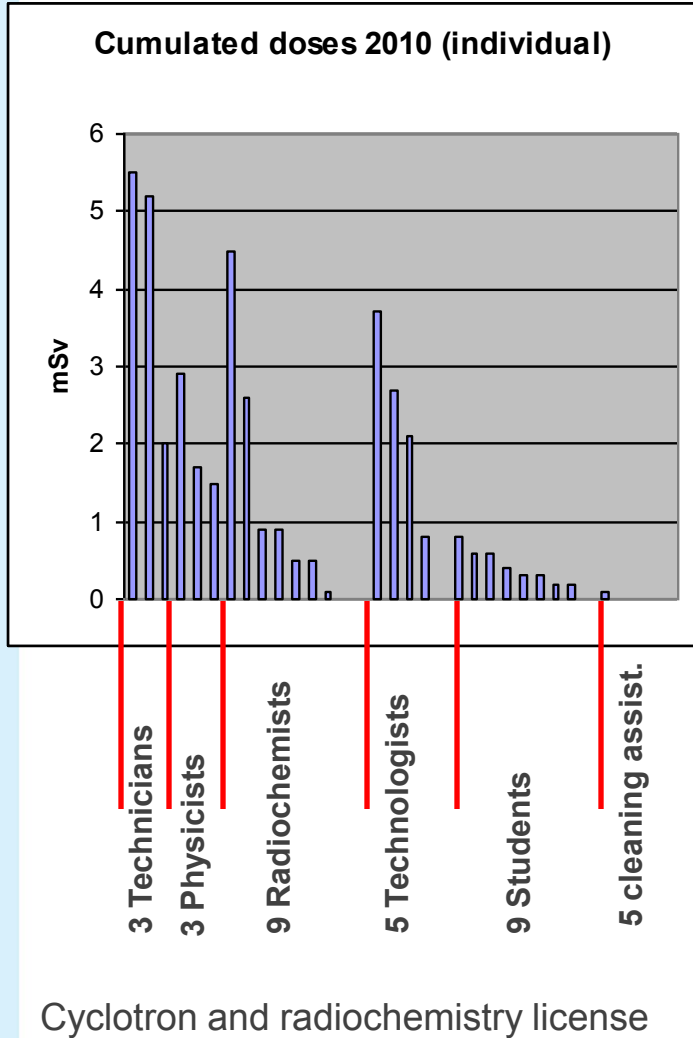
Quality control



Cyclotron and radiochemistry license

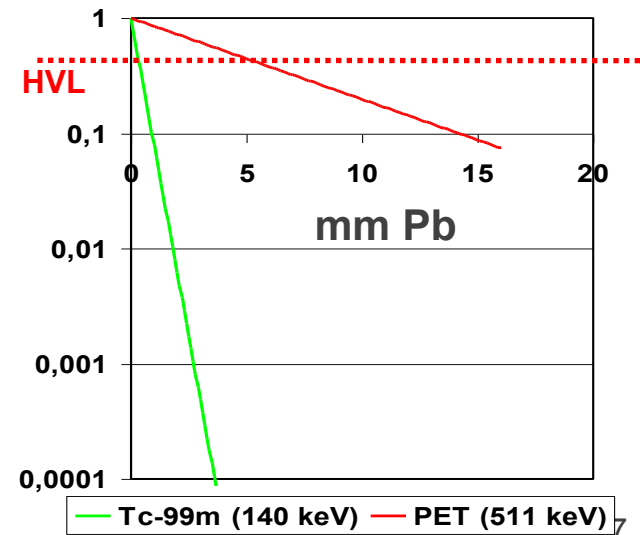
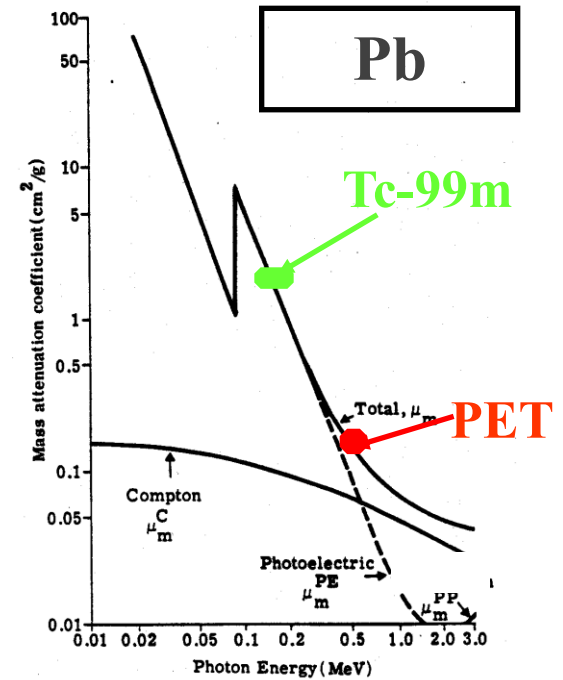
Clinical license

What staff receives the dose?



Radiation protection in PET

- PET is based on 511 keV annihilation photons
- Compared to Tc-99m:
- F-18 decay has 10 times the energy (8 times in photon energy)
- More photons escape the patient
- 511 keV is much harder to stop in lead
 - HVL for Tc-99m: **0.4 mm**
 - HVL for 511 keV: **4 mm**
- Lead aprons are useless in PET



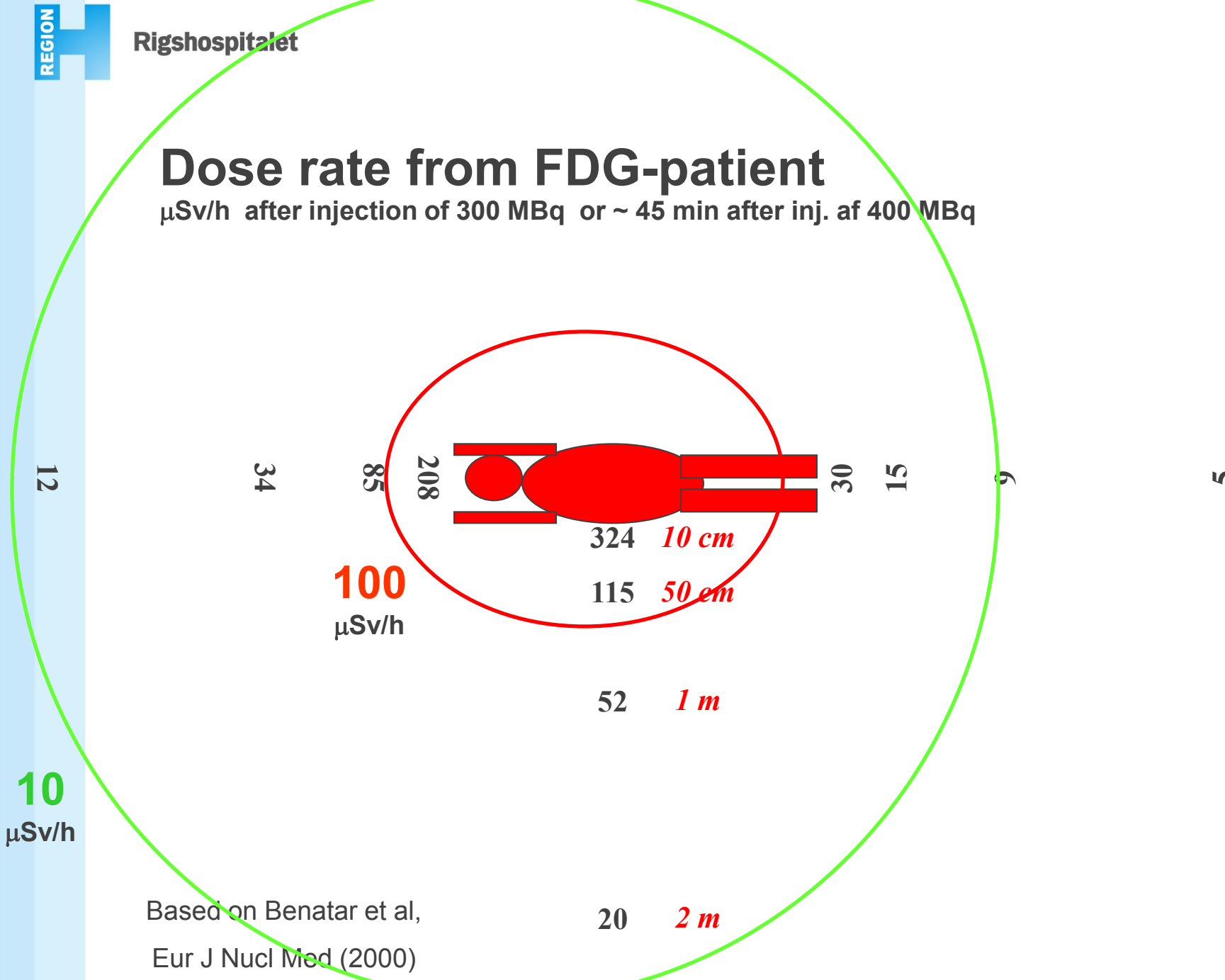
Staff dose is received by

1. Dose drawing
2. Transport of syringe
3. Injection of patient
4. Handling the patient
5. Background from "other" activities in the center, and from radioactive waste



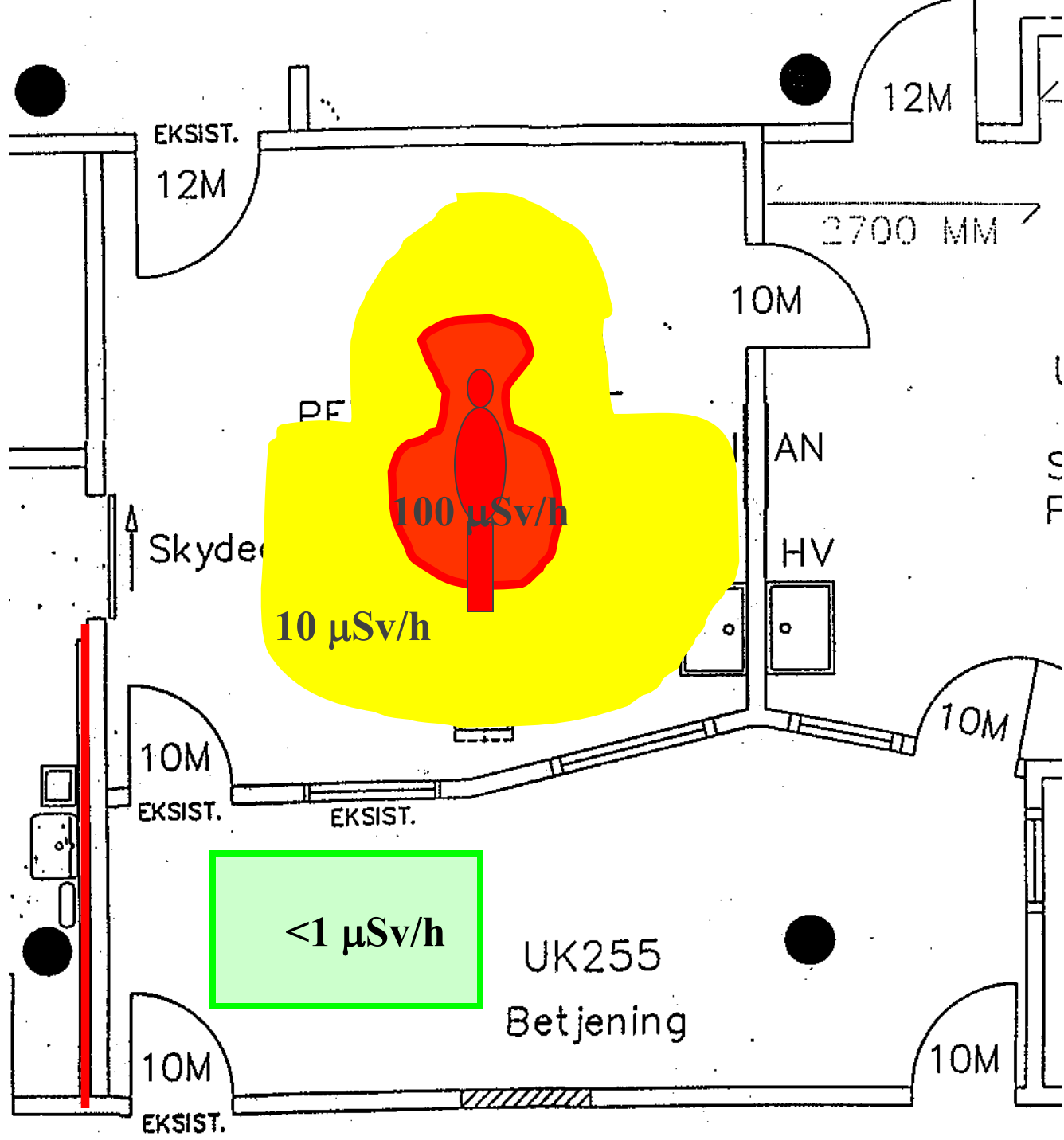
Dose rate from FDG-patient

$\mu\text{Sv/h}$ after injection of 300 MBq or ~ 45 min after inj. af 400 MBq



10 $\mu\text{Sv/h}$

Based on Benatar et al,
Eur J Nucl Med (2000)



The patient is **THE** most important source

- at injection
- in the uptake period
- to/from toilet
- during placement in the scanner
 - this is the most difficult part to reduce!
- during scanning
- after scanning

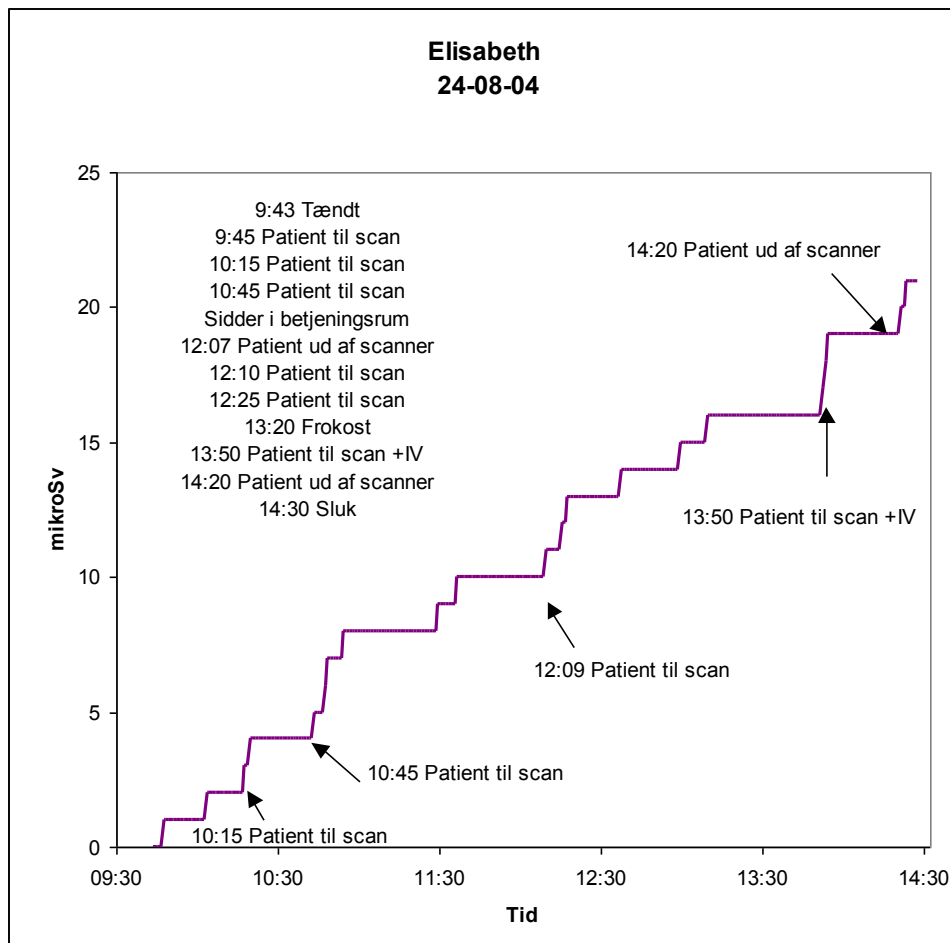
Staff Dose

- Staff wear film badges (from SIS) to measure monthly exposure
- We are working close to the detection limit (0,1 mSv)



- Electronic meters (with appropriate alarm level) are used as a supplement
- A study has shown that these values match film quite well at 511 keV

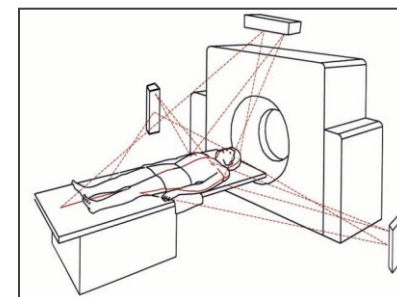
A day in the PET suite...



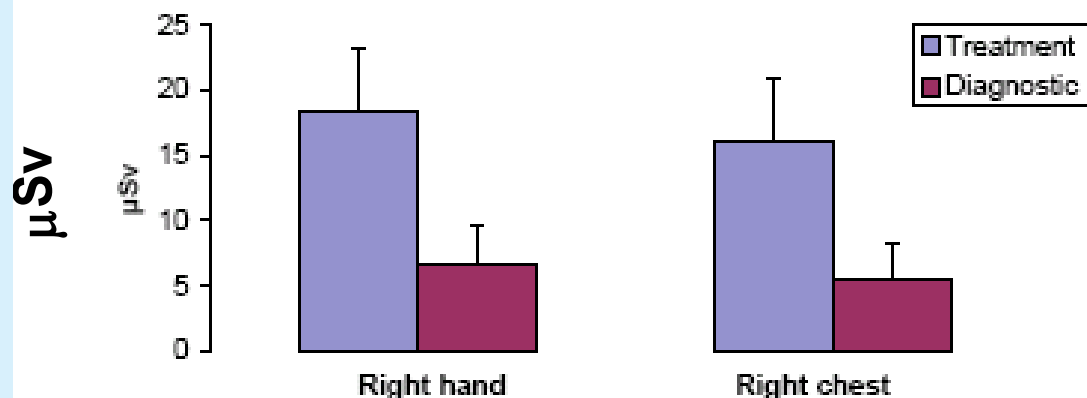
Using the electronic dose meters, we can estimate the contribution from different parts of the work for optimization

Patient handling is a major contribution

In particular, in scans for planning of radiation therapy



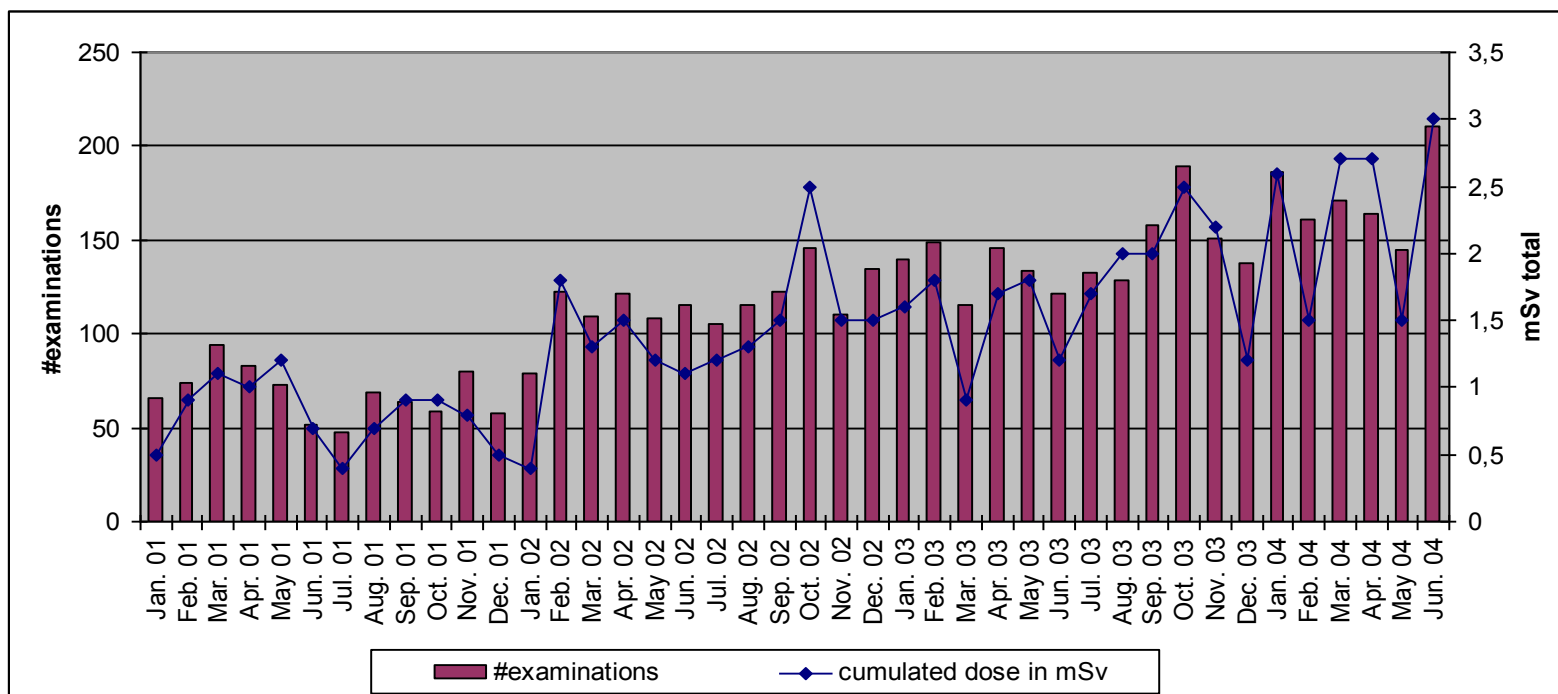
Example of comparison of procedures



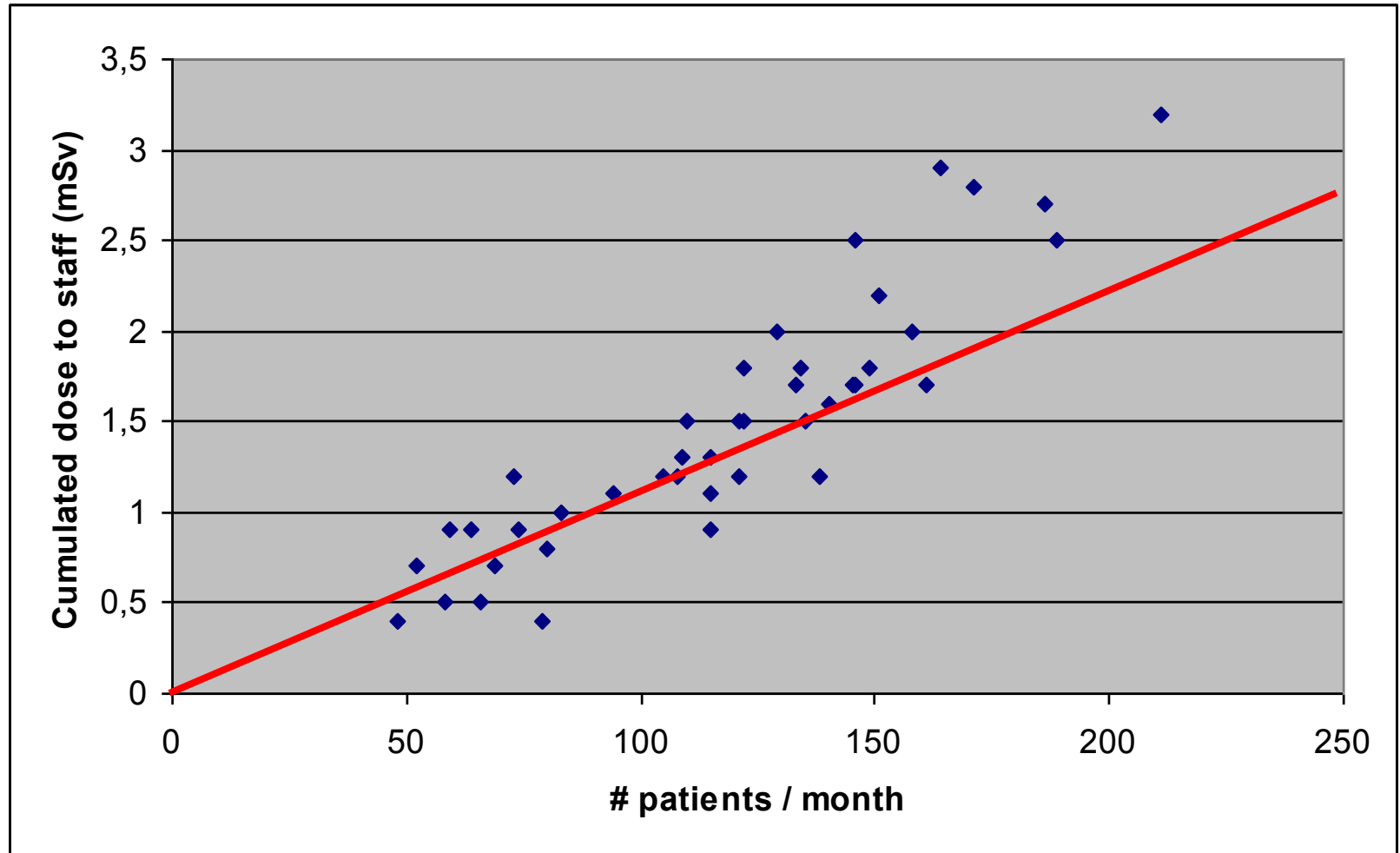
Placing patients for therapy planning, staff receive about 3 times the “normal” radiation dose for diagnostic scanning

The fraction of patients for therapy planning has been relatively constant 15-17% since 2006.

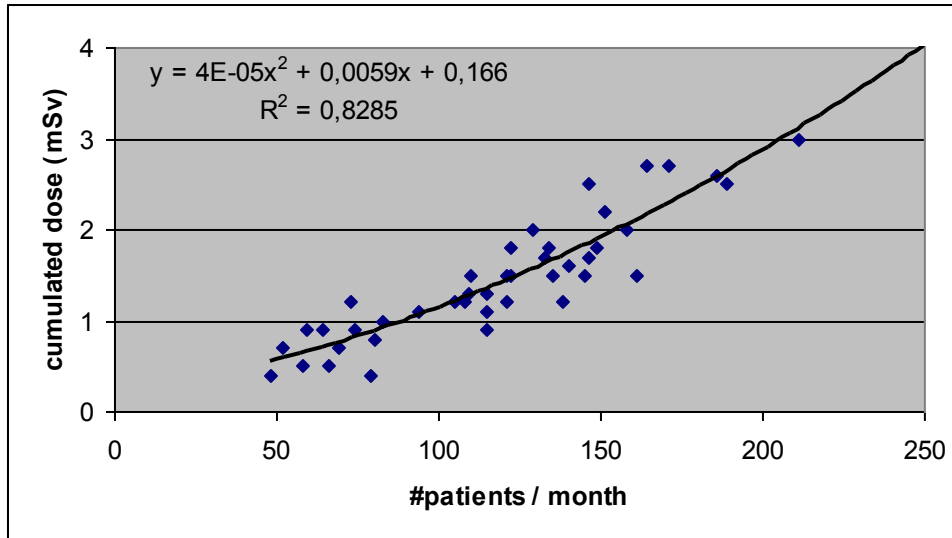
#patients and monthly staff doses 2001-2004



Cumulated dose depends on #patients...

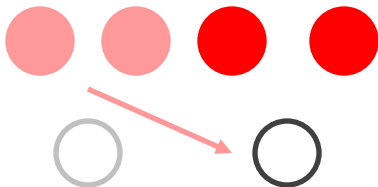


Data from 2001-2004

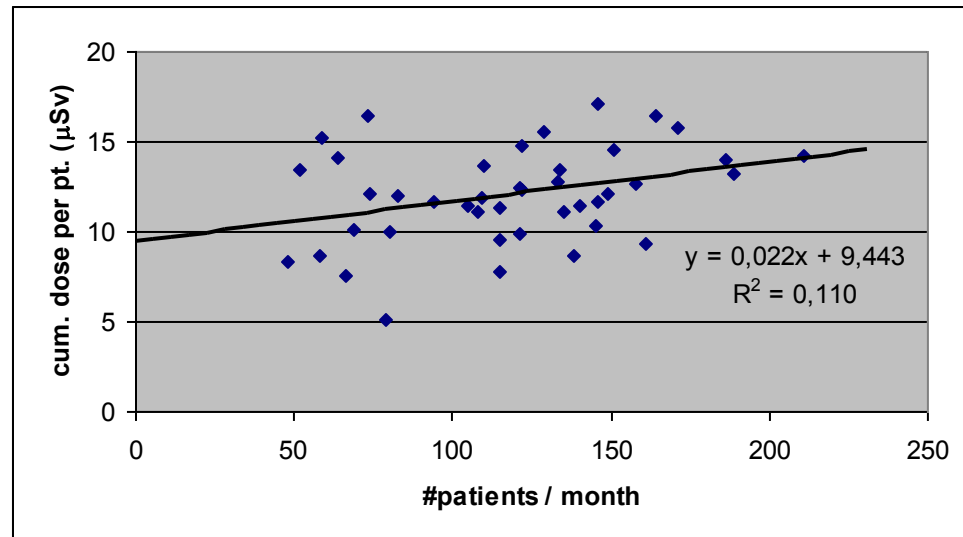


The cumulated dose is well fitted by a 2. Order polynomium in the number of patients

Easily modelled as a per patient term and a background term (from all the *other* patients in the area)



$$D/N = \Delta_{pt} + N * \Delta_{bg}$$



This means:

- Even to keep the staff dose/patient **constant**, when the number of patients increases is **NOT TRIVIAL**
- There is not one simple solution:
- All parts of the premises, logistics and procedures must be reexamined at intervals
- Encouragement of the "safety culture" is important
- One motivating factor is the possibility for technologists to propose and perform small measurement studies and present the results at meetings, e.g. the EANM

The patient is **THE** most important source

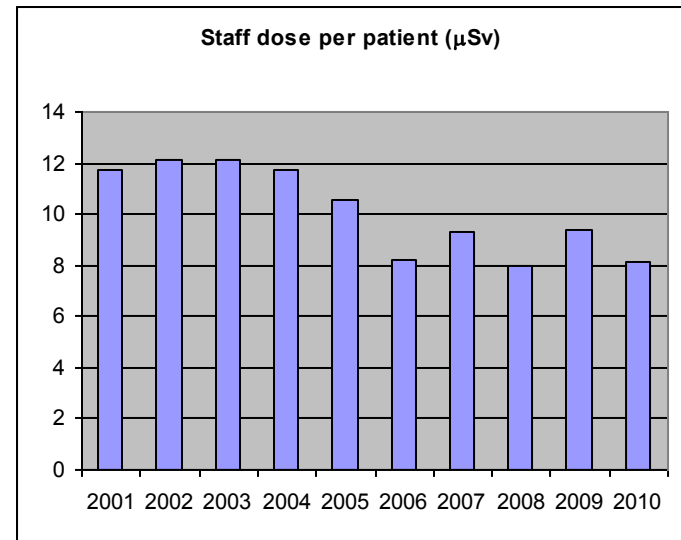
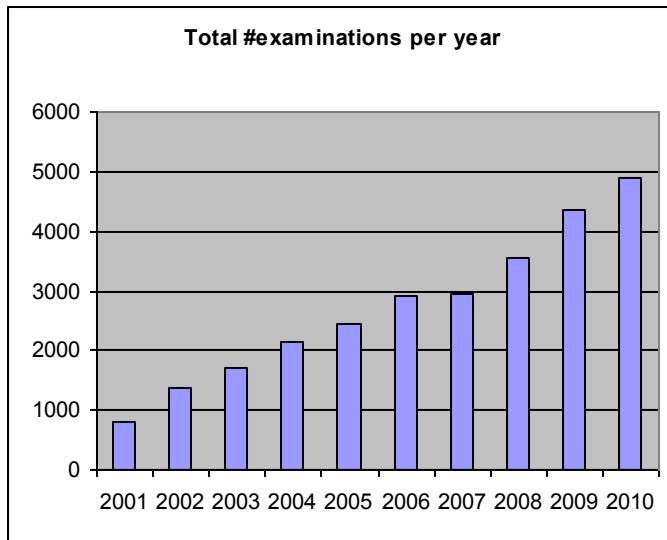
Among the lessons learned are:

- all instructions must be given before injection
- inform the patient that a distance is kept
- toilet direct accessible from active waiting room
- perform placement in the scanner as quick a.p.
 - this is the most difficult part to reduce, particularly in scans for radiation therapy planning!!!
- during scanning
 - Stay in (shielded) control room, use video survey
- after scanning...

Injection and "active" waiting facility for 2 PET/CT

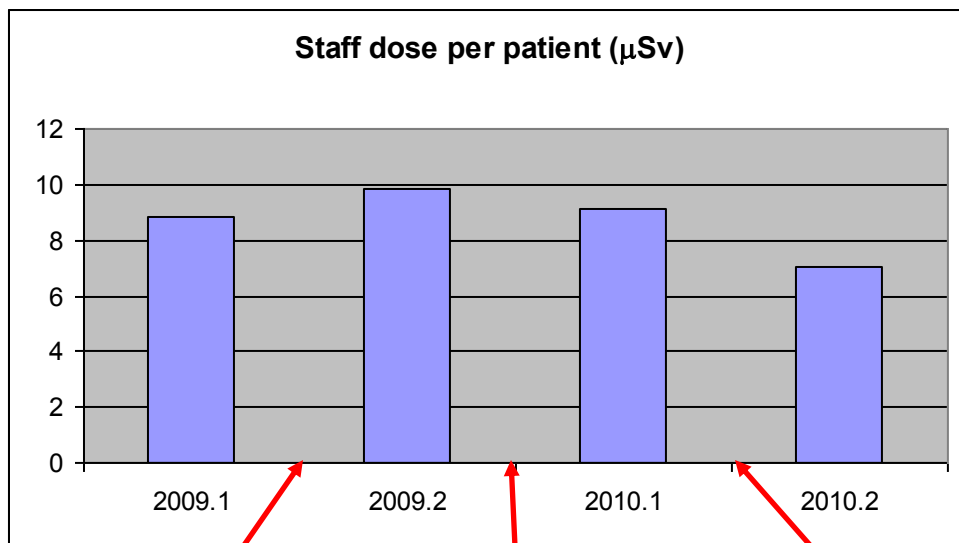


Data 2001 - 2010



Despite increasing #patients per year - staff dose per examination is reduced

Recent changes



In July 2009 we opened a new scanner sharing the most busy preparation area (doubling #pts here)

In January 2010 we went from manual to "automatic" injection for 80% of our patients

In July 2010 we changed dosing scheme from standard 400 MBq in most patients to 4 MBq/kg (max 500 MBq)

A reduction of 30% on average – facilitated by the injection cart



Summary

- Over the last 10 years, we have reduced the staff dose per examined patient from **12** to **7 μ Sv**
- equal to be 1 m from an injected pt. in **6 minutes**
- The typical monthly dose for a PET technologist is 0.2-0.3 mSv
- Our quality manual states that any monthly dose above 0.5 mSv calls for an examination/inquiry
- None of the PET technologists have ever exceeded 6 mSv in a year (max 4.8 mSv)