Imaging doses in radiotherapy

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Imaging in radiotherapy process

Diagnosis and staging

- Plain radiography, CT, PET/SPECT-CT

Planning and simulation

- CT, MRI

Set-up, localization

- kV and MV x-rays, CBCT, motion tracking, (MRI)

Follow-up

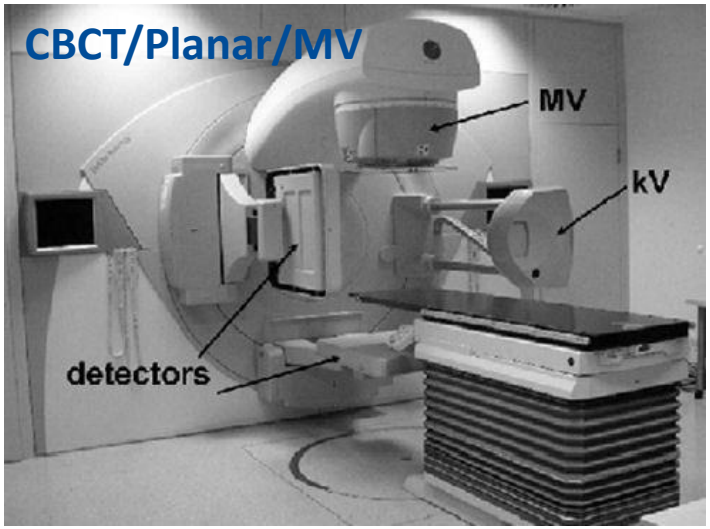
Highly conformal treatments are routine – target positioning is critical -> imaging at each fraction

Image-Guided RadioTherapy

Imaging techniques

CT

CBCT/Planar/MV



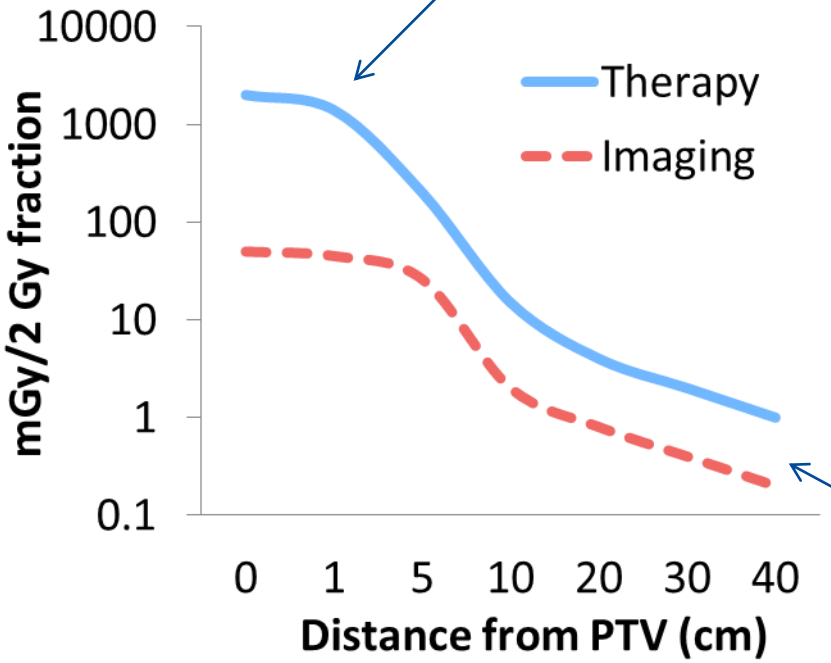
MRI

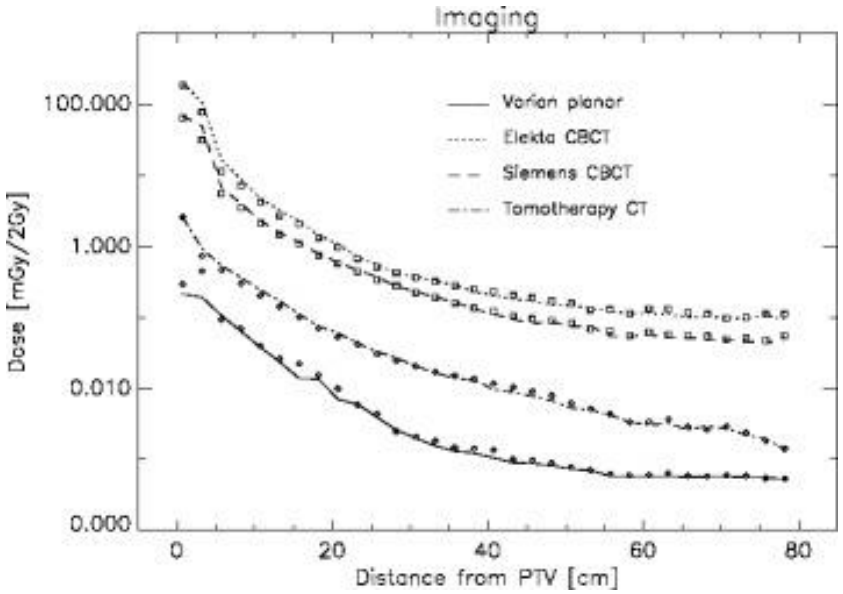
PET/SPECT CT

© Wertz et al., S. Kaijaluoto, J. Ainali

Should we be concerned about the doses from imaging?

- In PTV and close to PTV dose from the therapeutic beam clearly dominates
- Situation can be different in low-dose region further away



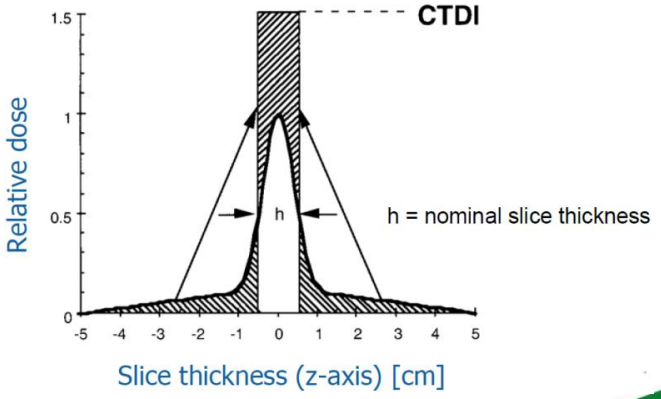


Schneider et al, Rad Onc 10 (2015)

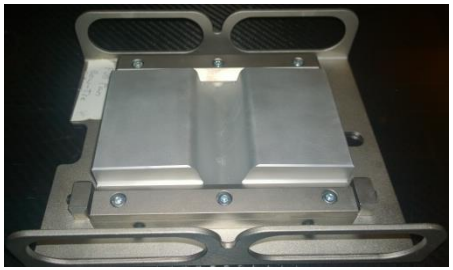
10 – 40 % contribution

How to estimate doses from imaging (especially kV CBCT)?

- Monte Carlo simulations in real patient anatomy – role of planning software?
- Dose volume histograms are needed close to PTV
  - Biologically weighted quantities should be avoided
- CBCT geometry can be problematic – new approaches and quantities are developed
  - Normalization to CTDI display or measurements
- TLD, Mosfet and other measurements in anthropomorphic phantoms



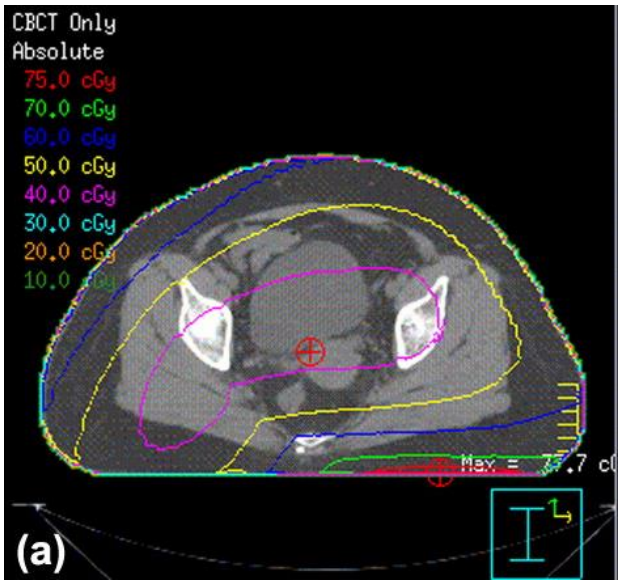
A Bow-tie filter for CBCT

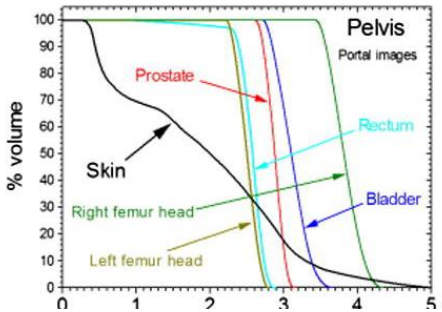


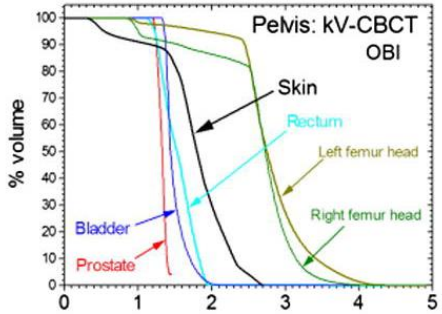
What are the doses from imaging?

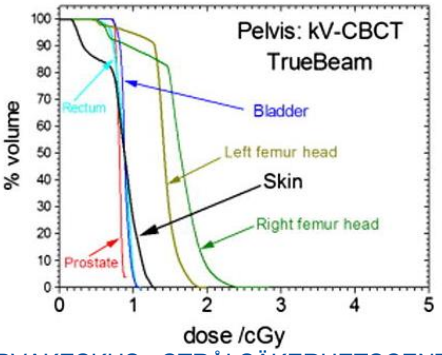
25 fractions/imaging
Alaei et al, Acta Onc 53 (2014)

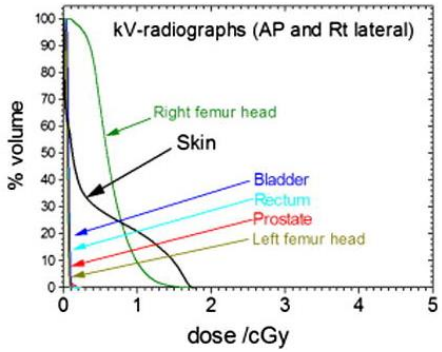
- CBCT, internal organs in imaged region: typically 10 - 30 mGy per fraction
- Skin doses can be higher
- MV imaging results in higher doses than kV
- **Lowest dose** in planar kV radiographs







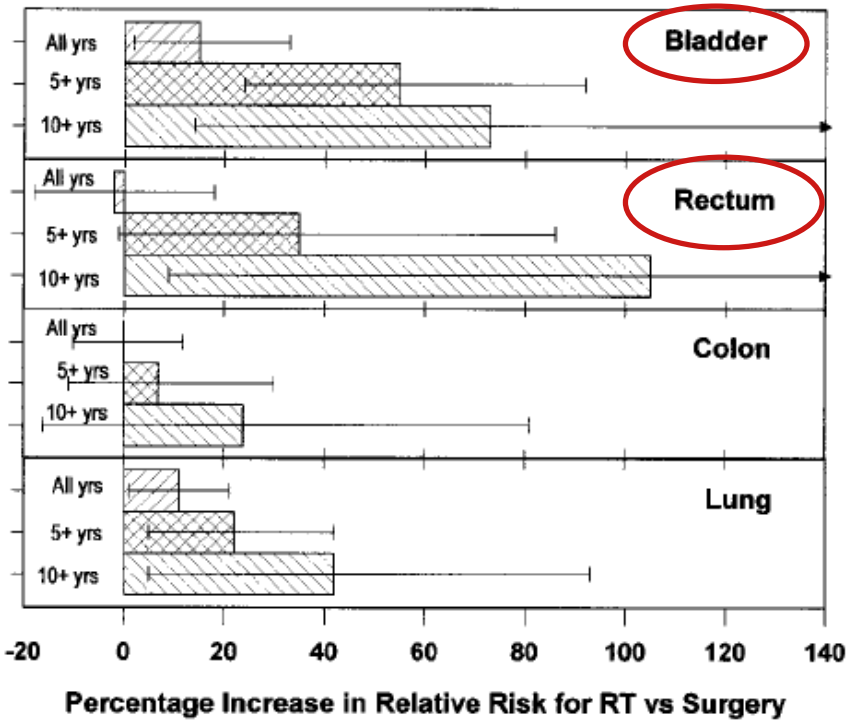




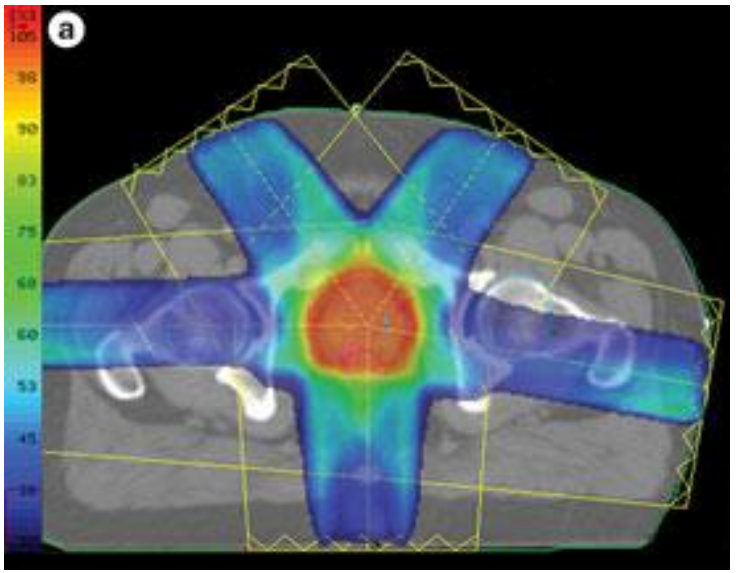
Dose per scan, pelvis
Ding and Munro, Radioth Onc 108 (2013)

Example: Prostate

High-dose region

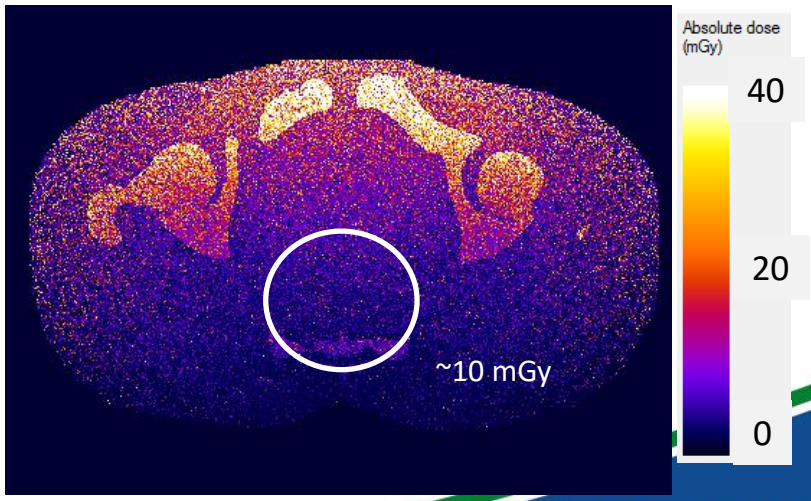


Brenner et al, Cancer 88 (2000)
Old data, but more recent data support this



IMRT plan of prostate gland

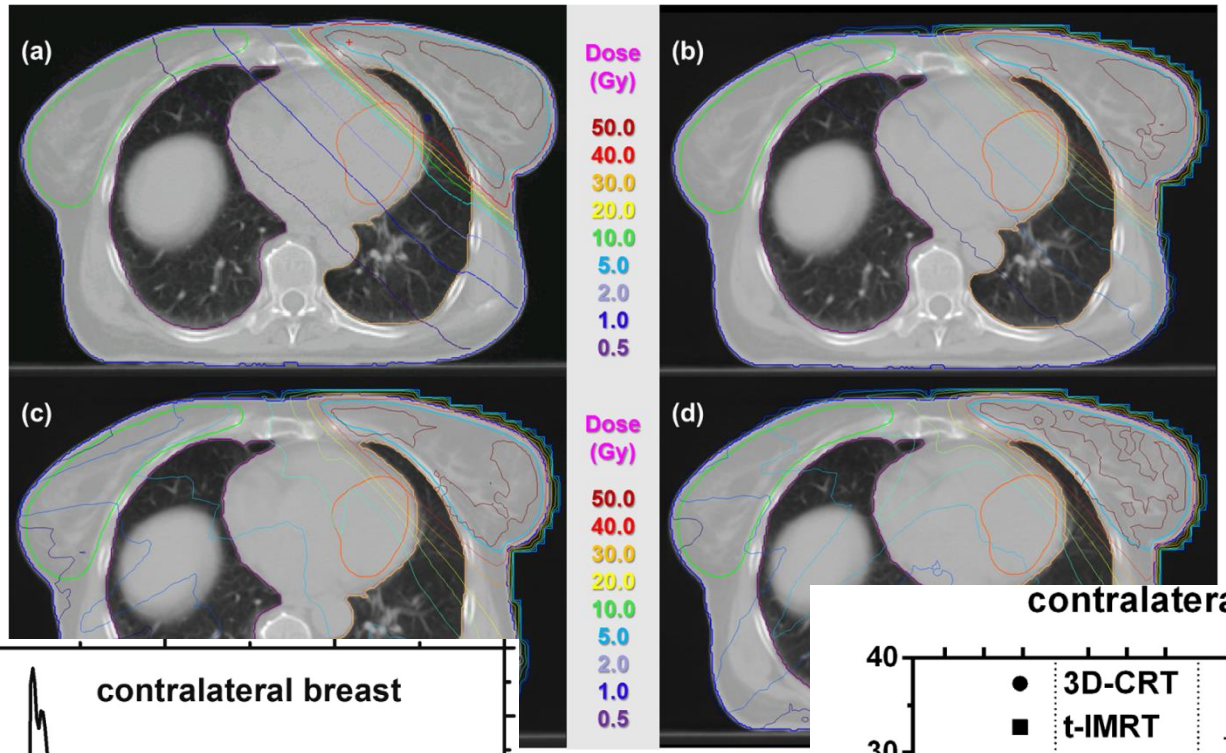
Wilkins and Parker, Nat Rev Clin Onc 7 (2010)



CBCT, tube over the patient, 200 deg rotation

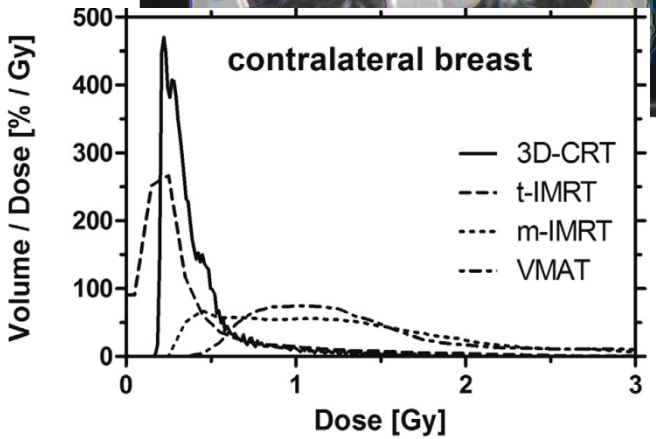
Example: Breast

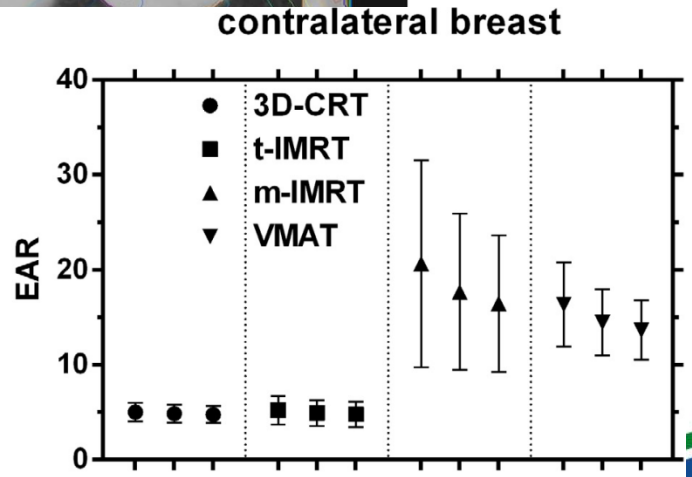
Low-dose region



(a) 3D conformal RT
(b) Tangential IMRT
(c) Multibeam IMRT
(d) VMAT

Abo-Madya et al, Radioth Onc 110 (2014)

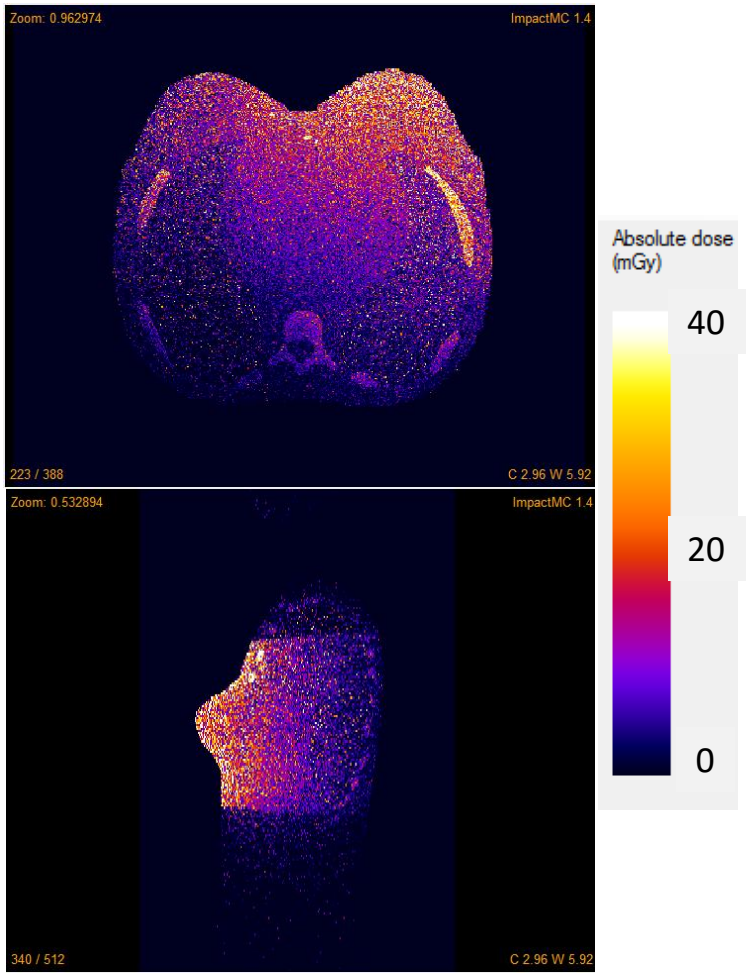




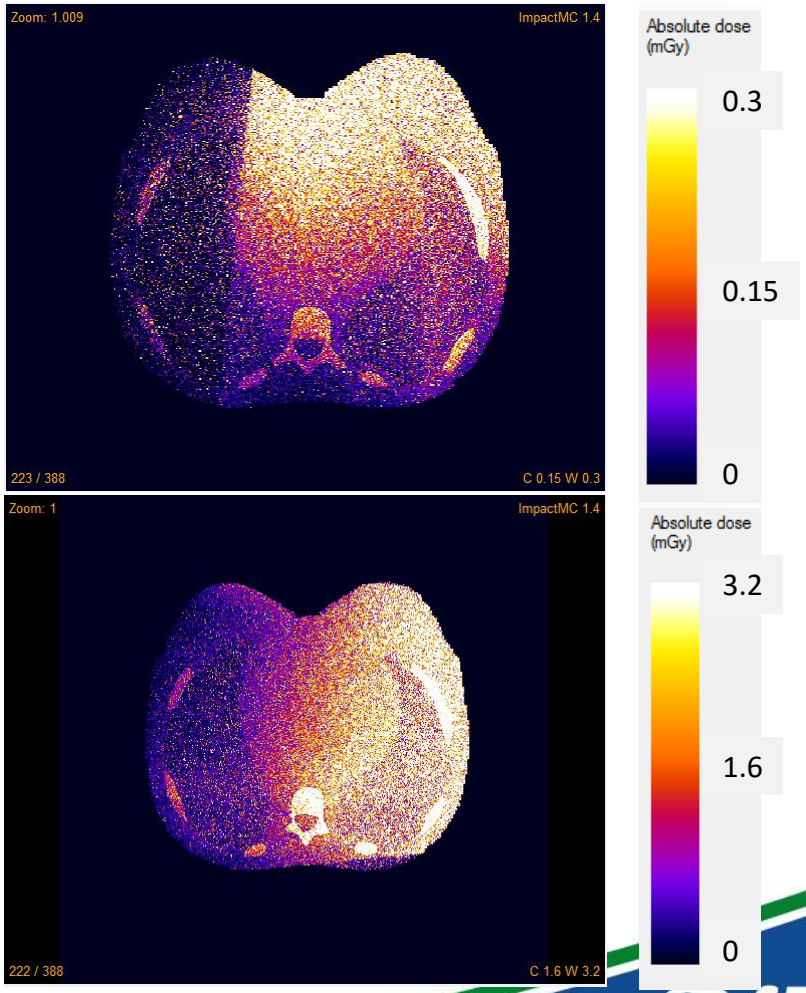
Breast: Monte Carlo simulation

CBCT, dose per scan

Tube above the patient, 200 deg rotation

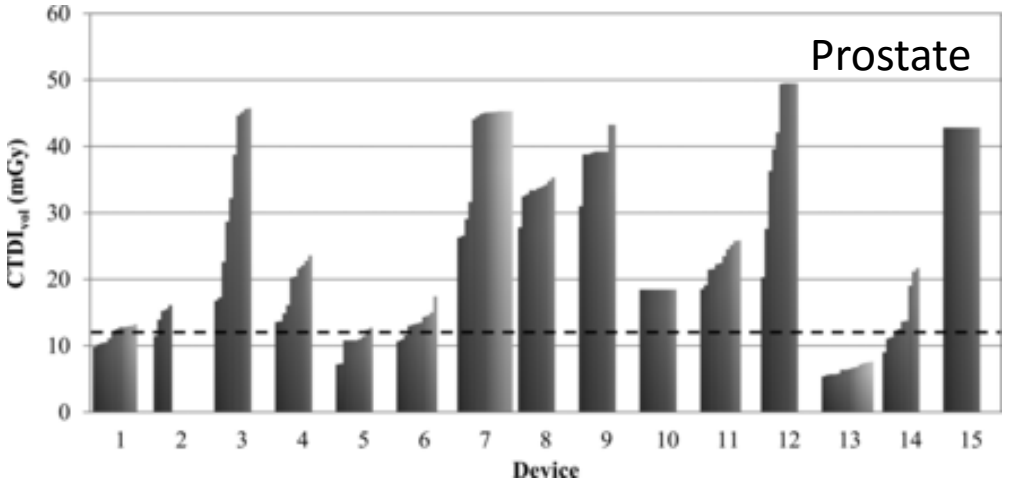


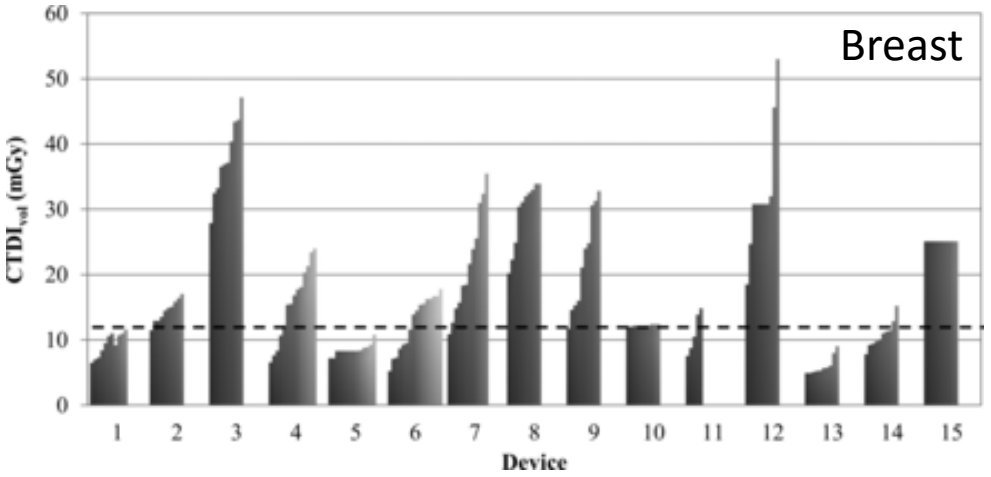
kV planar AP + LAT



CT planning and simulation

- Radiographs from CT images
- Less stringent requirements for image quality than in diagnostic CT
- Finnish DRL for diagnostics is 12 mGy (body)
- Scan length ~ 35 cm





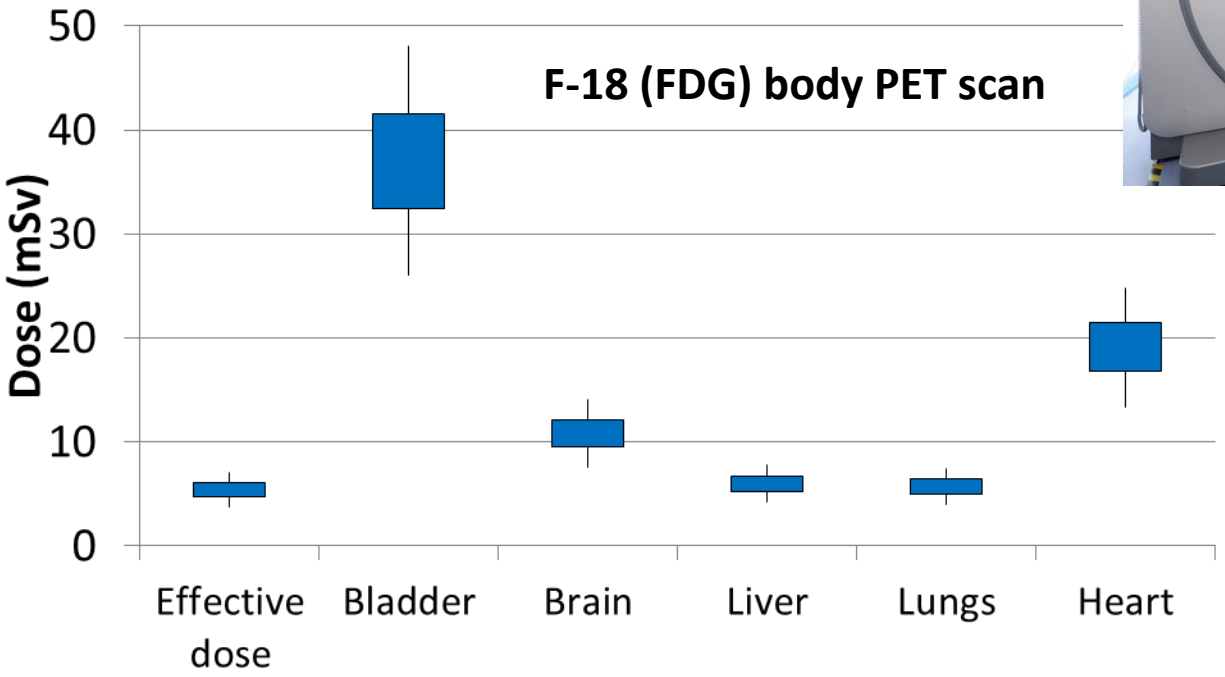
Toroi et al, Rad Prot Dosim 167 (2015)

Conversion factors to organ dose

Breast: ~ 1.2-1.4 mGy/mGy

Lungs: ~ 1.2-1.6 mGy/mGy

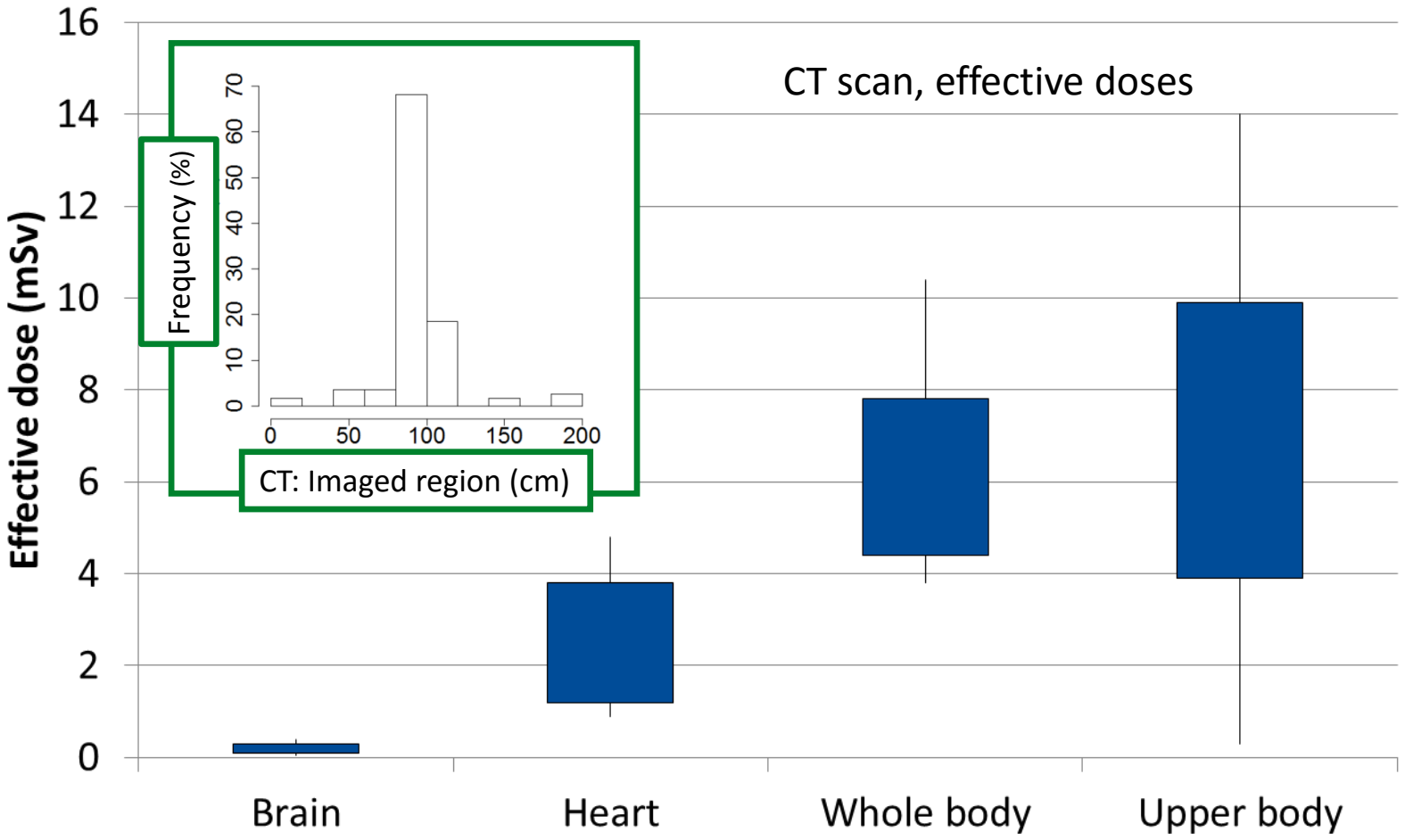
PET/SPECT-CT



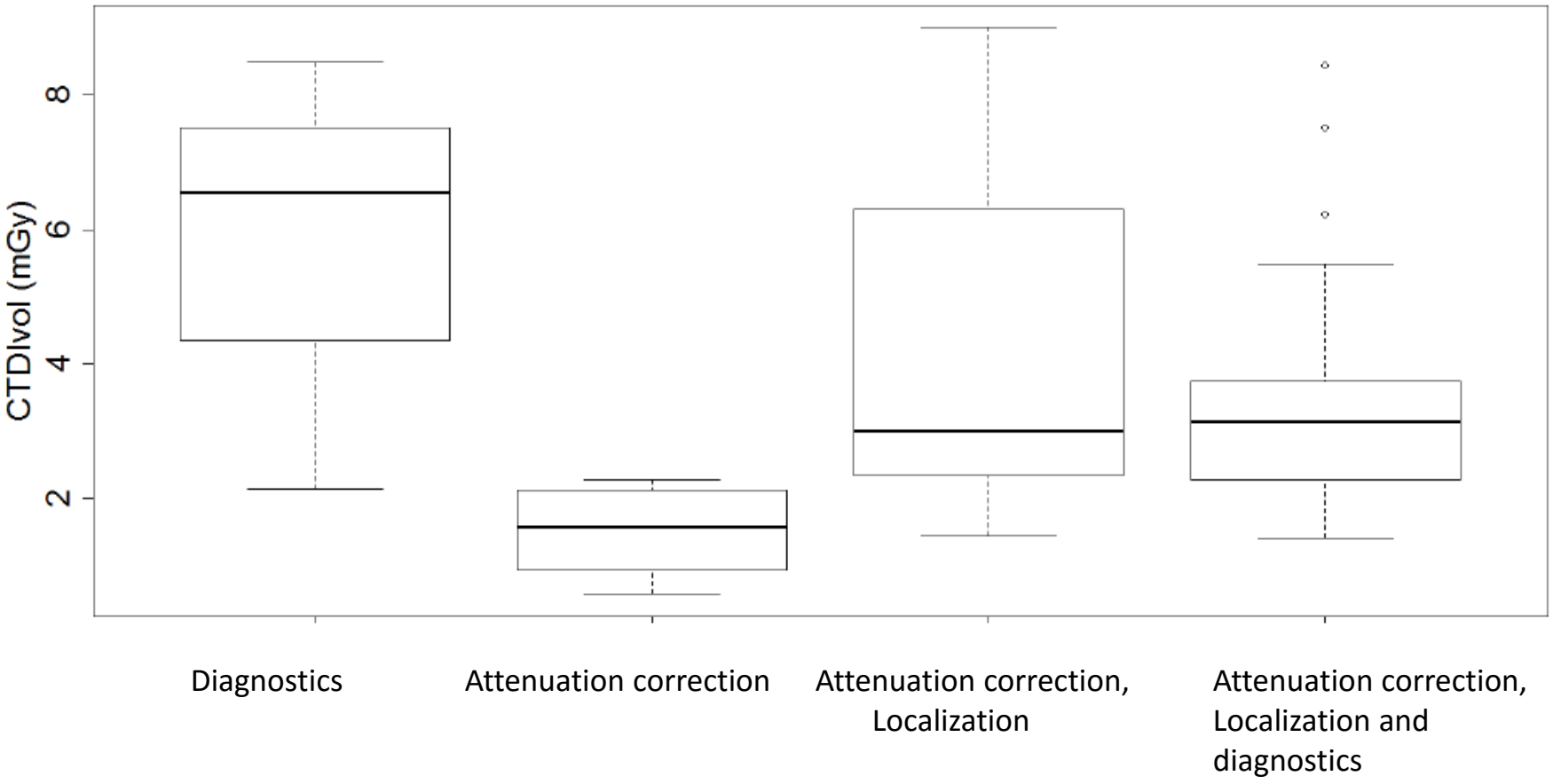
Median administrated activity 300 MBq

Conversion coefficients from ICRP 128

PET/SPECT-CT


CT scan, effective doses
Effective dose (mSv)
16
14
12
10
8
6
4
2
0
Brain
Heart
Whole body
Upper body
Frequency (%)
0
10
20
30
40
50
60
70
0
50
100
150
200
CT: Imaged region (cm)

PET/SPECT-CT



Primary use of the CT imaging

Imaging in radiotherapy process

10 - 100 mGy — Diagnosis and staging
- Plain radiography, CT, PET/SPECT-CT

10 - 100 mGy — Planning and simulation
- CT, MRI

100 - 1000 mGy — Set-up, motion tracking
- kV and MV x-rays, CBCT, motion tracking, (MRI)

10 – 100 mGy — Follow-up

This may add up to 1 – 2 Gy

Conclusions

- Doses from imaging vary significantly.
- There are cases where the contribution from imaging should be accounted for – even in the planning target volume.
- Traditionally, the doses from imaging were not considered to be important and therefore the optimization is not at mature stage. More work is needed!