Image Quality Optimisation and Dose Management in CT, SPECT/CT, and PET/CT

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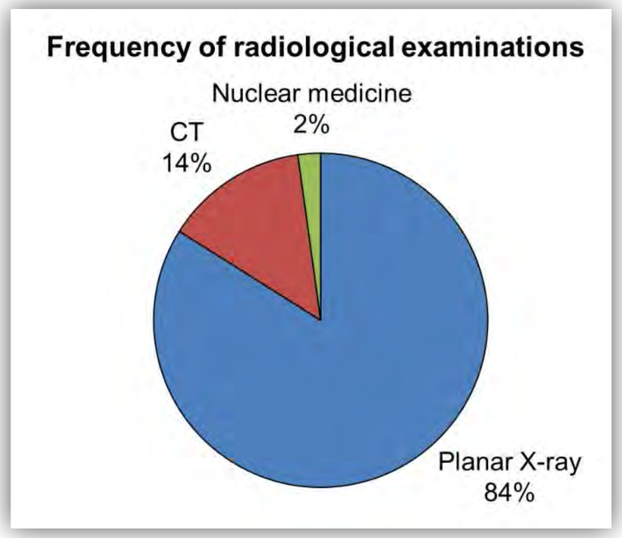
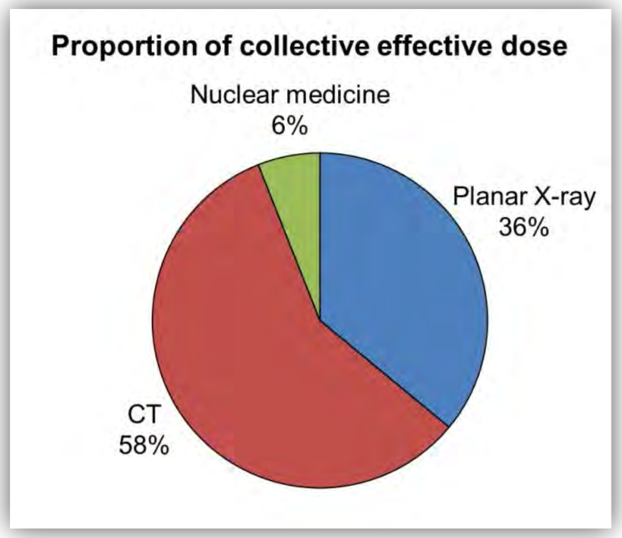
3 September 2013, Uppsala

Background

- Number of CT investigations increasing
- Hybrid imaging - SPECT/CT and PET/CT
- High-dose investigations compared to majority of planar X-ray investigations



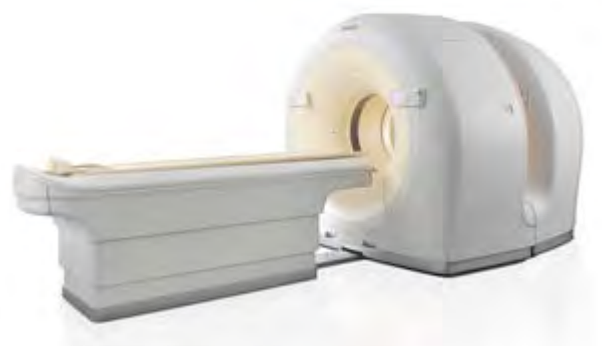


Almén et al., SSM Report 2008:03

Objectives

- Evaluate and optimise different approaches for minimising patient radiation absorbed dose and maintaining or improving image quality in CT, SPECT/CT, and PET/CT





Objectives

- Evaluate **automatic exposure control (AEC) systems** from different CT scanner manufacturers in terms of their potential for reducing absorbed dose to the patient while maintaining adequate image quality (Papers Ia and Ib)

- Evaluate an abdominal CT protocol reducing age-specific risks by balancing absorbed dose and the amount of intravenous (i.v.) **contrast medium** (CM) (Paper II)

- Estimate and optimise the absorbed dose and image quality of a new **cone-beam O-arm** imaging system for use in spinal surgery (Papers IIIa and IIIb)

- Describe and perform initial tests of a **new phantom** aimed at investigating spatial resolution, partial volume effect (PVE), and detectability in nuclear medicine tomography (Paper IV)

- Evaluate the influence of different image **reconstruction methods** for ^{123}I-MIBG-SPECT images using a rank-order study (Paper V)

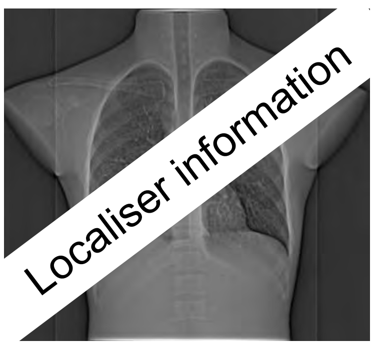
Papers Ia and Ib

Söderberg M, Gunnarsson M
Automatic exposure control in computed tomography – an evaluation of systems from different manufacturers
Acta Radiol 2010; 51(6): 625-634

Söderberg M, Gunnarsson M
The effect of different adaptation strengths on image quality and radiation dose using Siemens CARE Dose 4D
Radiat Prot Dosim 2010; 139(1-3): 173-179

AEC in CT

- Adaptation of the tube current relative patient attenuation



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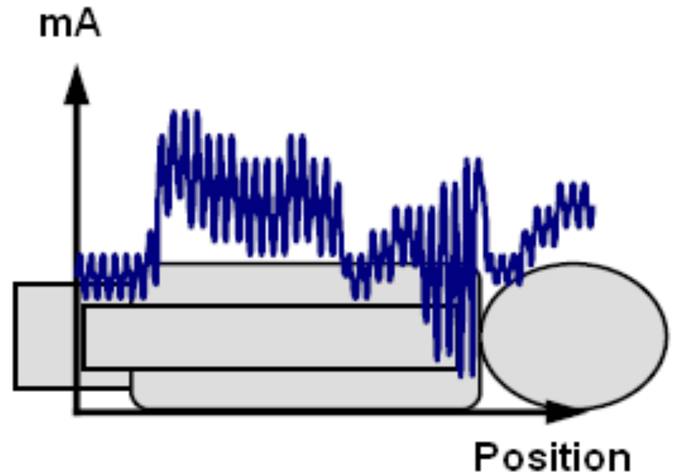
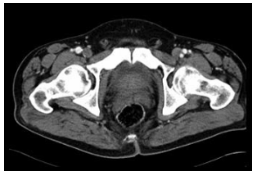
Attenuation profiles





130 mAs

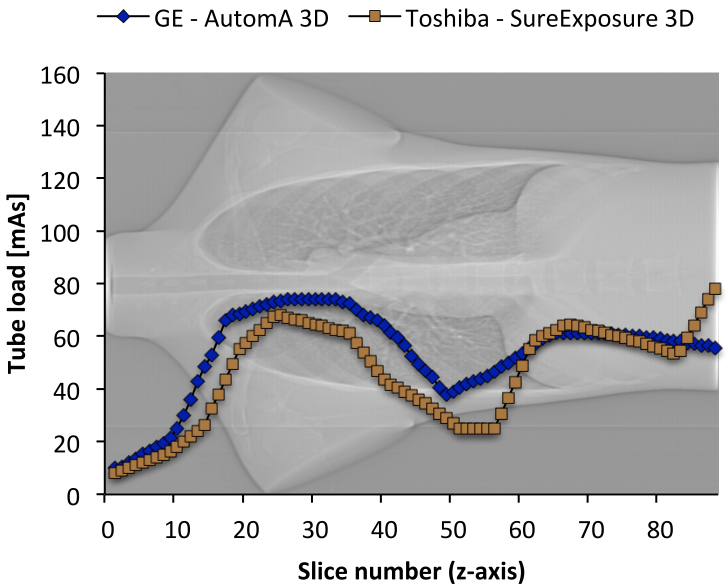
110 mAs

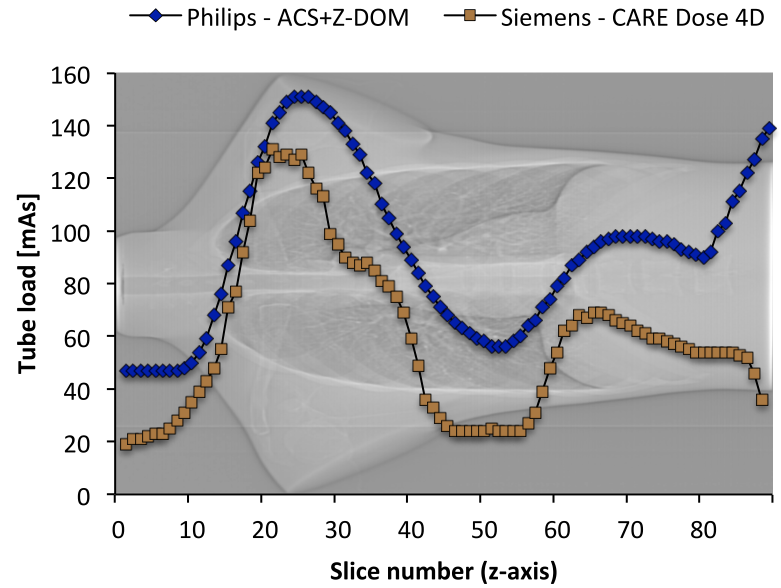
55 mAs

140 mAs

Illustrations: ImPACT Report 05016 and Siemens

Dynamics of tube current modulation, 64-slice





Fixed mAs: 100
Image quality: NI=12, min mA=10, max mA=200
Dose reduction: 48%

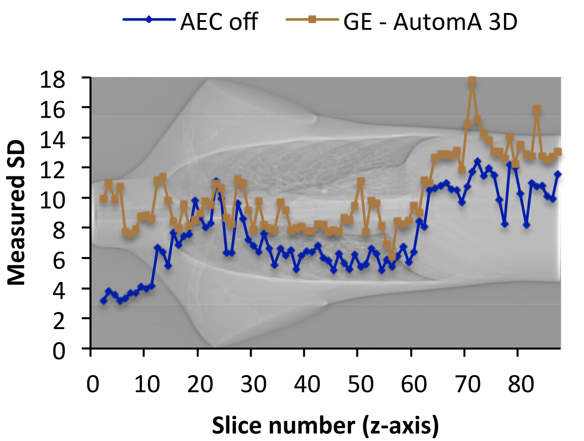
PHILIPS
Fixed mAs: 200
Image quality: 200 mAs/slice
Dose reduction: 51%

TOSHIBA
Fixed mAs: 100
Image quality: SD=10, min mA=10, max mA=500
Dose reduction: 59%

SIEMENS
Fixed mAs: 100
Image quality: Quality ref mAs=100, Average/Average
Dose reduction: 43%

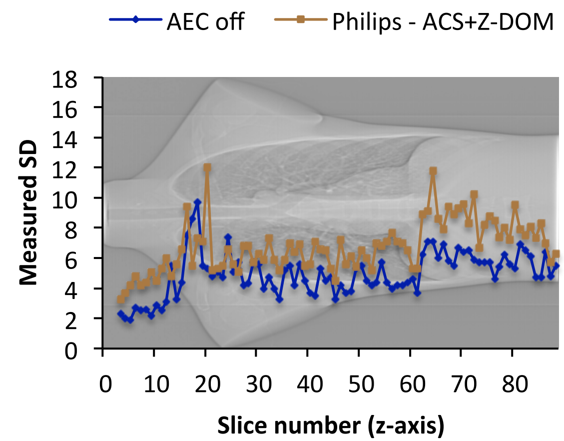
$$C_V = \frac{SD}{\text{Mean SD}} \cdot 100$$

Image quality / noise, 64-slice



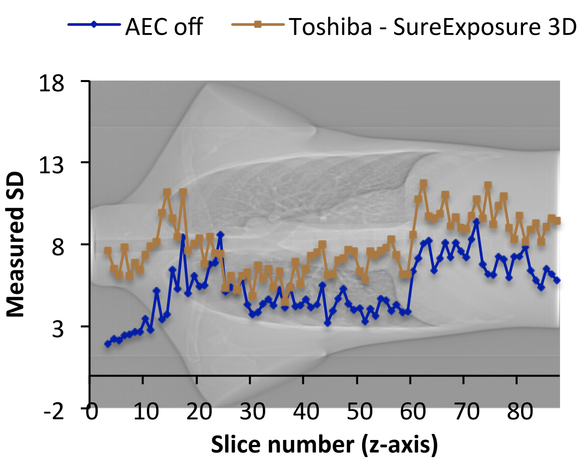
$C_{V,\ \text{AEC off}}$ = **34%**

$C_{V,\ \text{AutomA 3D}}$ = **23%**



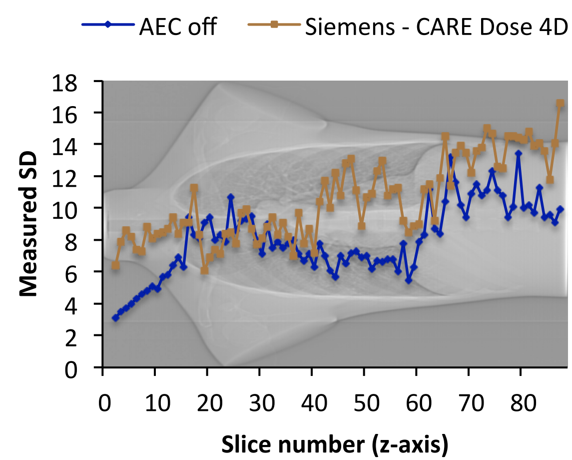
$C_{V,\ \text{AEC off}}$ = **30%**

$C_{V,\ \text{ACS+Z-DOM}}$ = **25%**



$C_{V,\ \text{AEC off}}$ = **33%**

$C_{V,\ \text{SureExposure 3D}}$ = **22%**

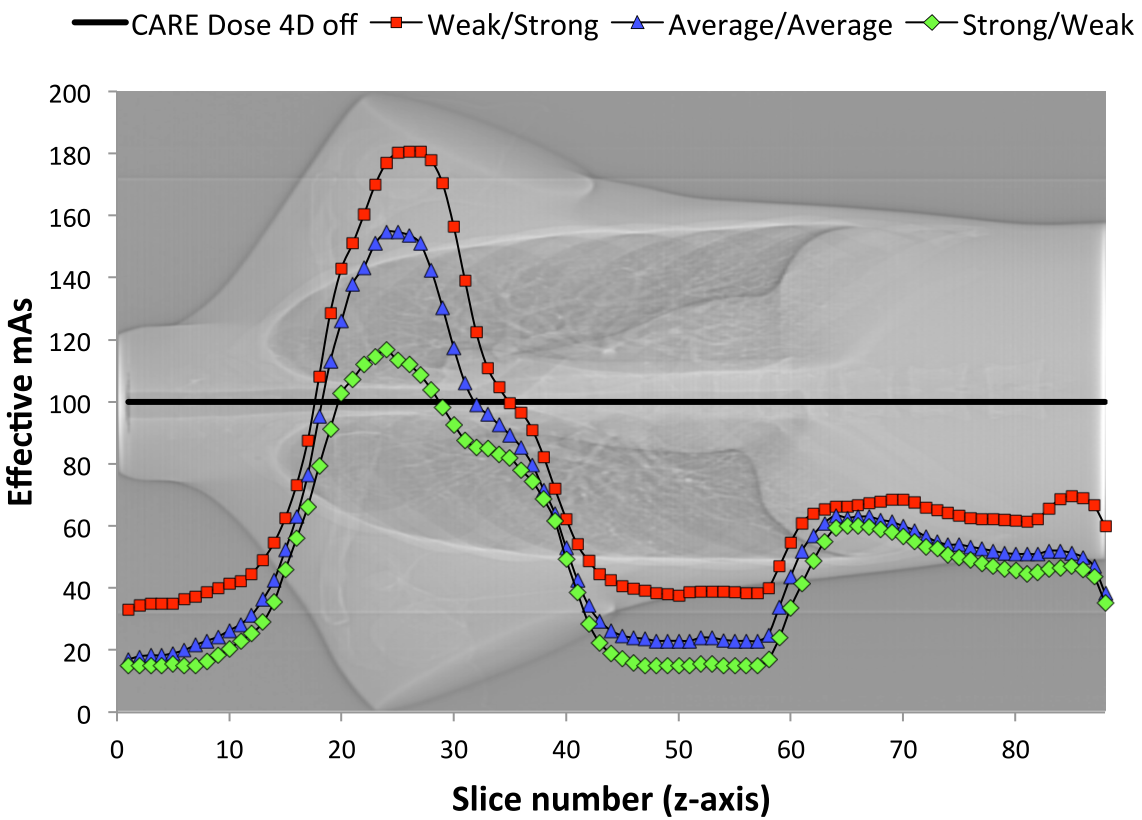


$C_{V,\ \text{AEC off}}$ = **28%**

$C_{V,\ \text{CARE Dose 4D}}$ = **24%**

Dynamics of tube current modulation

Siemens SOMATOM Sensation 16 – CARE Dose 4D



Dose reduction:

27-52 %

Conclusion

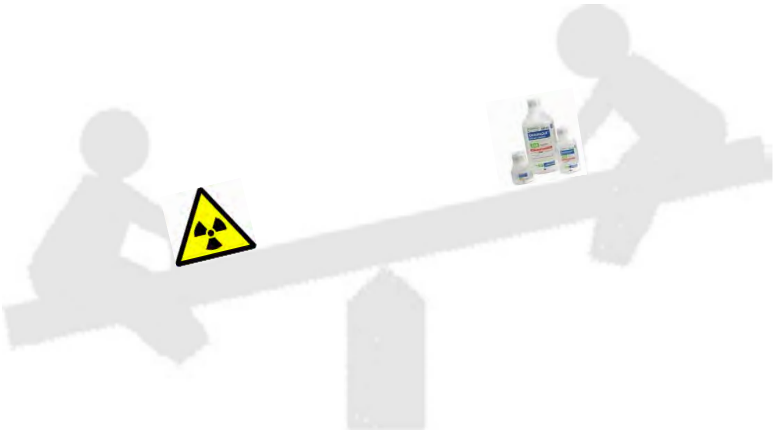
- AEC systems available in modern CT scanners can contribute to a significant reduction in absorbed dose to the patient
- The reduction ranged from 35-60% for an anthropomorphic chest phantom depending on the system and AEC settings
- The variation in image noise among images obtained along the scanning direction was lower when using the AEC systems, but the image noise generally increased
- User-specified variance of the adaptation strengths in Siemens AEC system can modify image quality or absorbed dose to the patient

Paper II

Fält T, Söderberg M, Hörberg L, Carlgren I, Leander P

A seesaw balancing radiation dose and intravenous contrast medium dose – evaluation of a new abdominal CT protocol reducing age-specific risks

Am J Roentgenol 2013; 200(2): 383-388

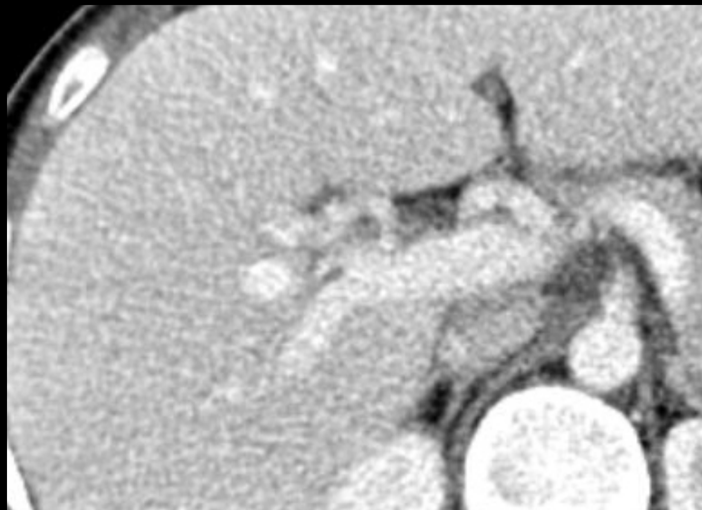


Radiation dose vs amount of contrast medium

- Two important risks associated with abdominal contrast enhanced CT are ionising radiation and contrast induced nephropathy (CIN)
- The risks for potential adverse effects from ionising radiation is greater in young patients
- Patients with reduced renal function and the elderly are at a higher risk for CIN

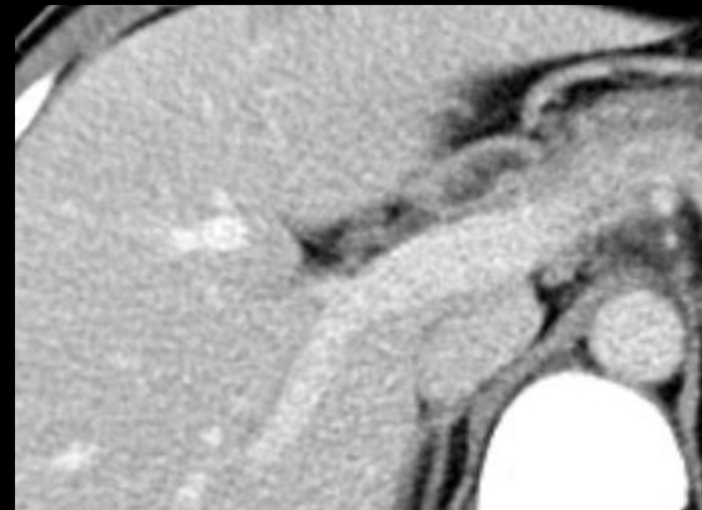
Younger patients:	↑	amount of i.v. CM,	↓	absorbed dose	maintain CNR
Older patients:	↓	amount of i.v. CM,	↑	absorbed dose	

Group I : 100 mAs – 600 mg I/kg
16-25 years



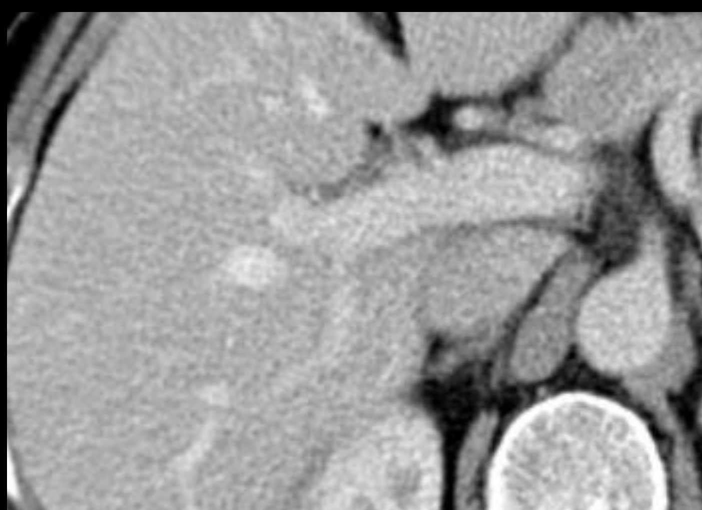
3.6 mSv

Group II : 150 mAs – 500 mg I/kg
26-50 years



6.6 mSv

Group III : 200 mAs – 420 mg I/kg
51-75 years

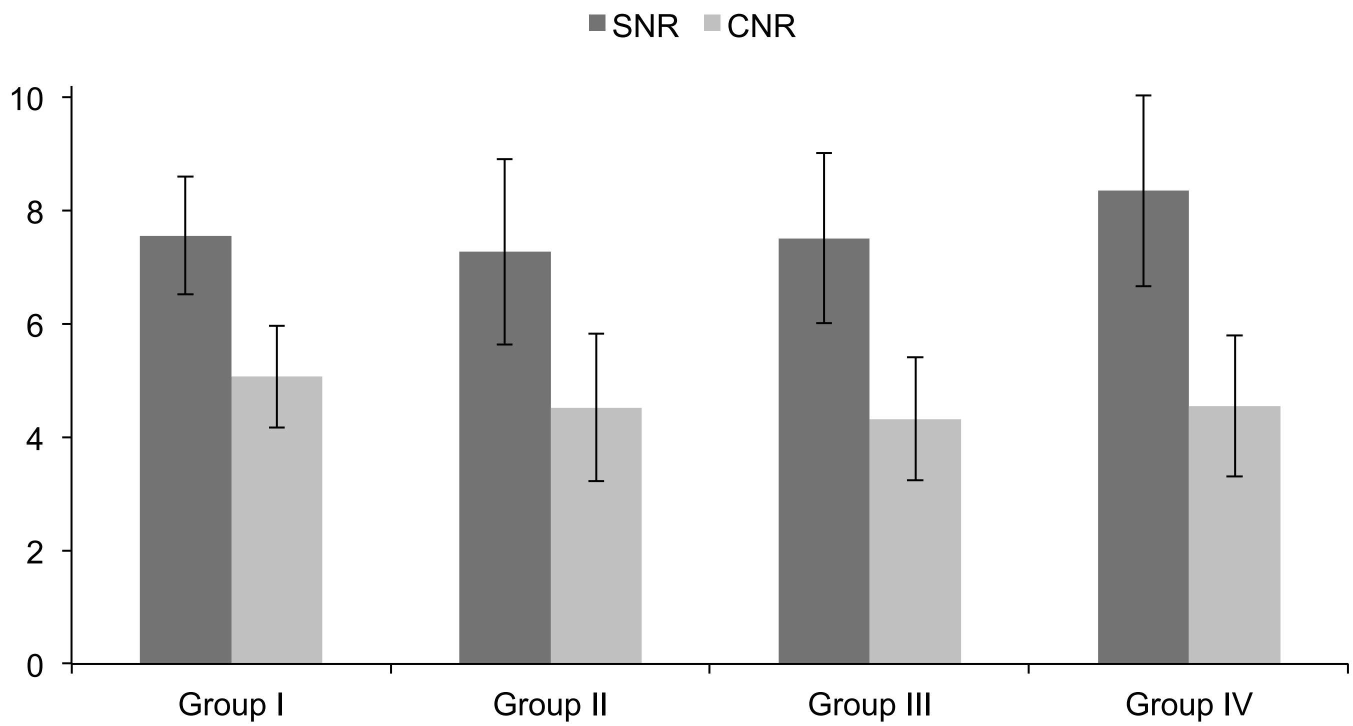


8.5 mSv

Group IV : 300 mAs – 350 mg I/kg
>75 years

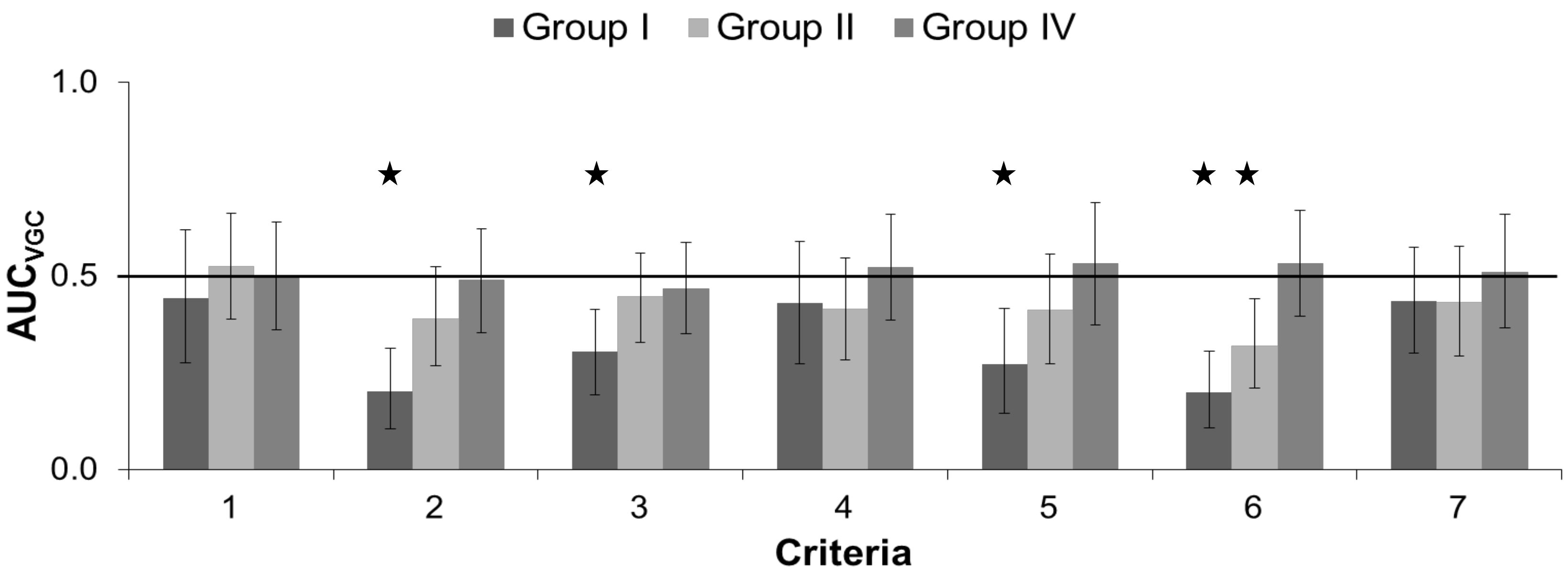
12 mSv

SNR and CNR



- ANOVA and Tukey´s test could not establish significant differences in SNR and CNR between the groups

VGC analysis



1. Visually sharp reproduction of the **liver parenchyma** and intrahepatic portal veins
2. Visually sharp reproduction of the **pancreatic contours**
3. Visually sharp reproduction of the **kidneys and proximal ureters**
4. Reproduction of the **gallbladder wall**
5. Visually sharp reproduction of the right **adrenal gland** from adjacent structures
6. Visually sharp reproduction of the structures of the **liver hilus**
7. Reproduction of the ductus choledocus in the **pancreatic parenchyma**

Conclusion

- Effective dose was reduced by 57% in the youngest patient group (16-25 years of age) and the amount of i.v. CM was reduced by 18% in the elderly group (>75 years of age)

- An increased amount of i.v. CM can compensate for a reduced radiation absorbed dose and vice versa, maintaining the SNR in the liver and CNR for a hypothetical hypovascular liver metastasis

- Subjective image quality was affected by an increased noise level in the images but was judged to be acceptable in all groups except the one with the lowest radiation absorbed dose

Papers IIIa and IIIb

Söderberg M, Abul-Kasim K, Ohlin A, Gunnarsson M
Estimation of organ and effective dose to the patient during spinal surgery with a cone-beam O-arm system
Proc SPIE 2011; 7961(79613G): 1-6

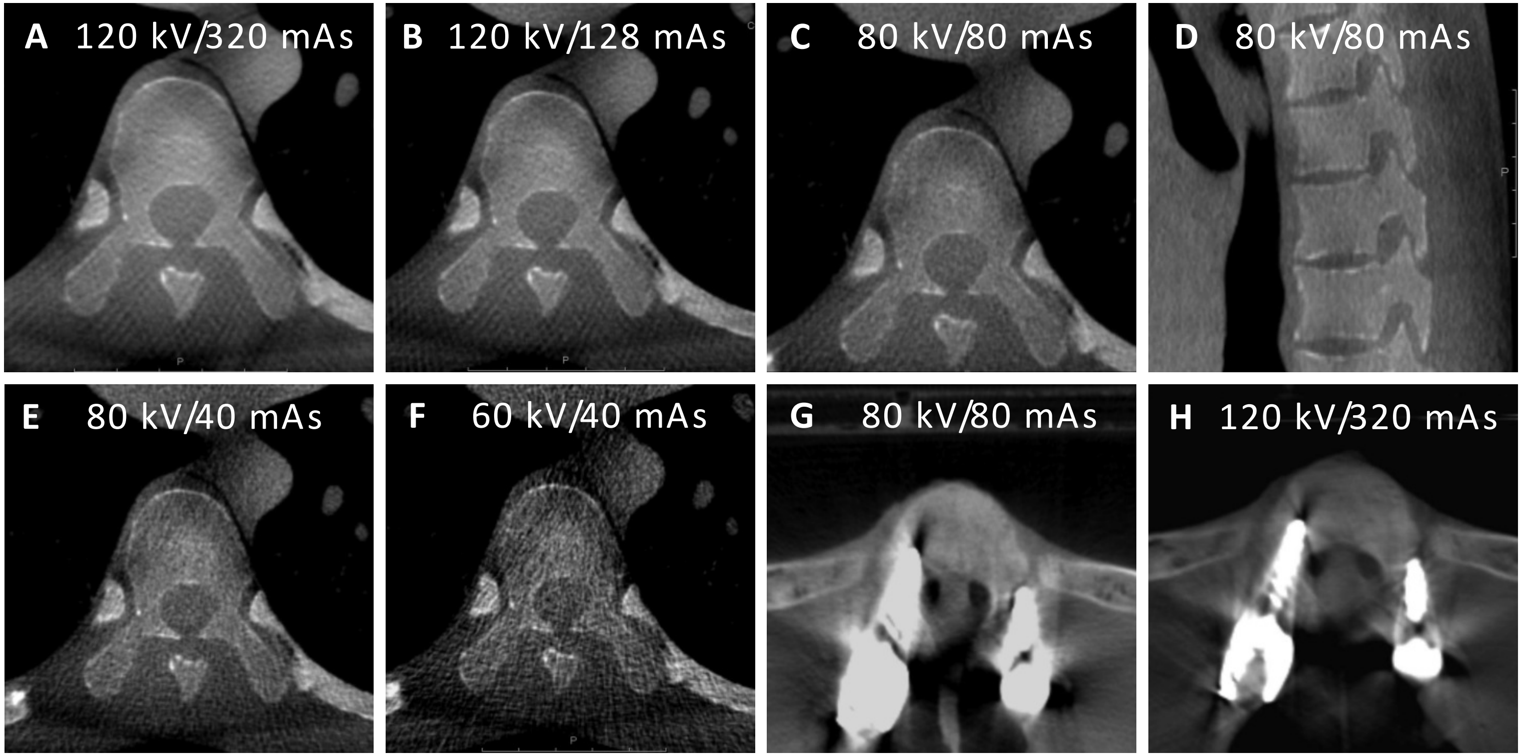
Abul-Kasim K, Söderberg M, Selariu E, Gunnarsson M, Kherad M, Ohlin A
Optimization of radiation exposure and image quality of the cone-beam O-arm intraoperative imaging system in spinal surgery
J Spinal Disord Tech 2012; 25(1): 52-58

The O-arm imaging system

- Cone-beam CT – conventional X-ray tube and a flat panel detector
- Spinal surgery – delineate the cortical borders of the pedicles, helping the surgeon correctly insert the pedicle screws between the inner and outer pedicular cortex

- Evaluate optimised scan settings:
  - 120 kV / 320 mAs (large patient)
  - 120 kV / 128 mAs (small patient)
  - 80 kV / 80 mAs
  - 80 kV / 40 mAs
  - 60 kV / 40 mAs

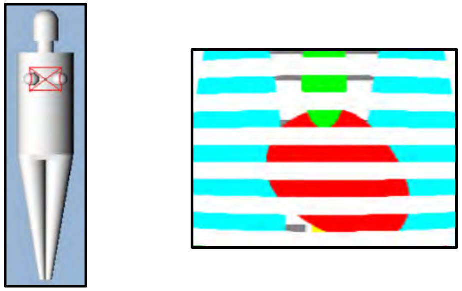
Evaluation of image quality

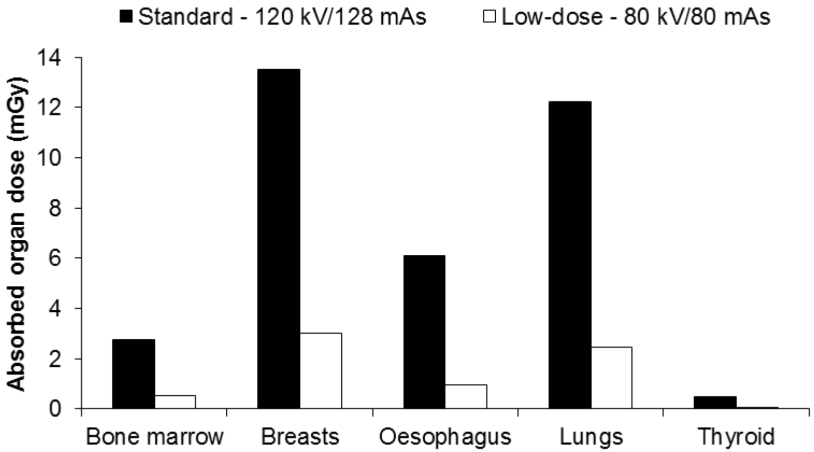


- Images with 80 kV/80 mAs were considered reliable with good interobserver agreement when measuring the pedicular width and almost perfect agreement when evaluating the screw placement

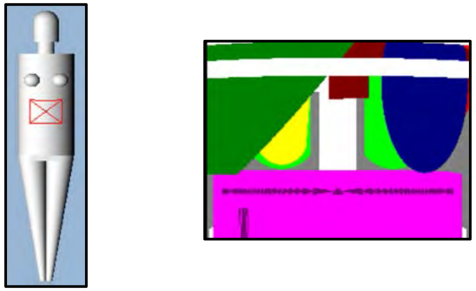
Estimation of organ and effective dose – PCXMC

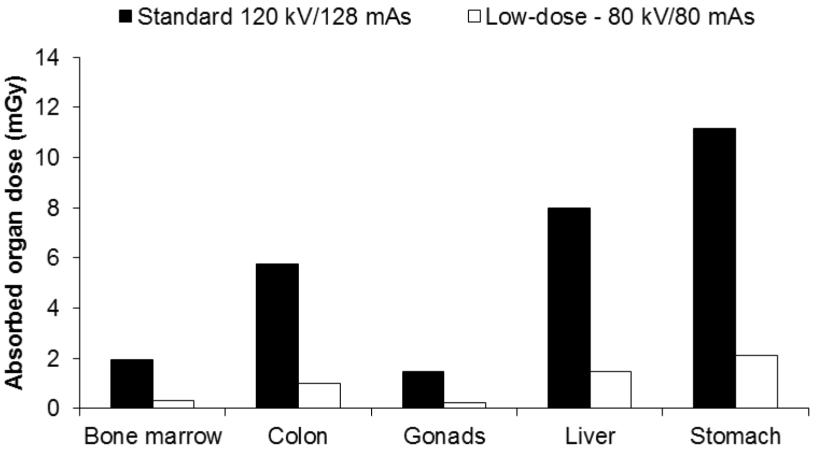
Thoracic spine





Lumbar spine





- Often 2-3 scans per patient is needed: ~10 mSv vs ~2 mSv

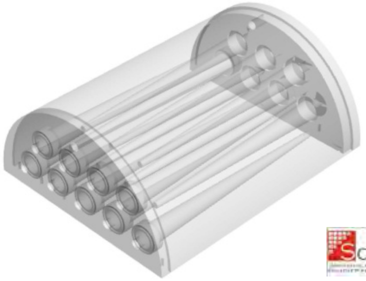
Conclusion

- The effective dose can be reduced to 1.5-2.4 mSv (80 kV / 80 mAs), which is 5 times lower than using the scan settings recommended by the manufacturer (120 kV / 128 mAs) for intra-operative imaging of the chest and abdominal regions in a small patient

- Such a dose reduction does not negatively impact image quality with regard to the information required for spinal surgery

Paper IV

Söderberg M, Engeland U, Mattsson S, Ebel G, Leide-Svegborn S
Initial tests of a new phantom for investigation of spatial resolution, partial volume effect and detectability in nuclear medicine tomography
J Phys Conf Ser 2011; 317(012017): 1-7



Conclusion

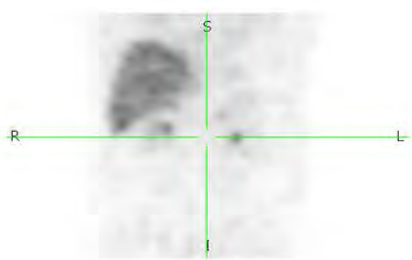
- The MADEIRA phantom has the potential to be a useful and important practical tool for comparing and optimising different acquisition and reconstruction parameters in nuclear medicine tomographic studies

Paper V

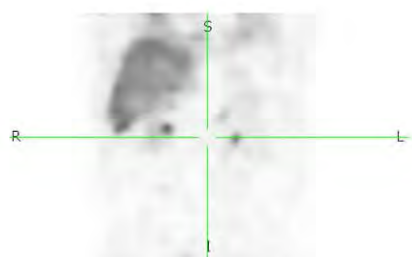
Söderberg M, Mattsson S, Oddstig J, Uusijärvi-Lizana H, Valind S, Thorsson O, Garpered S, Prautzsch T, Tischenko O, Leide-Svegborn S
Evaluation of image reconstruction methods for ^{123}I-MIBG-SPECT: a rank-order study
Acta Radiol 2012; 53: 778-784

Conclusion

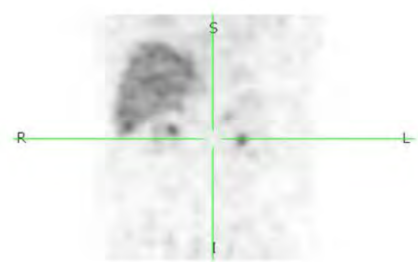
- Using Siemens Symbia T6 SPECT/CT and specified acquisition parameters, Flash $3D_{32}$ (4 h) and Flash $3D_{16}$ (24 h), followed by ReSPECT, were assessed to be the preferable reconstruction algorithms in visual assessment of ^{123}I-MIBG images



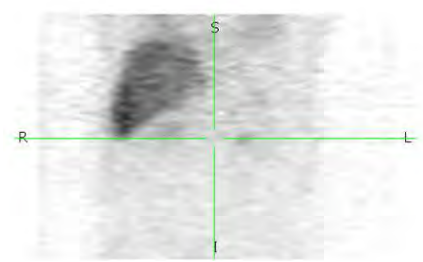
Flash $3D_{32}$



ReSPECT

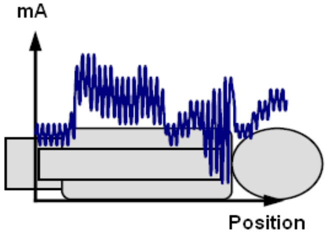


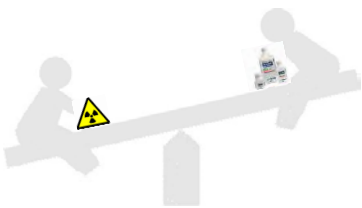
Flash $3D_{64}$

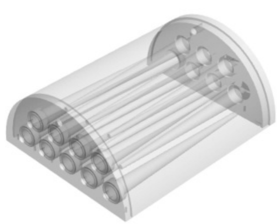


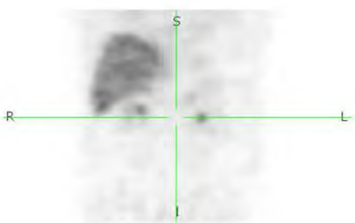
OPED

Summary



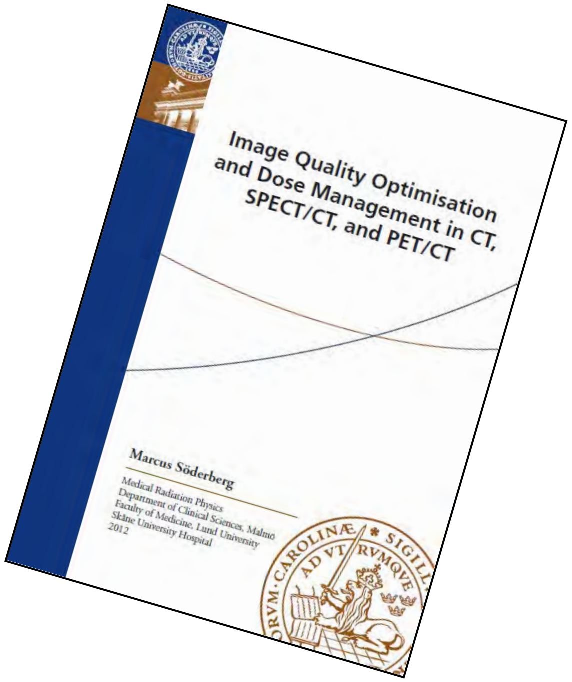






Several approaches are used to minimise radiation absorbed dose and improve image quality

Establish sufficient image quality for a specific diagnostic task with the lowest effective dose to the patient



Thanks for your attention!

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