MCMA2017 – International Conference om
Monte Carlo Techniques for Medical Applications
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Monte Carlo Methods for Diagnostic Radiology

Willi Kalender, Ph.D.

Institute of Medical Physics
University Erlangen-Nürnberg
www.imp.uni-erlangen.de

MCMA2017 is my first time at an MC conference, although I worked on MC topics from 1976-78.
It led to my PhD degree at the Univ. of Wisconsin + 2 publications in the journal Phys. Med. Biol.

Monte Carlo calculations of x-ray scatter data for diagnostic radiology

Willi Kalender,†

Medical Physics Division, Department of Radiology, University of Wisconsin, Madison, WI 53706, USA

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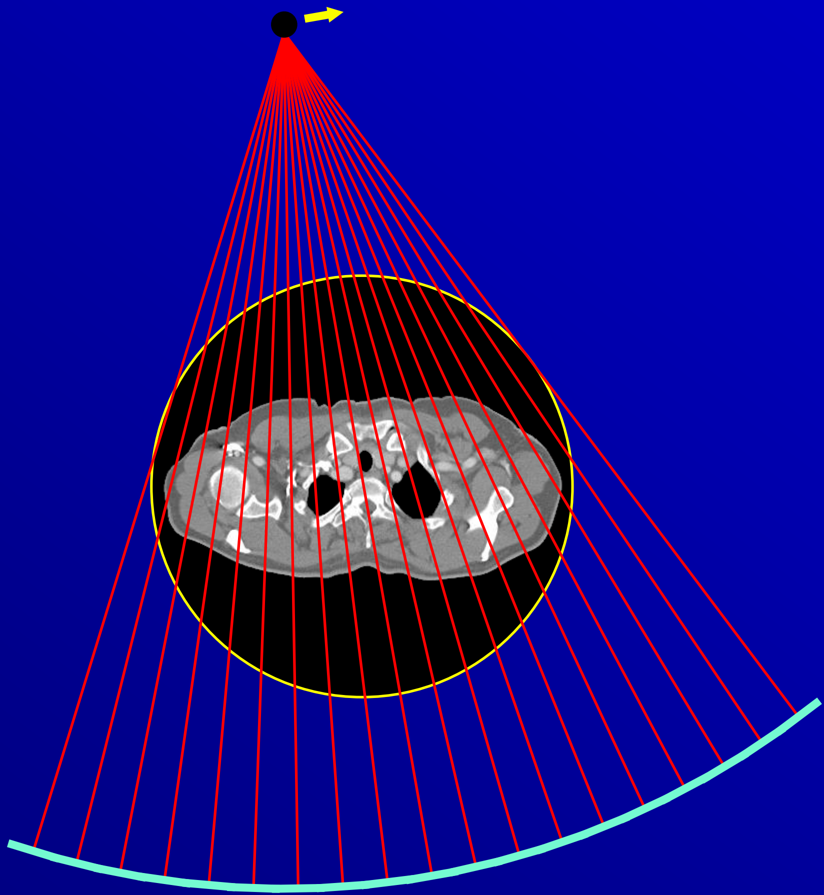
Abstract. x-ray scatter data have been calculated by Mone Carlo methods for diagnostic radiology applications. The scatter intensities relative to the primary intensities are given for different detectors for various values of object thickness, field size, object-to-detector distance, and primary energy. The results are compared with those from previous investigations. The calculations made it possible to resolve contradictions in published measurements regarding the dependence of scatter intensities on primary x-ray energy and

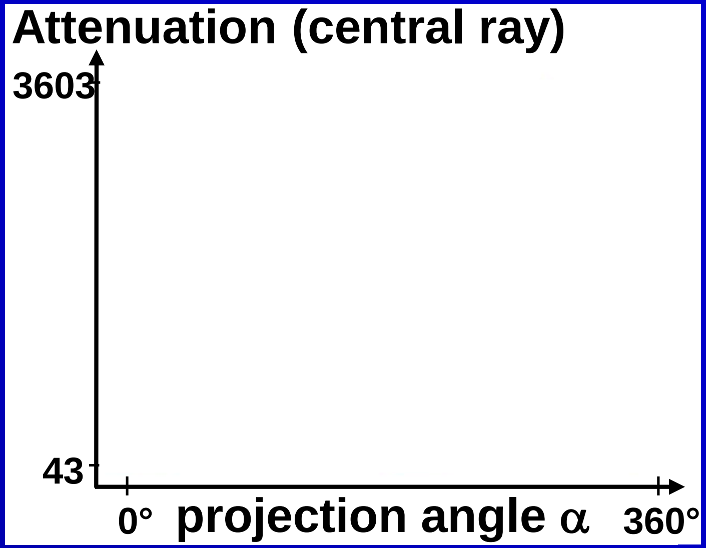
What can MC add to Diagnostic Radiology?

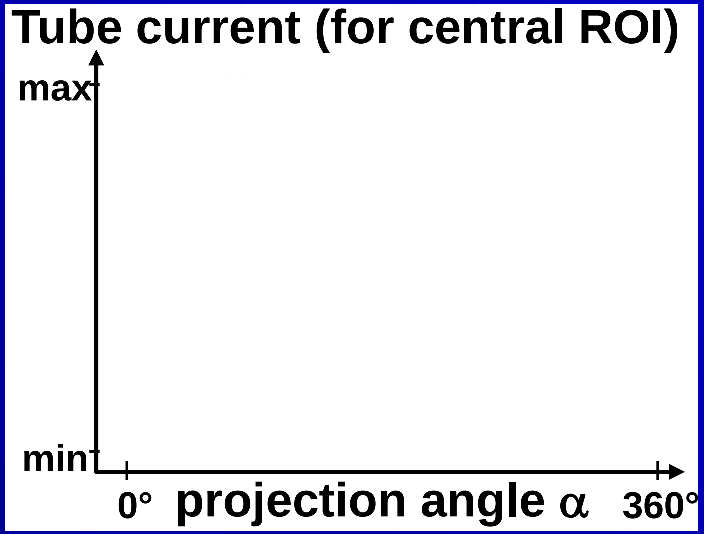
- MC calculation of x-ray dose
- support innovative technological approaches to reduce patient dose

- Tube current modulation
- Optimisation of X-ray spectra
- Dose efficient image reconstruction
- Detector systems with higher efficiency

In-plane or rotational TCM (α-TCM)







Attenuation for the central ray:

in a.p. direction: 43

in lateral direction: 3603

Attenuation-based Tube Current Modulation

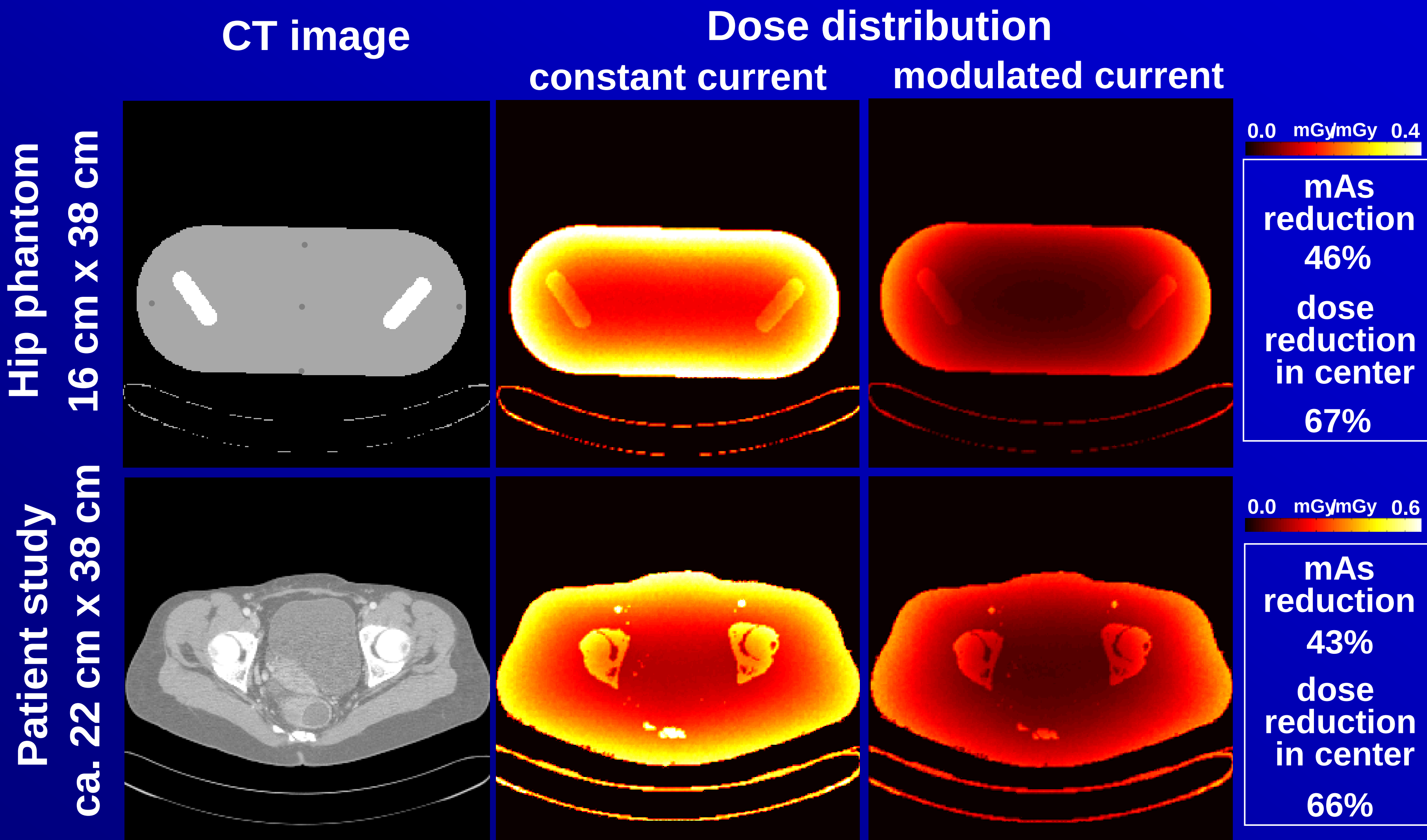
Conventional scan: 327 mAs

Online current modulation: 166 mAs

53% mAs reduction on average for the shoulder region
49% mAs reduction in this case

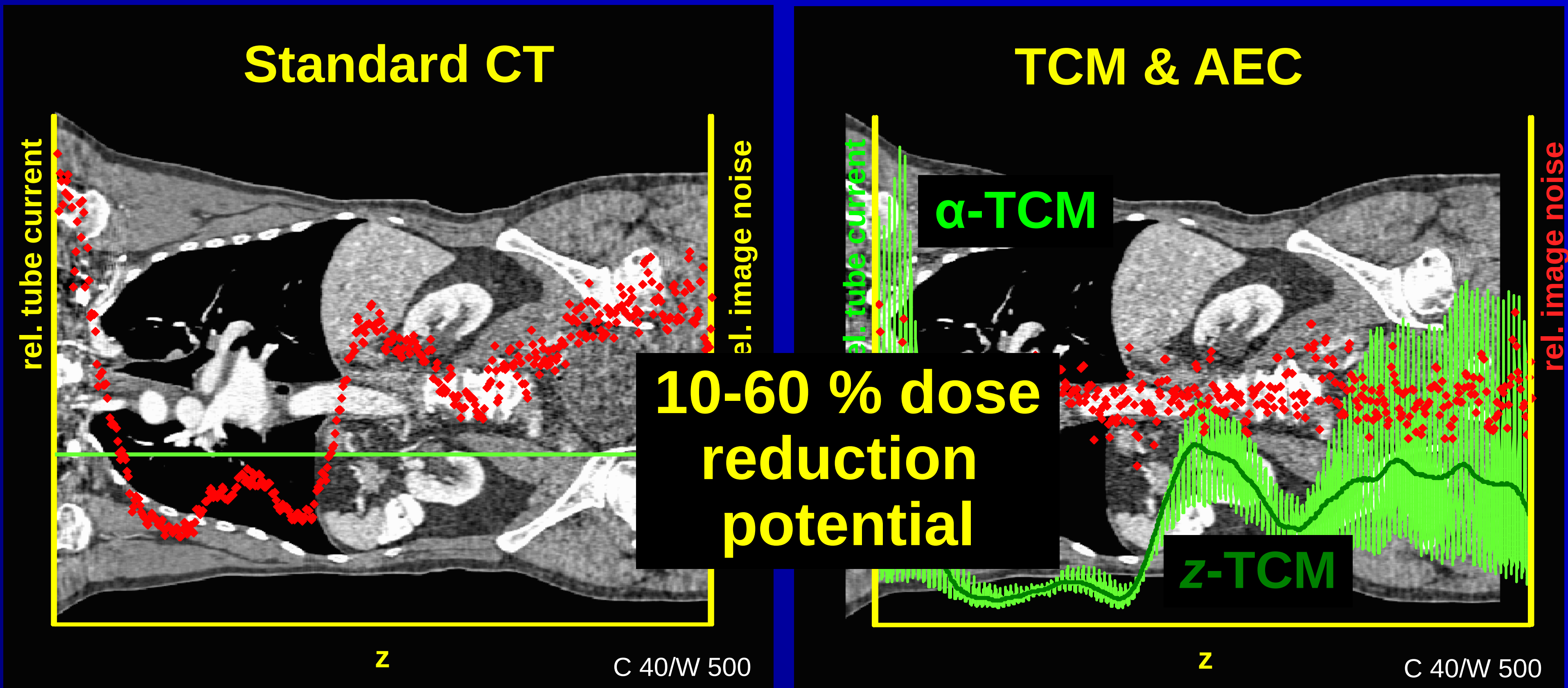
Kalender WA et al. Med Phys 1999; 26(11):2248-2253

mAs Reduction vs. Patient Dose Reduction



Kalender WA. Computed Tomography. Wiley, New York 2001

Tube Current Modulation (TCM) and Automatic Exposure Control (AEC)

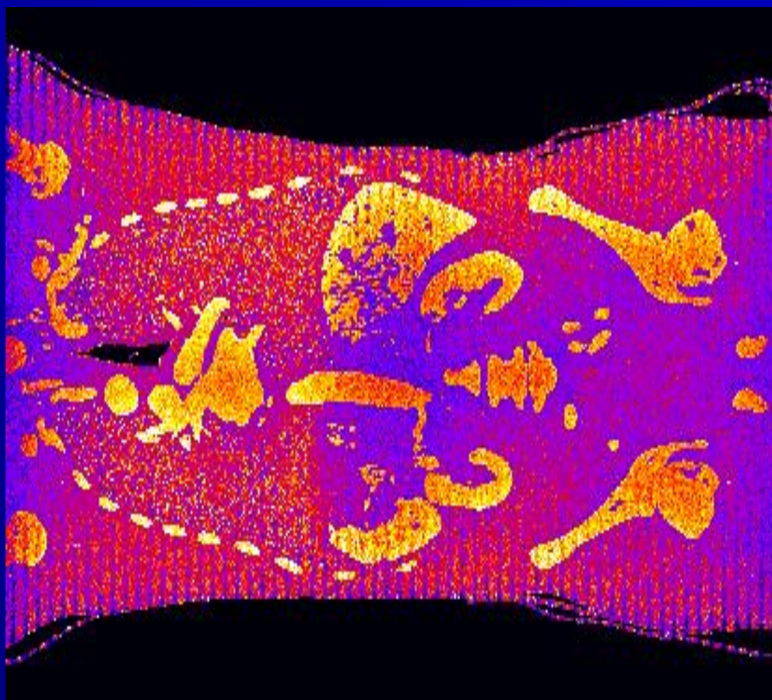


Principle of operation

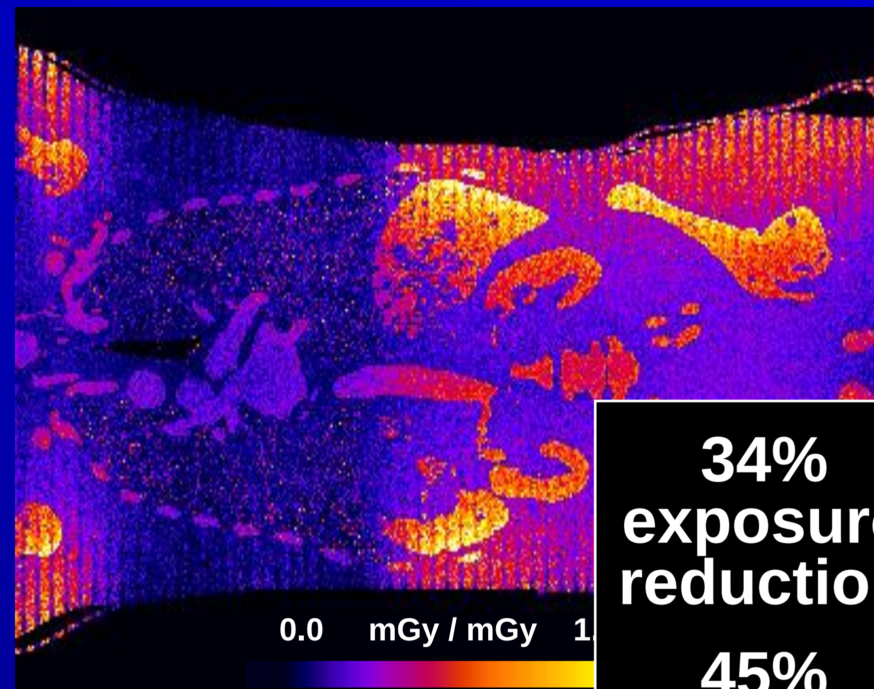
Detectors with smaller z-extent yield better performance!

Kalender WA. Computed Tomography. 2nd ed. Wiley, New York 2005

Tube Current Modulation (TCM) and Automatic Exposure Control (AEC)



Constant tube current



AEC

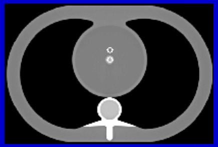
34% exposure reduction

45% dose reduction (center)

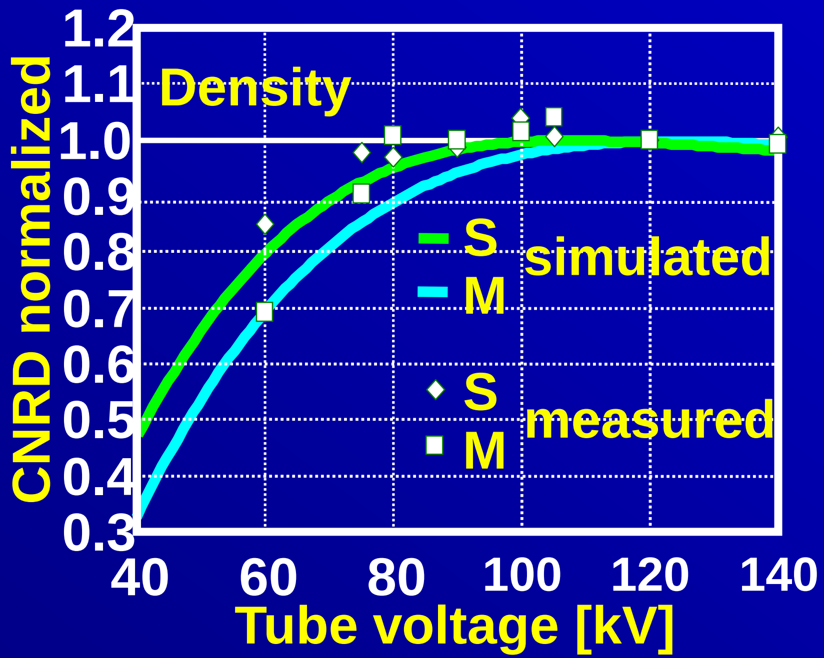
Resulting 3D dose distributions

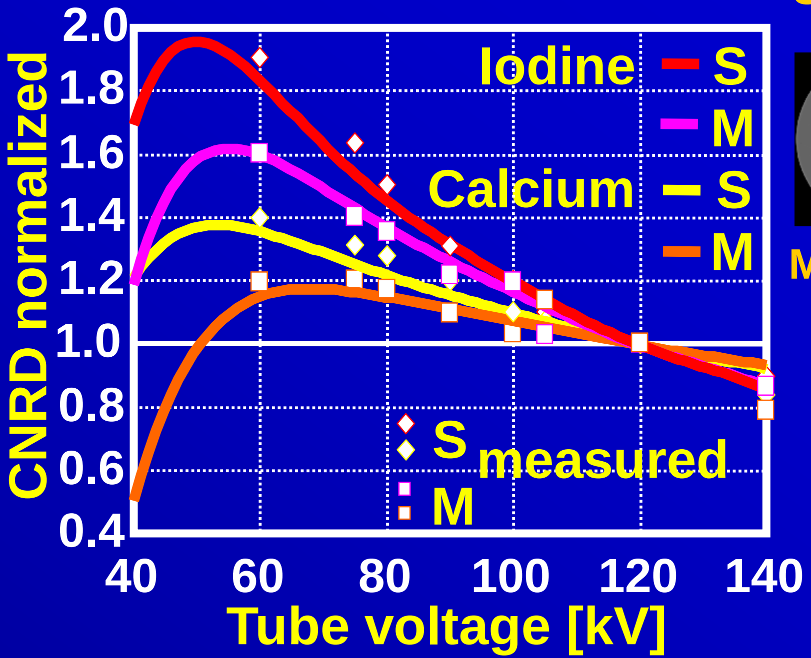
Spectral Optimization for Thoracic CT

Simulations and Measurements


S: 300 x 200


M: 350 x 250

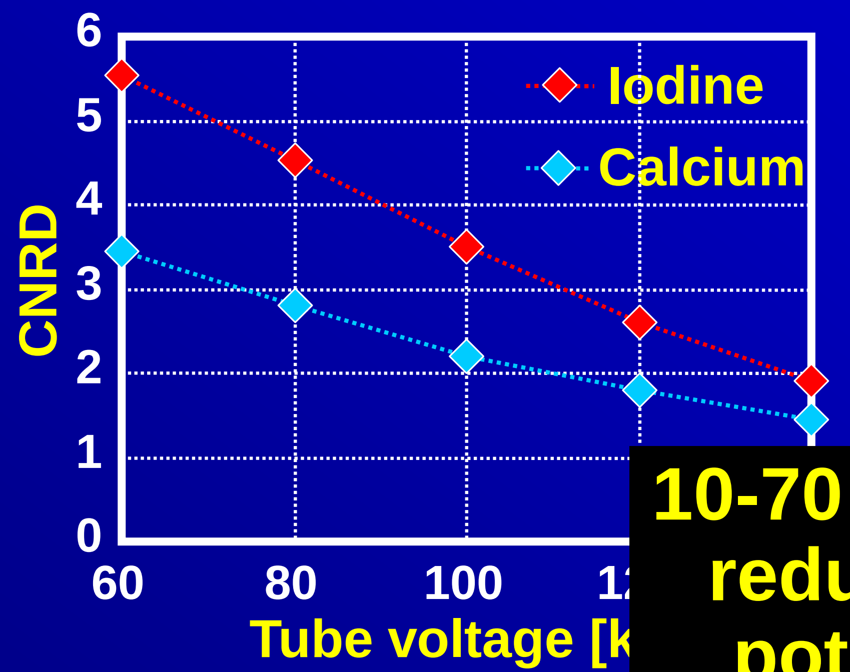


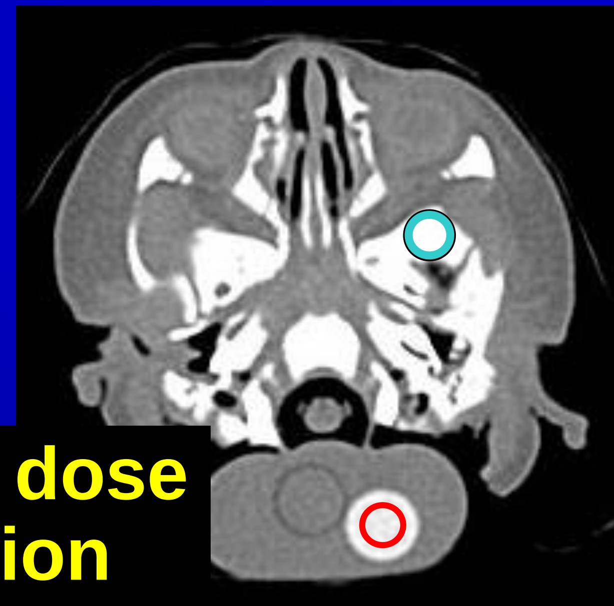


Contrast due to	Density		Iodine		Calcium	
Size	S	M	S	M	S	M
Optimum tube voltage	110 kV	120 kV	50 kV	60 kV	50 kV	70 kV
Change in dose at const. CNR 120 kV → 80 kV	+ 9 %	+ 21 %	- 53 %	- 45 %	- 37 %	- 24 %

Kalender et al. Med Phys 2009; 36:993-1007

Spectral Optimization for Pediatric CT
Cadaver Measurements





10-70 % dose reduction potential

Contrast due to	Iodine	Calcium
Optimum tube voltage	< 80 kV	< 80 kV
Change in dose at const. CNR 120 kV → 80 kV	- 67 %	- 62 %

Kalender et al. Med Phys 2009; 36:993-1007

Summary of dose reduction potential

	typ. values
• Optimal choice of x-ray spectra	10-70%
• TCM & AEC	10-60%
• Elimination of z-overscanning effects	5-30%
• Dose-efficient image reconstruction	20-80%
• New detector developments	10-40%
• ...	

- The indicated reduction by a total of >80%, i.e. by at least a factor of 5, appears realistic and makes sub-mSv CT a realistic option.

CT with intelligent approches and innovative technology

70 cm/s Tischvorschub bei 70 kV
mit TCM, dyn. Kollimierung, iterative reconstruction
and dose-efficient „low noise“-detector:
0.22 mSv effective dose!

Courtesy of Stefan Schönberg, U of Mannheim

Niedrigere Dosis, bessere Bilder?

- **Ja, niedrigere Dosis und bessere Bilder sind gleichzeitig erreichbar!**
- **Das Ziel ist aber nicht, die niedrigste Dosis zu wählen, sondern die richtige Dosis.**

(http://www.ub.uni-erlangen.de/)

IOPscience

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Dose in x-ray computed tomography

FEATURED ARTICLE REVIEW ARTICLE

Thank you for your attention!

Risk estimates for a 0.2 mSv CT scan

- Assumption of the worst possible case:
  „5% mortality per 1 Sv effective dose“ valid for the high-dose range holds for the low-dose range also.
- This would mean:
  5 persons out of 100 exposed to 1 Sv (high dose),
  5 persons out of 100.000 exposed to 1 mSv or
  1 person out of 100.000 exposed to 0.2 mSv
  is at risk of dying from x-ray-induced cancer.
- Risks between 1:100.000 and 1:10.000 are generally termed „very low“.

Eur. Radiol. 9, 555–562 (1999)

Physics

European Radiology

Original article

A PC program for estimating organ dose and effective dose values in computed tomography

W. A. Kalender[1], B. Schmidt[1], M. Zankl[2], M. Schmidt[1]

[1] Institut für Medizinische Physik, Universität Erlangen, Krankenhausstrasse 12, D-91054 Erlangen, Germany
[2] Institute of Radiation Protection, GSF National Research Center for Environment and Health, Neuherberg, Germany

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Abstract. Dose values in CT are specified by the manufacturers for all CT systems and operating conditions in phantoms. It is not trivial, however, to derive dose values in patients from this information. Therefore, we have developed a PC-based program which

277 mm

calculates organ dose and effective dose values for arbitrary scan parameters and anatomical ranges. Val-

quency of use in clinical radiology is still increasing. Although it was assumed that MRI would largely substitute CT, the introduction of spiral CT [1], a volume-scanning mode which has been generally established, has renewed interest in CT. New applications based on spiral CT, e.g. CT angiography or multiphasic imaging of the liver, indicate an upward trend. Conse-