Performance evaluation for new-technology CT systems

256-Channel CT

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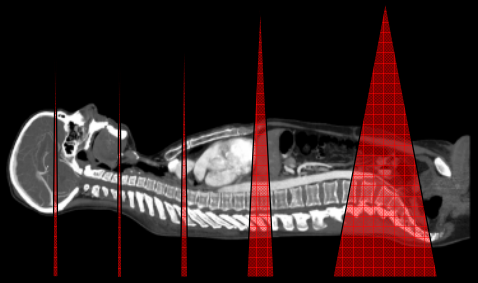
Performance evaluation for new-technology CT systems
256-Channel CT



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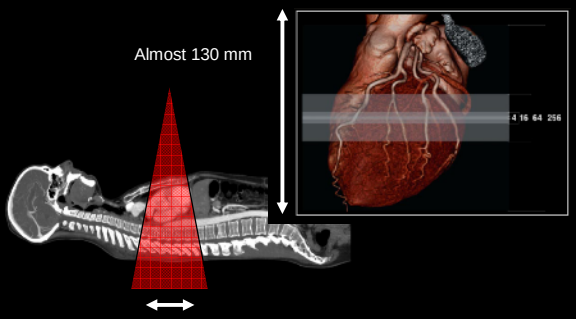


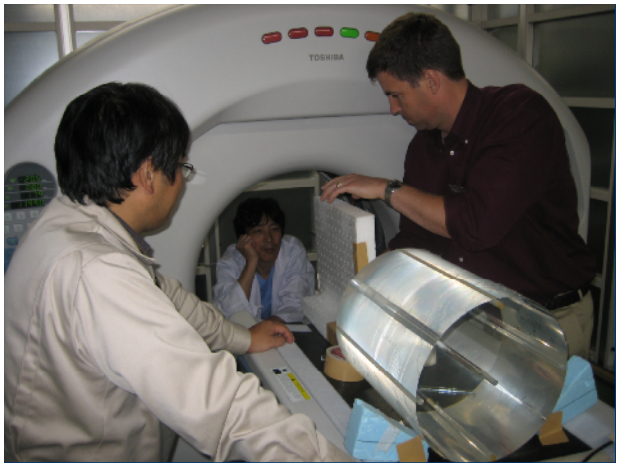
Performance evaluation for new-technology CT systems
256-Channel CT

- Medical physicists are challenged to assess the new technology of 256-Channel CT scanners:
  - Current concepts for measurement of image quality still remain valid (PSF, MTF, NPS)
  - **Concepts for CT dosimetry will have to change fundamentally**

Performance evaluation for new-technology CT systems 256-Channel CT

- First: experimental 256 Channel CT Scanner at the Japanese National Institute of Radiological Sciences
- Now also: Toshiba prototype 256 Channel CT scanner

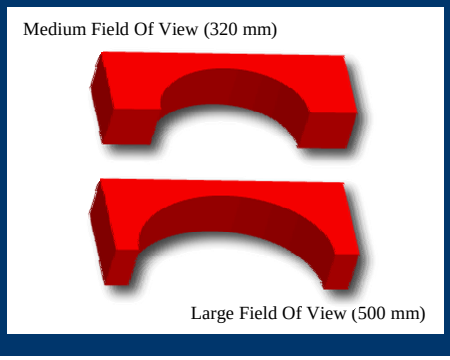
Toshiba prototype 256 Channel CT scanner



Methods for dosimetry with 256-Channel CT

- Characterisation of the x-ray beam
  - Measurements free in air
- Dosimetry in phantoms
  - Cilindrical CT dose phantoms
- Patient dose
  - Monte Carlo dosimetry and voxel phantoms

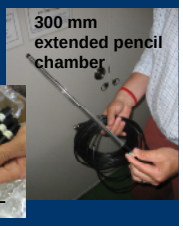
Two wedge filters: 320 mm FOV and 500 mm FOV

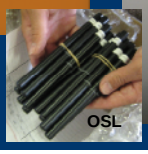


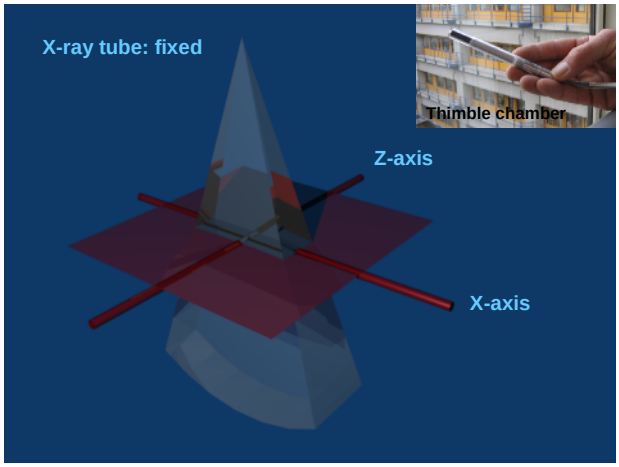
Characterisation of the x-ray beam

- Dosimetry free in air
  - Small ionisation chamber (thimble, 2.4 cm lenght)
  - Film dosimetry (GafChromic XR-QA)
  - Extended CT ionization chamber (extended pencil, 30 cm lenght)
  - Optically stimulated luminescence (OSL) dosemeter

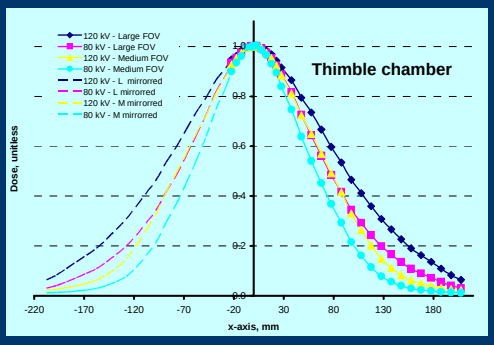
GafChromic XR-QA 25.4 x 30.5 cm



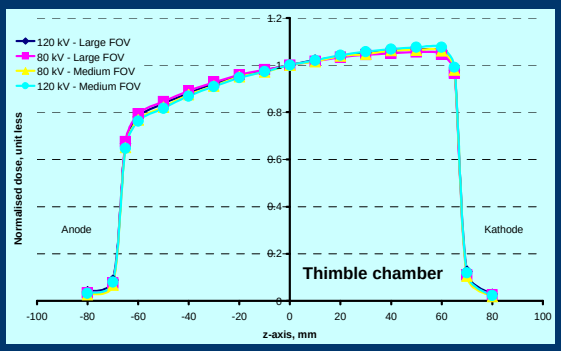


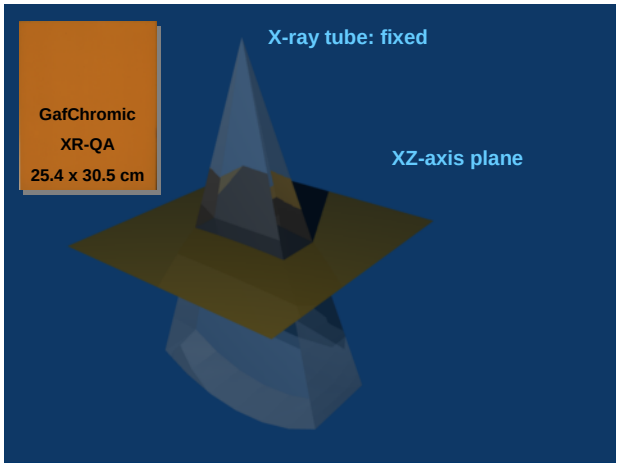


X-axis (axial plane) profile in air



Z-axis profile in air

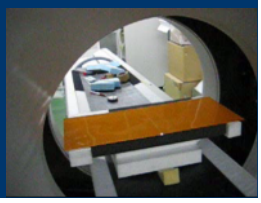




Film dosimetry

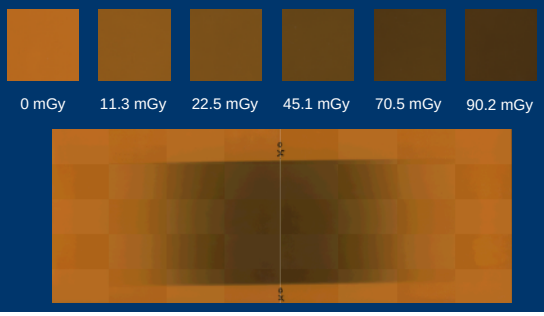
- Gafchromic XR-QA film
- Sensitive in the 0 – 100 mGy range
- 2D dose profile

- X-ray tube: fixed at 12 o'clock position

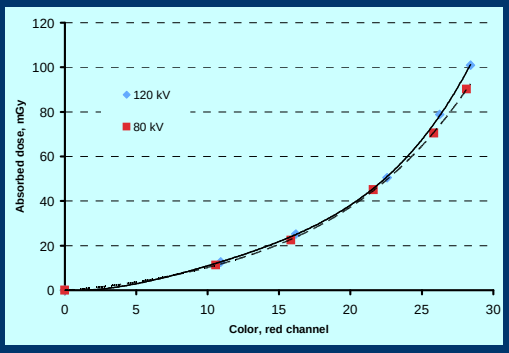


GafChromic XR-QA dosimetry and calibration

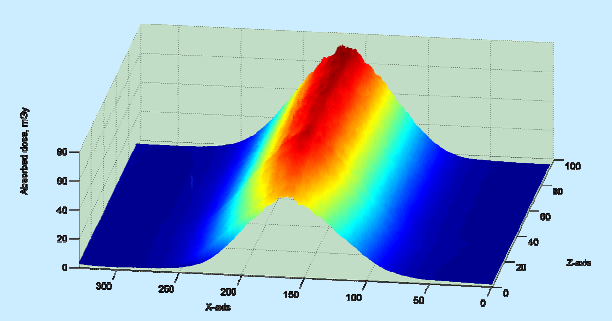
Entire FOV, fixed x-ray tube, film at the level of the Center Of Rotation (COR)



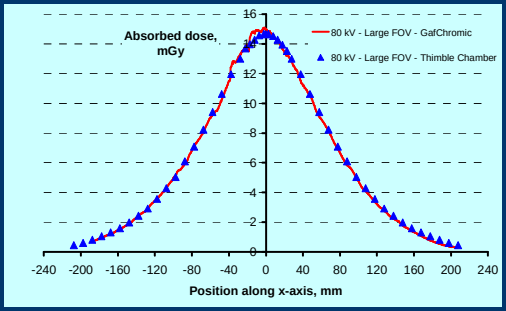
GafChromic XR-QA film calibration curve



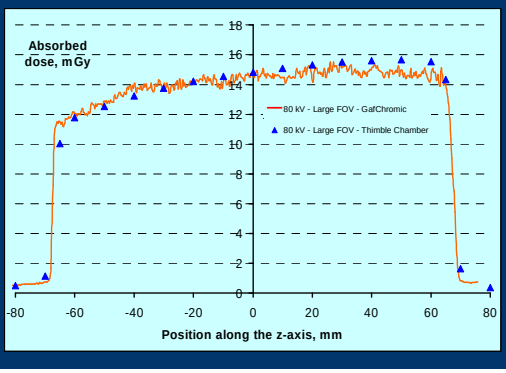
GafChromic XR-QA 2D dose distribution

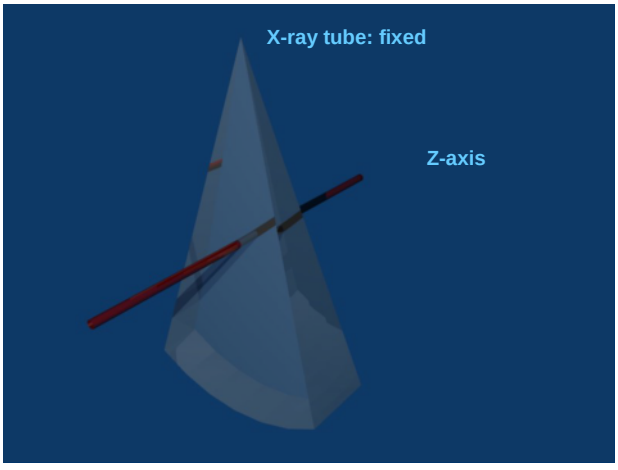


Comparison of thimble chamber and Gafchromic XR-QA film: profile along the x-axis

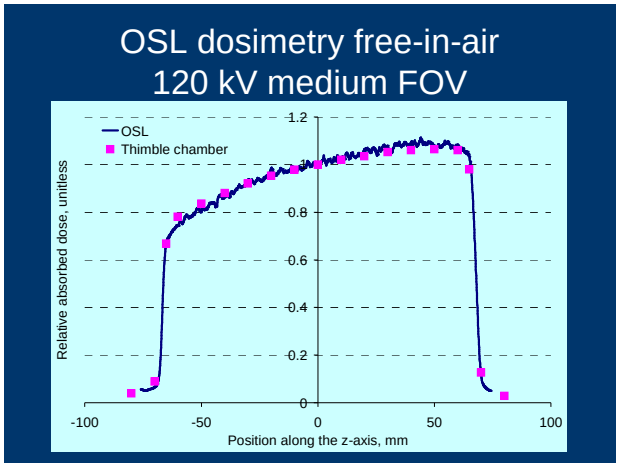


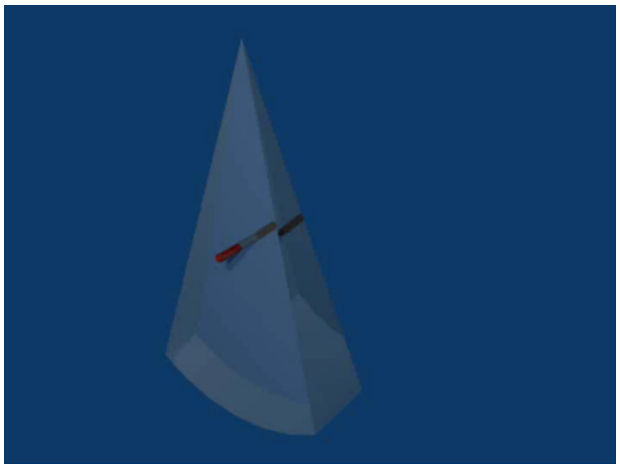
Comparison of thimble chamber and Gafchromic XR-QA film: profile along the z-axis

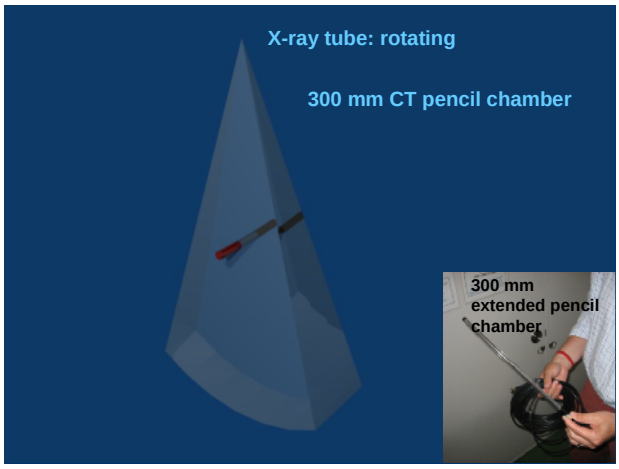





(courtesy Mike McNittGray and Rich Mather)


OSL dosimetry free-in-air
120 kV medium FOV
OSL
Thimble chamber
Relative absorbed dose, unitless
1.2
1
0.8
0.6
0.4
0.2
0
-100
-50
0
50
100
Position along the z-axis, mm




X-ray tube: rotating
300 mm CT pencil chamber
300 mm
extended pencil
chamber

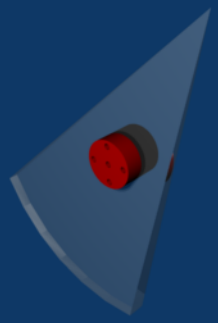
Dosimetry in phantoms

The “correct” way:

- Extended (350 mm) CT dose phantoms: head and body
  - Extended CT ionization chamber (extended pencil, 300 mm lenght); or
  - Optically stimulated luminescence (OSL) dosemeter

The “incorrect” way:

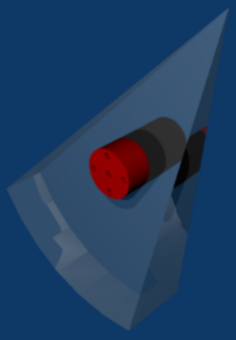
- Regular (150 mm) CT dose phantoms: head & body
  - Regular CT ionization chamber (pencil, 100 mm length)



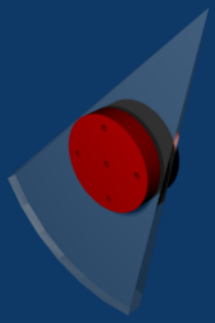
- 64 Channels
- CT Head Phantom
- 150 mm Long Phantom
- 100 mm Pencil Chamber

- 256 Channels
- CT Head Phantom
- 150 mm Long Phantom
- 100 mm Pencil Chamber is too small ….

The “correct” way



- 256 Channels
- CT Head Phantom
- 350 mm Long Phantom
- 300 mm Pencil Chamber



- 64 Channels
- CT Body Phantom
- 150 mm Long Phantom
- 100 mm Pencil Chamber

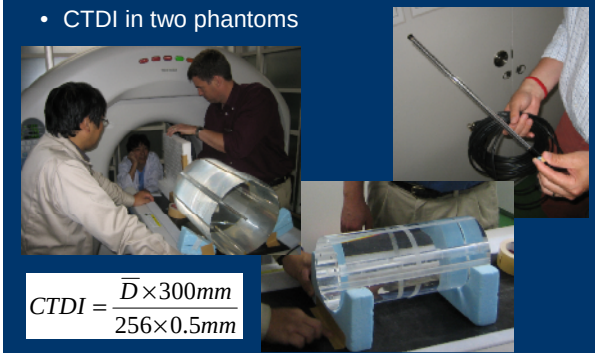
- 256 Channels
- CT Body Phantom
- 150 mm Long Phantom is too small ….
- 100 mm Pencil Chamber is too small ….

The “correct” way

- 256 Channels
- CT Body Phantom
- 350 mm Long Phantom
- 300 mm Pencil Chamber

$CTDI_{300}$: 300 mm pencil chamber
(courtesy Yoshihisa Muramatsu)

- CTDI in two phantoms



$$CTDI = \frac{\overline{D} \times 300mm}{256 \times 0.5mm}$$

The "incorrect" way in a head phantom
NOT CTDI but an average dose

- 256 Channels
- CT Head Phantom
- 150 mm Long Phantom
- 100 mm Pencil Chamber

Average dose (D) in a 150 mm long head phantom measured with a 100 mm CT chamber relative to $CTDI_{300}$ (CTDI)

kV	Wedge	Phantom	Center	Periphery	Weighted
			D/CTDIc	D/CTDIp	**D/CTDIw**
80	**L**	**head**	82%	93%	**89%**
80	**M**	**head**	83%	92%	**89%**
120	**L**	**head**	82%	93%	**89%**
120	**M**	**head**	82%	94%	**90%**

The "incorrect" way in a body phantom
NOT CTDI but an average dose

- 256 Channels
- CT Body Phantom
- 150 mm Long Phantom
- 100 mm Pencil Chamber

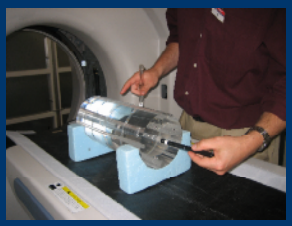
Average dose (D) in a 150 mm long body phantom measured with a 100 mm CT chamber relative to $CTDI_{300}$ (CTDI)

kV	Wedge	Phantom	Center	Periphery	Weighted
			D/CTDI	D/CTDI	**D/CTDIw**
80	**L**	**body**	69	104%	**97%**
80	**M**	**body**	69	103%	**96%**
120	**L**	**body**	67	99%	**91%**
120	**M**	**body**	67	99%	**91%**

OSL Landauer (w.i.p.)

(courtesy Mike McNittGray and Rich Mather)

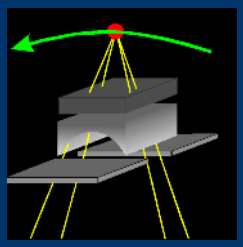
- OSL dosimeters
- Z-axis dose profile (in air and in phantoms)



Monte Carlo dosimetry courtesy Marcal Salvado

Monte Carlo dosimetry

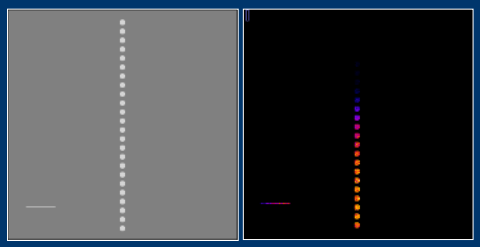
Using EGS4 code (Electron Gamma Shower)



CT Scanner model: wedges, collimators, inherent filtration … and heel effect

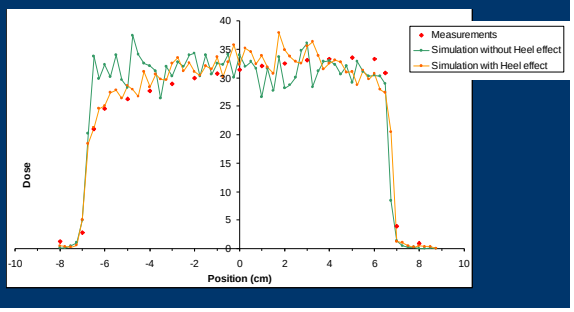
Monte Carlo dosimetry

Checking of MC dosimetry against dose measurents (thimble chamber): axial plane



Monte Carlo dosimetry

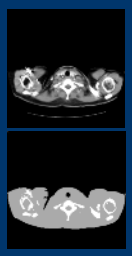
Checking of MC dosimetry against dose measurents (thimble chamber): z-axis profile



Monte Carlo dosimetry

CT Cardio and CT Brain examinations in voxel phantoms
Segmented in organs for calculation of effective dose

Small Female



5 Materials:
- Air
- CT table
- Lung
- Bone
- Muscle

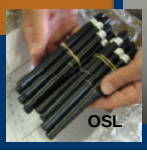
Conclusion

- Dosimetry for 256 channel CT scanners requires new concepts
- Problem: the large cone beam becomes larger than the CT dose (body) phantom and the 100 mm CT pencil ionization chamber
- Advantage: the large beam allows for measurements with small (thimble) ionization chambers

Characterisation of the x-ray beam

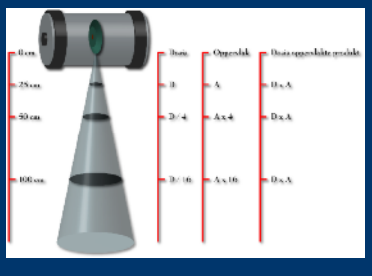
- Dosimetry free in air
  - Small ionisation chamber (thimble, 24 mm lenght)
  - 2D dosimetry (GafChromic XR-QA, **but also CR**)
  - Extended CT ionization chamber (extended pencil, 30 cm lenght)
  - But also OSL.

GafChromic XR-QA 25.4 x 30.5 cm



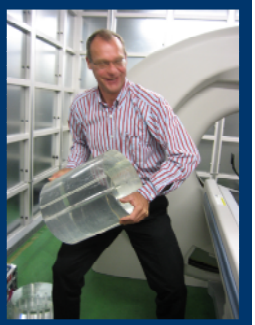
Characterisation of the x-ray beam

- Clinical implementation of dosimetry free in air. Why not dose area product, like in radiography and fluoroscopy?



Dosimetry in phantoms?

- CTDI is currently the most widely used dosimetric quantity in CT
- The concept of CTDI has serious limitations (not accurate, not additive, …)
- Larger phantoms (e.g. 35 cm long) are expensive and HEAVY (body phantom 34.5 kg)
- The regular phantoms may still be used, with some correction factor



Monte Carlo dosimetry

- Monte Carlo dosimetry should be used for development and assessment of new dosimetric concepts in 256 channel CT
- Monte Carlo dosimetry is required for calculation of patient dose: organ dose and effective dose