Acceptance testing of state-of-the-art CT scanners using a new national protocol: first experience on a large number of scanners of different make and model

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QC by the MPE in Belgium

- Annual test by MPE on all CT scanners
- Same minimal protocol for all MPEs,
  - From RP91 EC document -> new text
  - Annual patient dosimetry surveys

- The phantom available with the MPEs is used
- MPEs are engaged by the hospitals or work for independent companies

Overview

- X-ray tube
  - Tube voltage (beam quality)
  - Tube output
  - Reproducibility
- Image quality
  - Low contrast detail
  - High contrast detail
  - Hounsfield units
- Geometry
  - Radiation field
  - Irradiated slice thickness
  - Light field marker
  - Table movement

- Dose indications (all)
  - CTDI 16cm and 32cm
  - Tube voltage
  - Collimation
  - Tube modulation
- Tube load modulation
  - Z-axis and X-Y
- Patient protocols
- Performance of SNR^2 / dose
  - Over time
  - Compared to other systems

Material

Siemens	19	70,37%
GE	2	7,41%
Toshiba	2	7,41%
Philips	4	14,81%

Radiology	17	62,96%
Radiotherapy	4	14,81%
PET-CT	2	7,41%
SPECT-CT	3	11,11%

Vendor	Name	numb. of arrays	Tubes
GE	VCT light speed	64	
GE	Bright speed	16	
Philips	MX 8008 IDT	16	
Philips	Brilliance Big boor	16	
Philips	Brilliance	64	
Philips	Brilliance Big boor	16	
Siemens	Somatom Emotion	16	
Siemens	Somatom Emotion	6	
Siemens	Somatom Definition	64	dual source
Siemens	Somatom Emotion	4	
Siemens	Symbia T6 (SPECT-CT)	6	
Siemens	Somatom Emotion	6	
Siemens	Somatom Emotion	6	
Siemens	Somatom Definition Flash	64	dual source
Siemens	Somatom	64	
Siemens	Somatom Sensation	16	
Siemens	Biograph 16 (PET-CT)	16	
Siemens	Biograph 40 (PET-CT)	40	
Siemens	Symbia (SPECT-CT)	16	
Siemens	Somatom Definition AS+	128	
Siemens	Somatom Definition	64	dual source
Siemens	Symbia Truepoint (SPECT-CT)	2	
Siemens	Somatom Sensation	64	
Siemens	Somatom spirit		
Siemens	Emotion duo	2	
Toshiba	Aquillion 64	64	
Toshiba	Aquillion ONE	64	

Data made available by the team in : UZ LEUVEN

Tube voltage & output

Motivation:

- Safety for the personnel
- Is the tube OK?
- (scatter radiation)

Side remarks:

- Expensive measurement equipment
- Scan in scout mode or service mode

Results

- Example (GE VCT Bright Speed 64)

Tube voltage accuracy

set mA: 10

set kV	measured kV	Deviation (%)
120	123,67	3,06%
140	146,14	4,39%
100	101,93	1,93%
80	80,05	0,07%
	Maximum:	**4,39%**
	limit:	10,00%

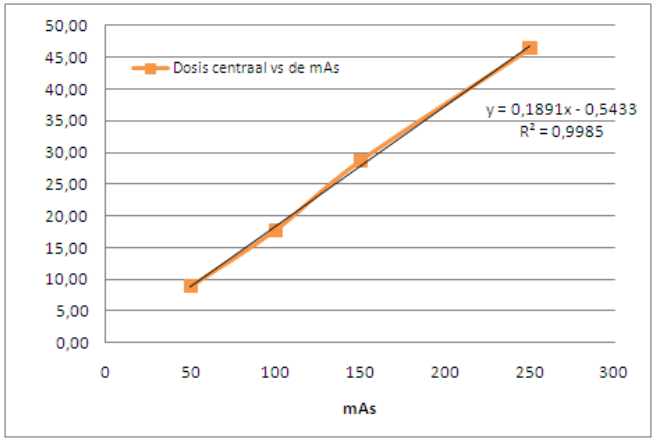
Tube Voltage reproducibility

Set mA: 10
set kV: 120

Measured kV	Deviation %
123,67	0,08%
123,76	0,01%
123,70	0,06%
123,97	0,15%

Mean: **123,77**

Maximum: **0,15%**
Limit: 5,00%



- Deviation in tube voltage in 5/27 systems
  - Is it a problem of the measurement device?
- Other parameters: Fine on all systems

Image quality

Motivation:

- Can the scanner achieve minimal quality limits?

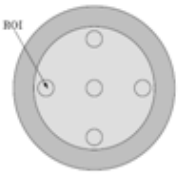
Side remarks:

- Ex: use of Catphan
- Define reproducible reference exposure conditions:
  - $CTDI_{vol}$ about 10mGy
  - 2 kernels
  - Sequential scanning

Results

- Example (Siemens Somatom Definition)

Uniformity



Filter: soft kernel
kV: 120

	HU	SD	Uniformity (HU)	Uniformity (%)
ROI central	14,47	6,32		
ROI top	15,31	6,31	0,84	0,08%
ROI right	15,68	5,24	1,21	0,12%
ROI bottom	15,02	5,70	0,55	0,05%
ROI left	15,40	6,22	0,93	0,09%
Mean:	**15,35**	**5,87**		
			1,21	**0,12%**

Are low contrast objects with diff. HU = 10 and 10mm diameter visible?

120kV	soft kernel	yes
	sharp kernel	yes
>120kV	soft kernel	yes
	sharp kernel	yes
<120kV	soft kernel	yes
	sharp kernel	yes

- Uniformity: always fine;
- Artefacts: should it be tested for all positions on the table?
- Low contrast test of cathphan: always fine; subjective
- High contrast (line pairs or MTF): method and interpretation ?

Accuracy of HU

Motivation:

- Brain:
  - 55 – 70 HU: bleeding or thrombus; >75HU: no bleeding
  - Intracranial extracerebral fluid > 15HU : includes blood rests
- Abdomen
  - Liver steatoses < 30HU; hemochromatosis > 70HU
- Urography
  - Cysts 0 – 20 HU; cysts incl. proteins 60 – 80 HU
- Musculo-skeletal:
  - Diff between fluid (0-20HU)and blood (30 - 35HU)

Results

- Verification of HU in water:

CT number water		120kV	10HU	fails in 3/27
		140kV	10HU	fails in 12/27
		80kV	10HU	fails in 16/27

- HU of water can be adjusted
- Does it become even more important in dual energy CT?

Geometry

Motivation:

- Scan at the right position
- Irradiate the right amount of tissue
- Moving parts move correctly

Side remarks:

- For radiotherapy purposes more stringent tests required
- Accurate positioning also required for Catphan

Results

- Irradiated slice width: fails in 5/27;
- Reconstructed slice thickness: fine
- Table motion: fine
- Gantry tilting angle: fine

(indicated) $CTDI_{vol}$

Motivation:

- If well indicated, it can be used directly for:
  - Optimization
  - Automated patient dose surveys

Side remarks:

- Time consuming

Indicated

- $CTDI_{vol}$ for all tube voltages
- $CTDI_{vol}$ for phantoms of 16cm and 32cm diam.

Measurements in the center of the phantom only

- for all collimations
- for reproducibility
- tube load
- with tube modulation on
- small focus, special filters, sliding window, . …

Results

- Deviation between measured and indicated $CTDI_{vol}$ for 12 scanners

Reprod	120kV (110kV), 32cm	> 120kV, 32cm	<< 120kV, 32cm	TCM	Finest coll	120kV (110 kV), 16cm	> 140kV, 16cm	<< 120kV, 16cm
4,27	11,27	10,09	17,77	17,86	8,21	4,56	7,37	17,56
1,06	15,2	14,96	18,8	12,93	15,5	1,57	4,16	7,27
2,75	14,11	2,77	2,9	11,87	20,37	14,3	1,92	5,89
0,81	11,81	2,94	38,66	-7,45	-18,3	-3,82	6,48	-36,2
0,06	-4,95	-4,31	-11,62	9,92		9,68	14,62	4,11
0,52	0,73	8,08	6,64	3,14	10,11	8,86	13,4	7,61
0,34	1,01	-0,26	19,46	6,15	-1,5	11,79		22,96
0,53	11,29	11,07	3,6	3,7	0,41	9,93	10,82	2
2,21	-4,36	12,86	10,98	-1,49	5,37			
0,09	6,25	6,16	5,19	-23,82	5,6	-10,78	-10,51	-8,92
0,32	-5,63	-6,08	-3,07	3,19	-7,7	-17,9	-21,87	-35,1
0,67	9,91	14,55	17,88	17,38	4,12	4,82	7,79	-1,44

Tube modulation

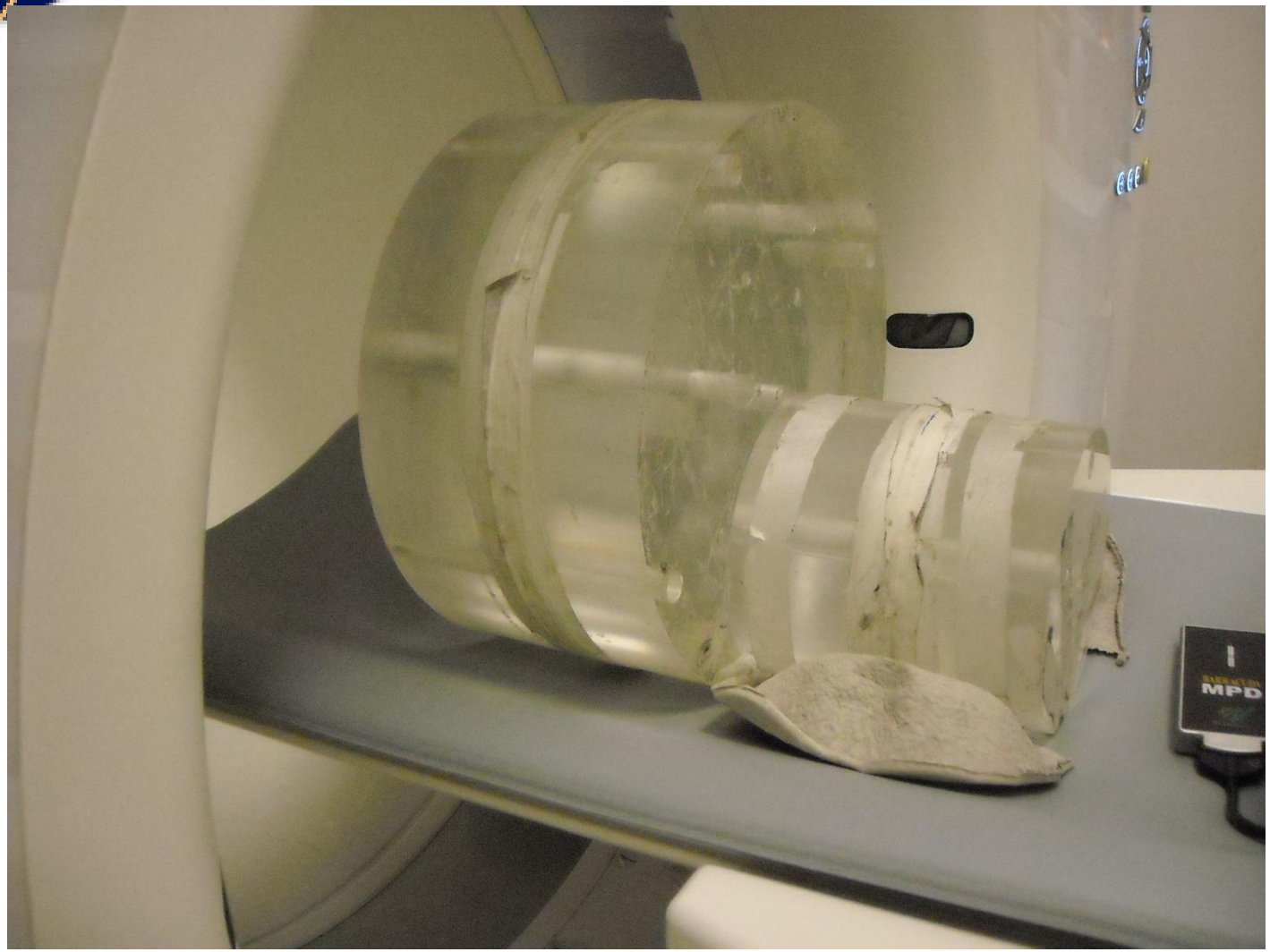
Motivation:

- Substantial effect on patient dose
- Have to understand or give advice on settings

Side remarks:

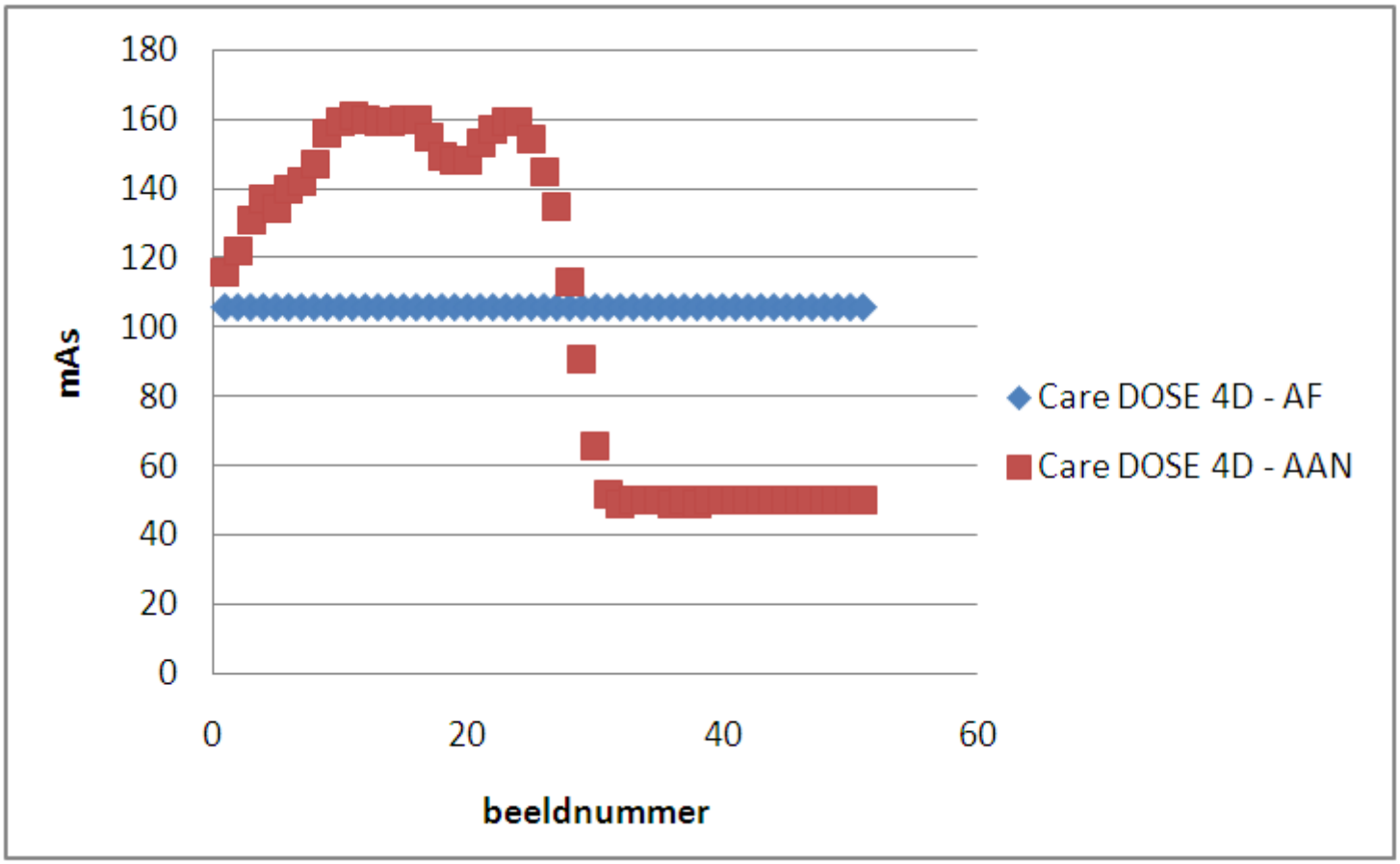
- New methodology has to be developed

Z-axis modulation

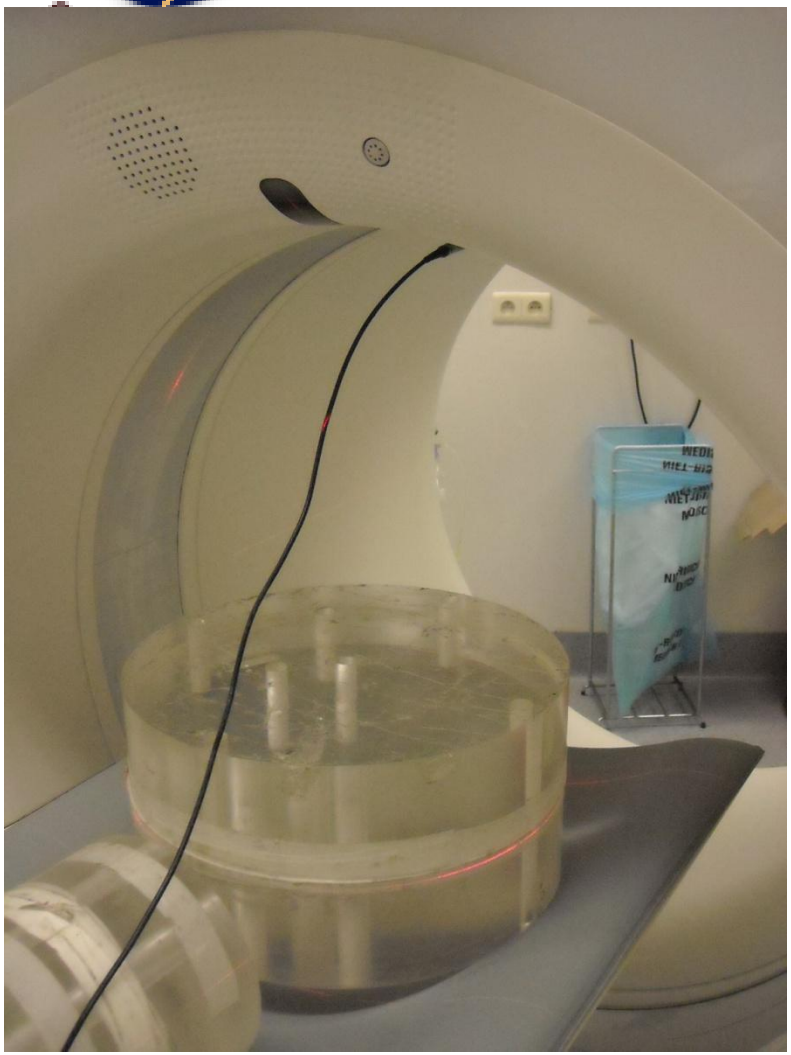


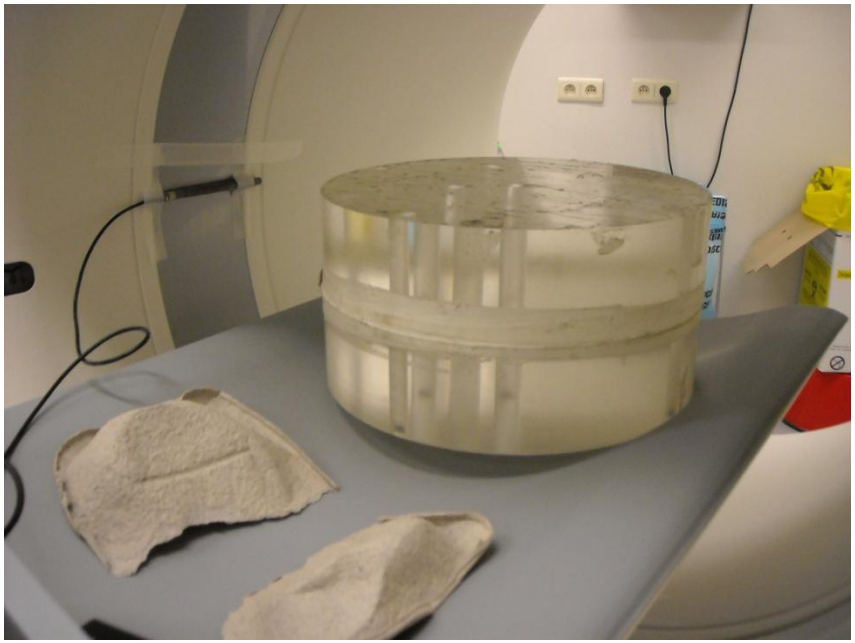
Results

- Example: Care Dose 4D(Somatom Definition)



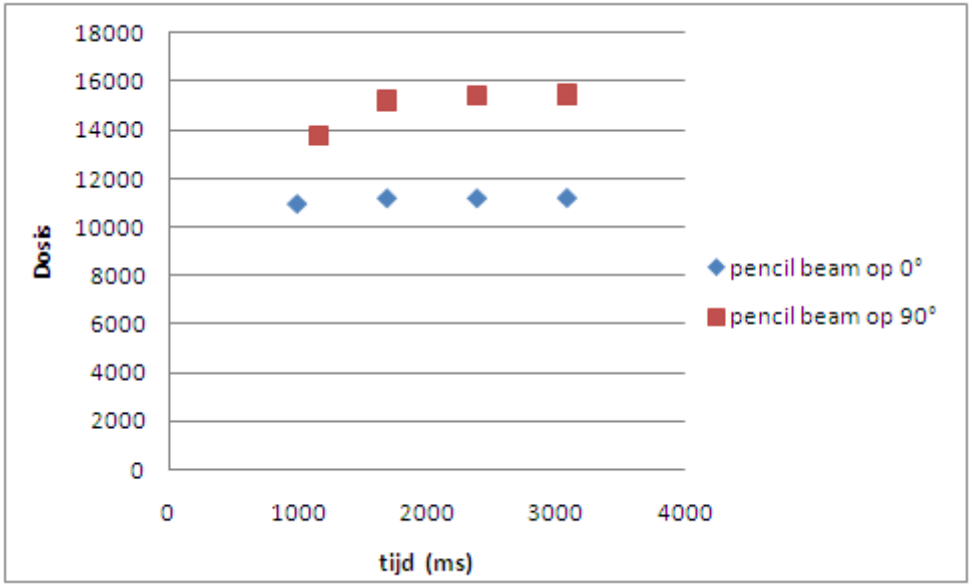
X- Y modulation





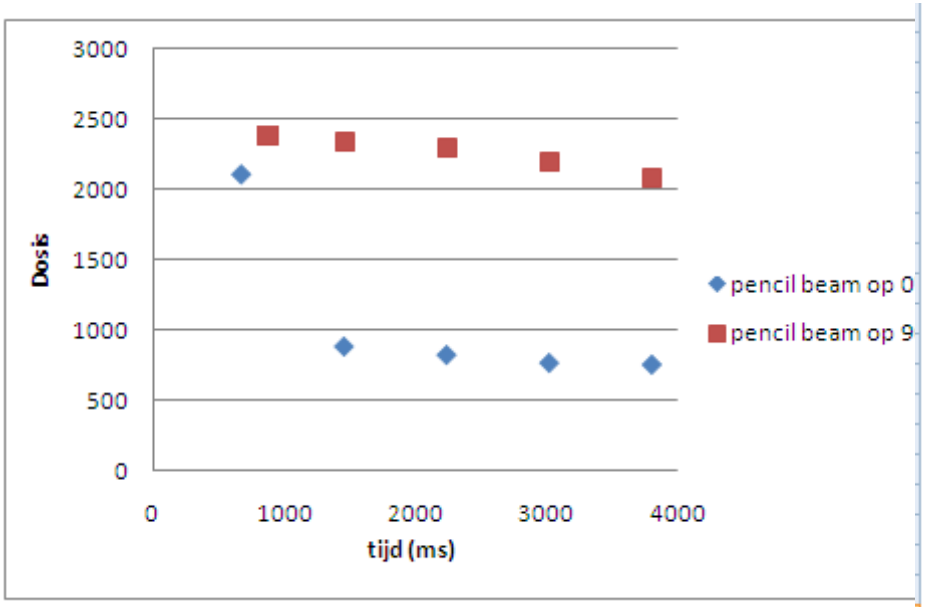
Results

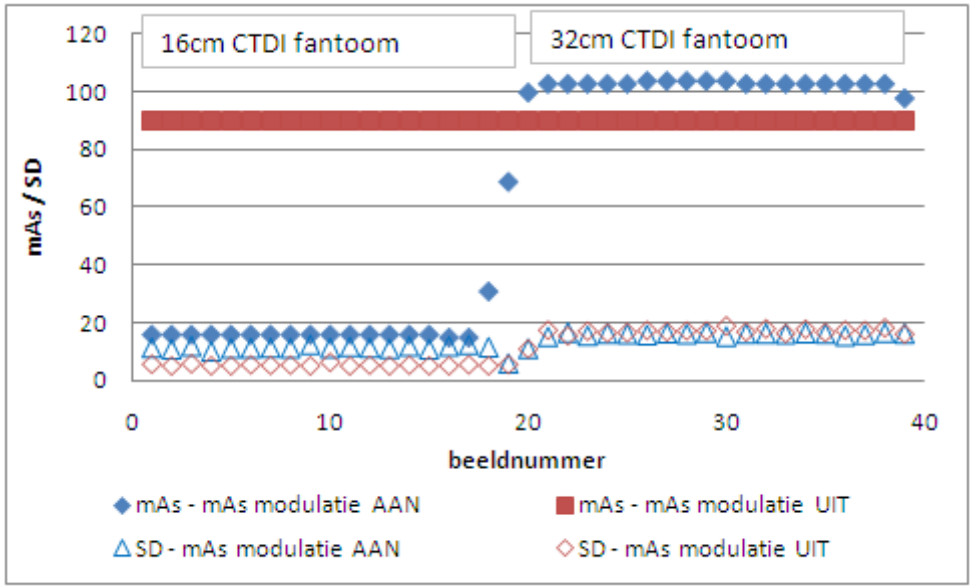
- Example: smart mA (GE system)



Siemens Symbia Truepoint

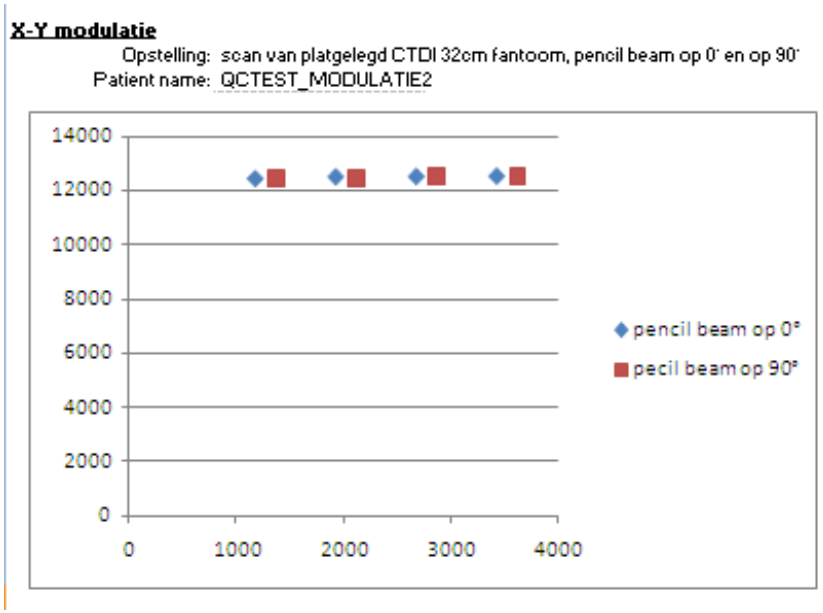
- Care Dose 4D

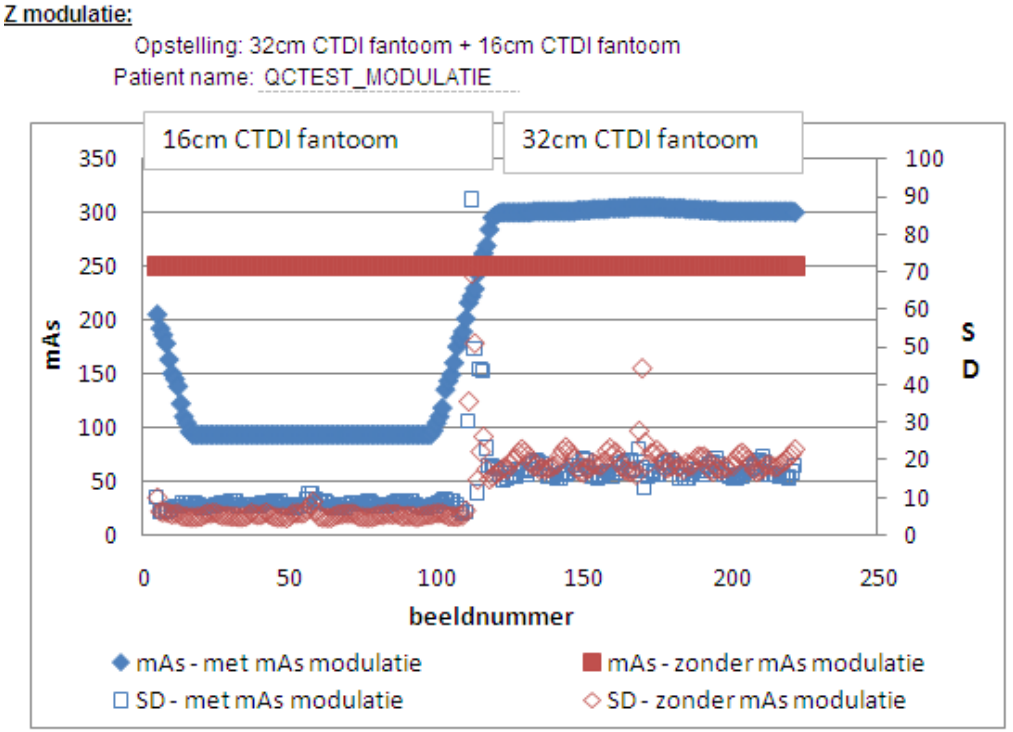




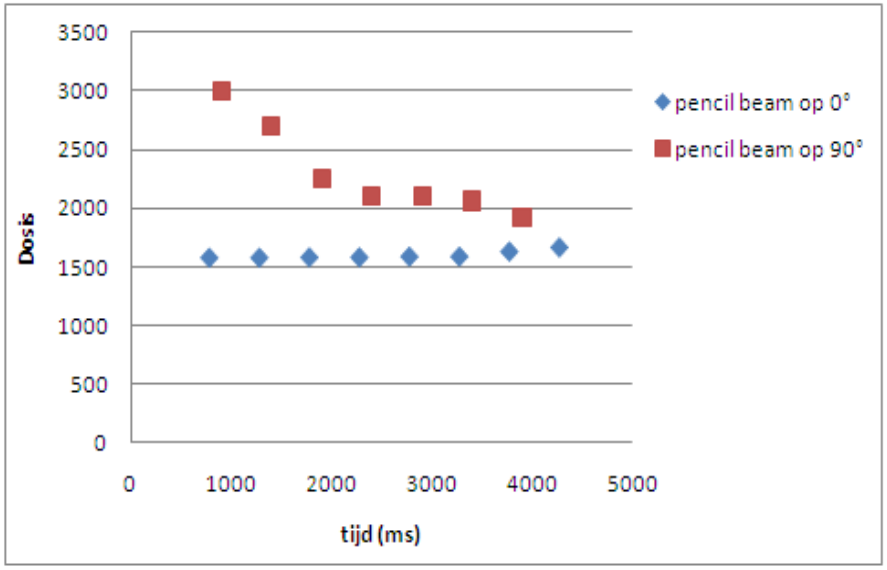
Philips Brilliance Big Bore

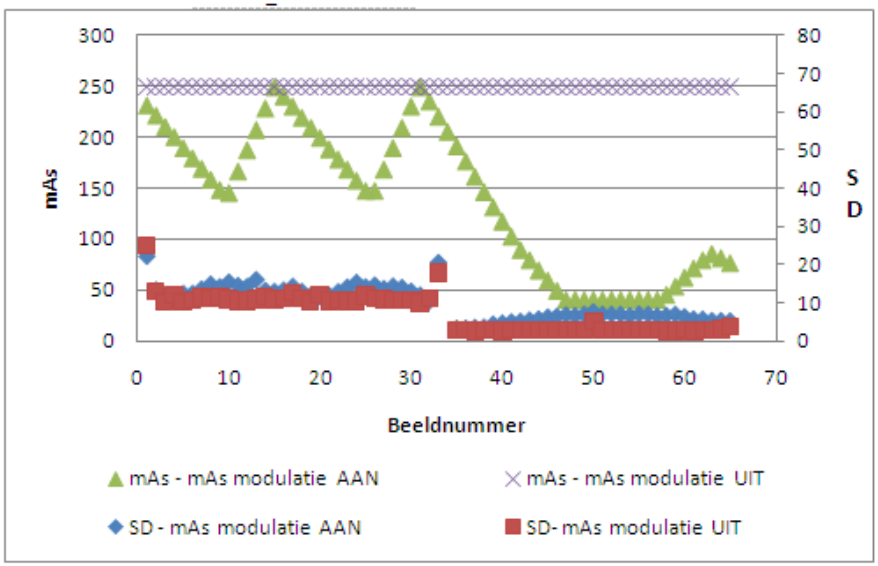
- z-DOM + ACS





Example: Toshiba Aquillion 64





Patient protocols

Motivation:

- Exposure settings determine patient dose & quality

Side remarks:

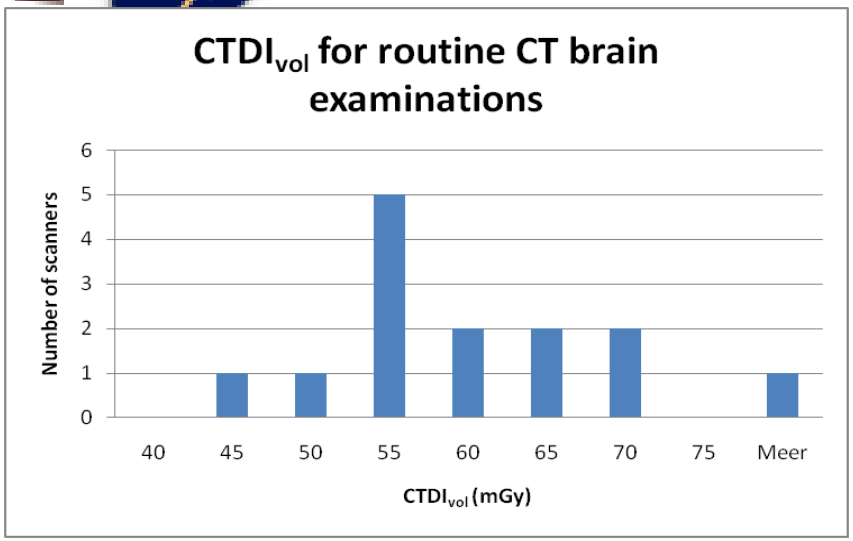
- Settings are the responsibility of the radiologists, but I propose we guide them
- Are preprogrammed settings representative for a typical patient?

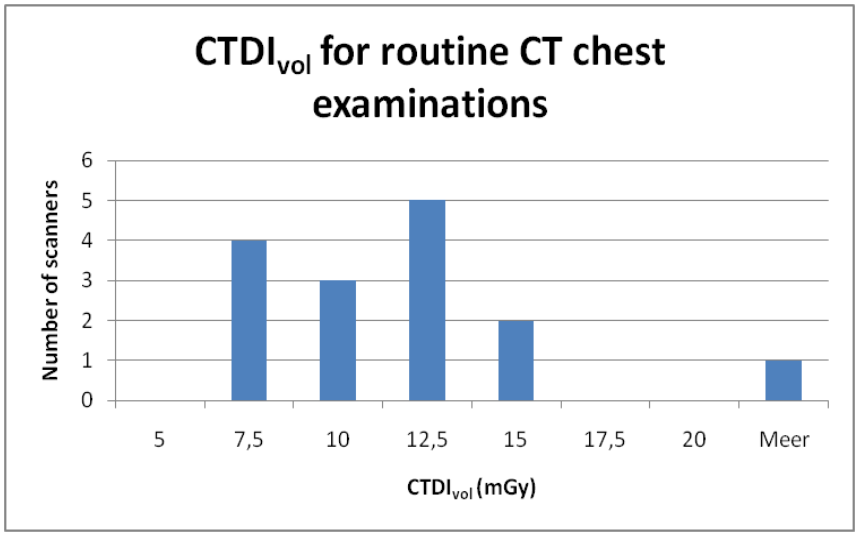
Patient protocols

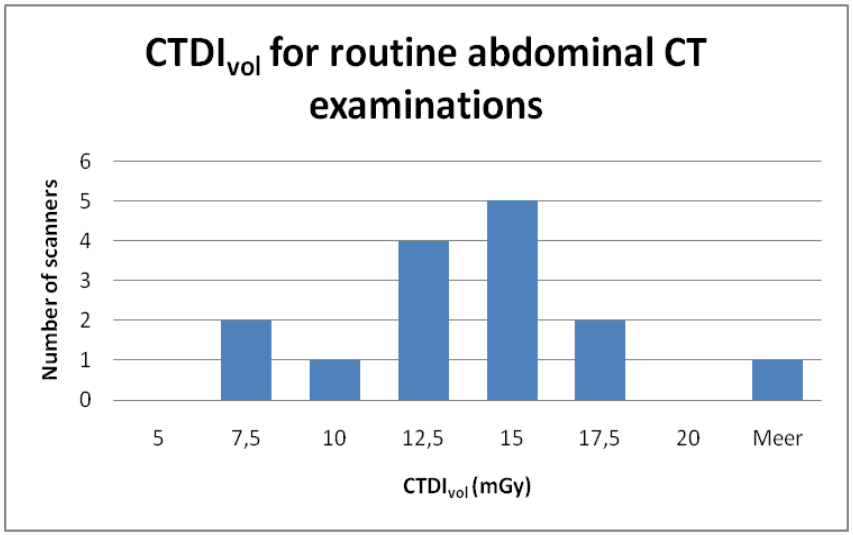
- Example: we verify…
  - Is TCM used?
  - Are pitch and reconstruction kernel reasonable?
  - CTDIvol ?

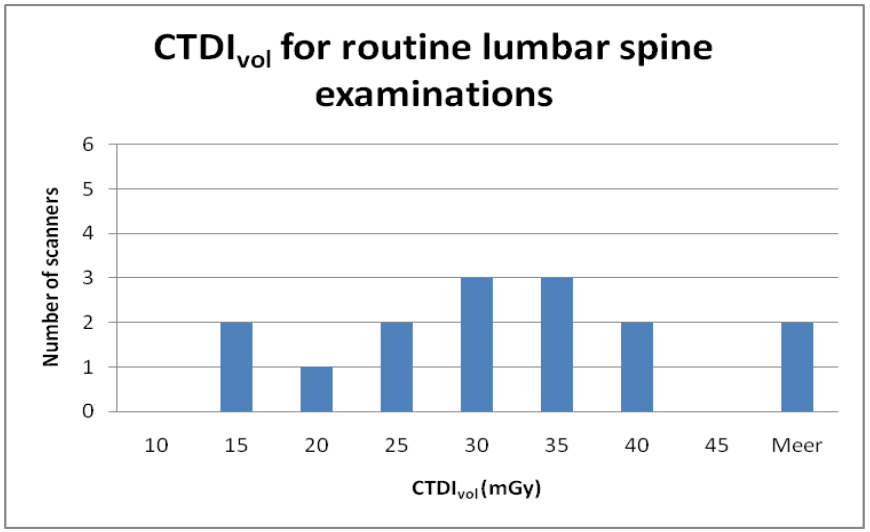
		Scan Parameters				Reconstructie		Fantoom Dosis	
CT volwassenen	Protocol naam	kV	mA	Pitch	collimatie (mm)	gereconstrueerde snededikte (mm)	Kernel	mAs modulatie?	Aangeduide $CTDI_{vol}$
CT schedel	1.1 Schedel zonder	140	100-600	0,531	20	0,625	std,	NI 6	99,55
CT van de sinussen	2.1 SInussen	120	60	0,516	40	1,25	detail, bone,	NEE	4,26
Standaard CT thorax	5.1 Thorax Standaard	120	150-600	1,375	40	0,625	std, lung	NI 25	20,5
Hoge resolutie CT longen									
CT lumbale wervelzuil	7.1Lumbale wervelzuil	120	250-650	0,516	40	1,25	bone,std,de	NI 15	68,59
CT abdomen	6.1 Abdomen	120	200-600	1,375	40	1,25	std,	NI 25	24

Survey of CT protocols

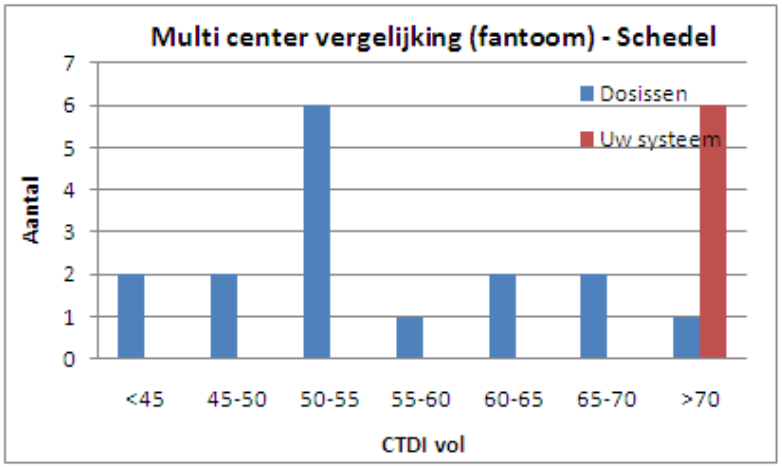


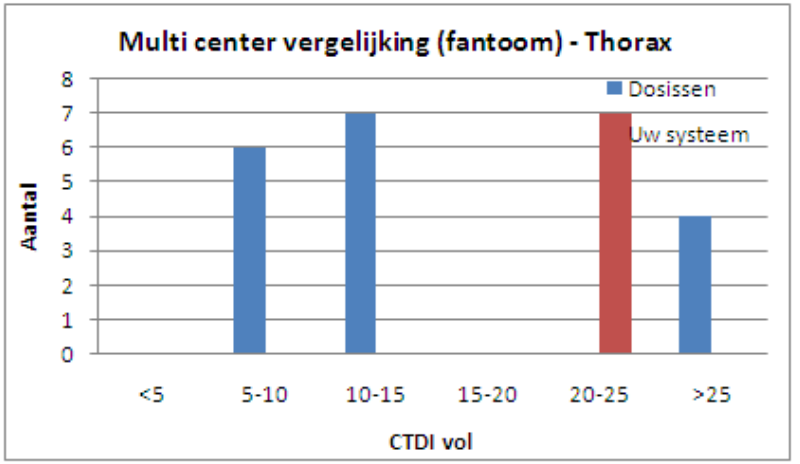


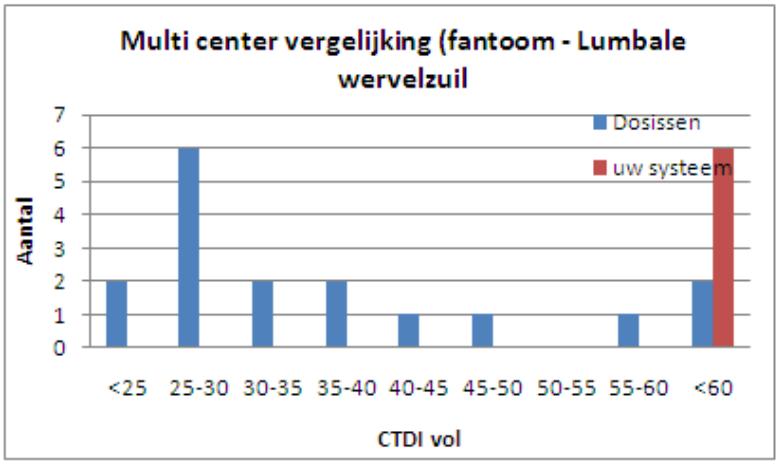


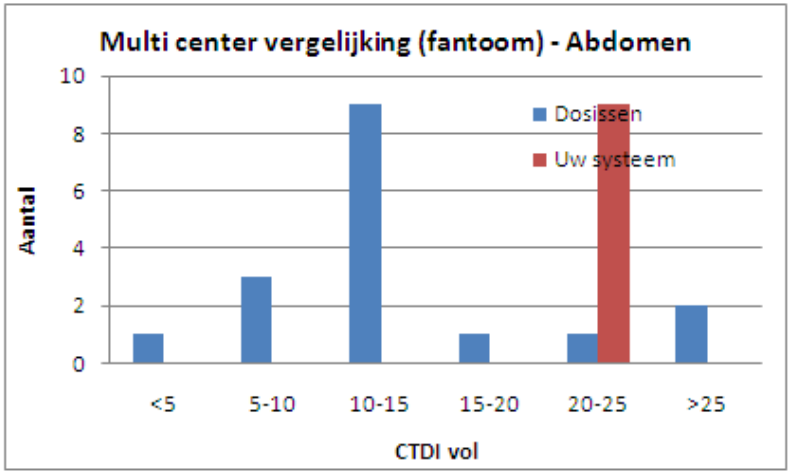


Example. Trigger for urgent patient dose survey !









Performance:
over time;
compared to similar systems

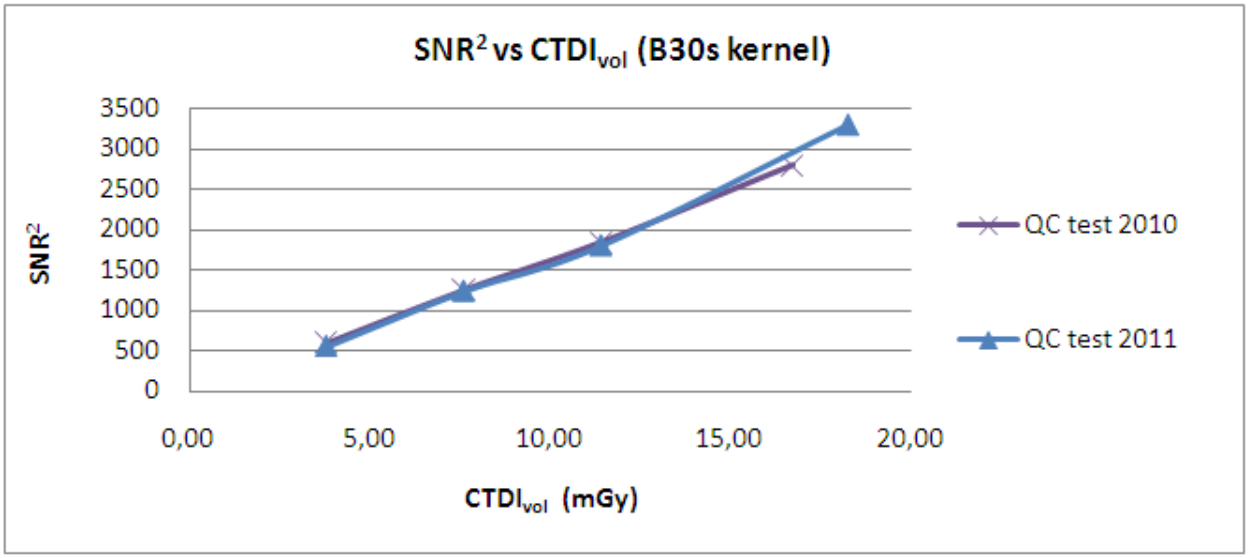
Motivation:

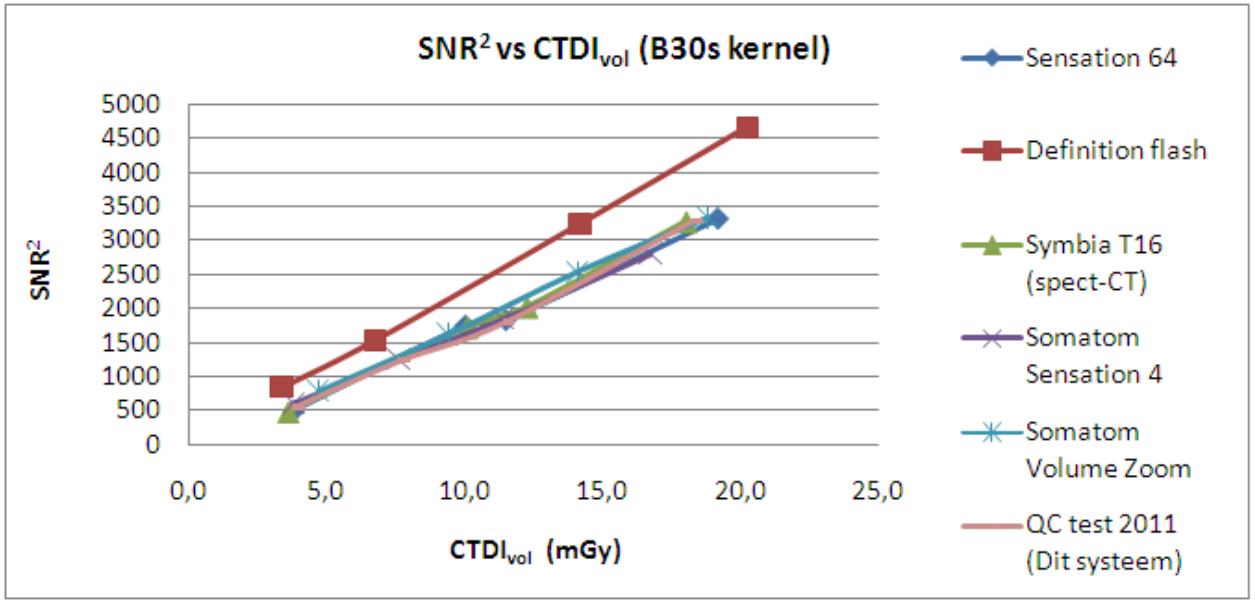
- Foreseen in many int. protocols, a ‘standard test’
- Let’s go beyond ‘exposure’ and include ‘quality’, with SNR^2 as a function of $CTDI_{vol}$

Side remarks:

- Fixed exposure conditions are required
- Which FOM would be optimal?

Example





Somatom Sensation 4

Discussion

- X-ray tube
  - Tube voltage (beam quality)
  - Linearity of tube output
  - Reproducibility
- Image quality
  - Low contrast detail
  - High contrast detail
  - Hounsfield units
- Geometry
  - Radiation field
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  - Light field marker
  - Table movement

- Dose indications
  - CTDI 16cm and 32cm
  - Tube voltage
  - Collimation
  - Tube modulation
- Tube load modulation
  - Z-axis and X-Y
- Patient protocols
- Performance, SNR^2 / dose

Discussion

- Results of present protocol = more work than before (follow – up !)
- Several ‘problems’ detected

- New techniques increase the need for (automated) (personalized) patient dosimetry
- The MPE can be active in ImageGently ImageWisely

Future directives

1. Find an absolute image quality index and/or phantom for optimization work
2. Automate QC of CT scanners

Conclusion

Making exciting new CT features happen

in practice

is an exciting challenge

and will be a challenge for many more years