Irradiation et scanner, ce que le prescripteur doit savoir en 2016

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SERVICE DE RADIOLOGIE HUG

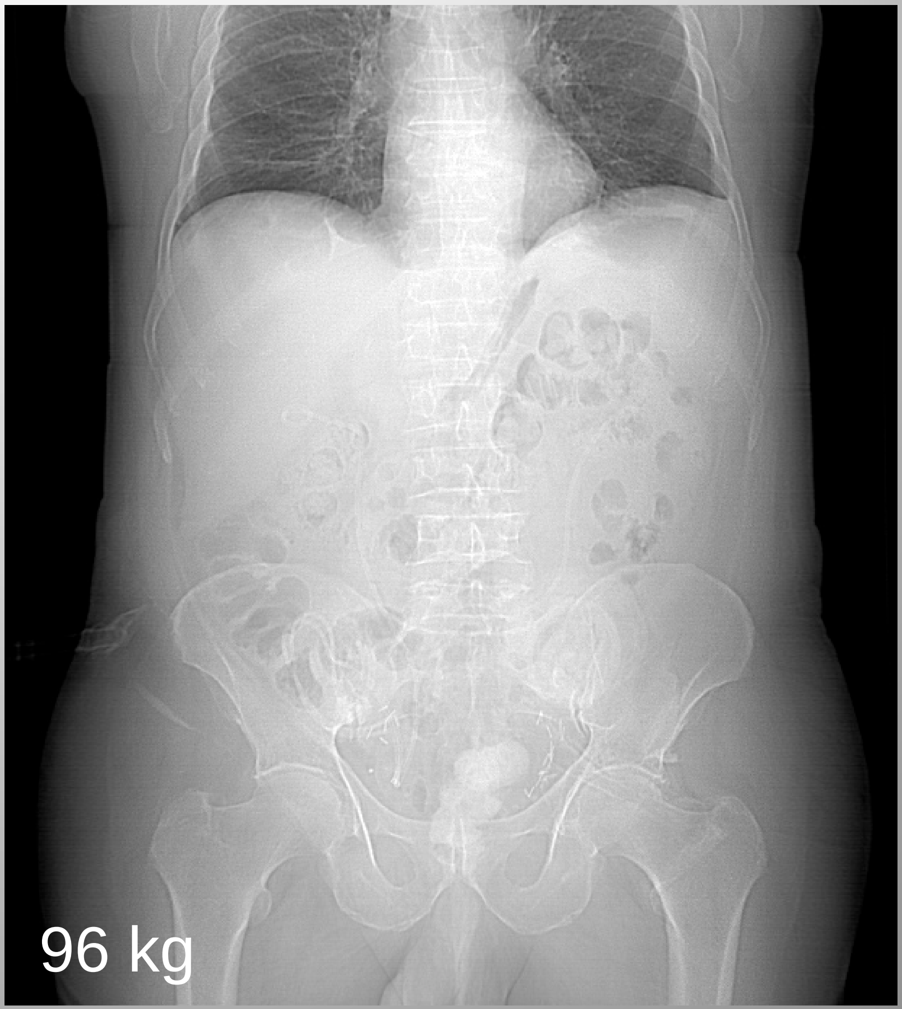
Personalized CT protocols ?

- Should we use the same CT protocol for
  - A 16-years old women of 40 kg
  - A 86-years old men of 96 kg

Personalized CT protocols ?

- Should we use the same CT protocol for
  - A 16-years old women of 40 kg
    - More sensitive to radiation
    - More time to develop a cancer
    - Less sensitive to iodinated contrast media
  - A 86-years old men of 96 kg
    - Less sensitive to radiation
    - Less time to develop a cancer
    - More sensitive to iodinated contrast media

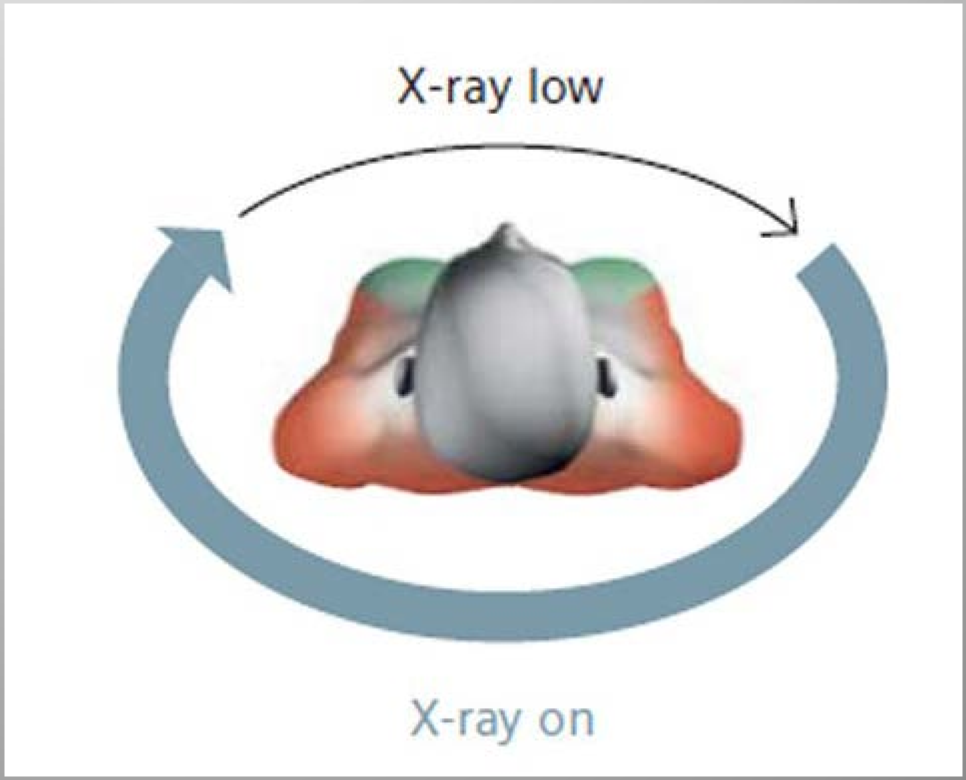
Weight



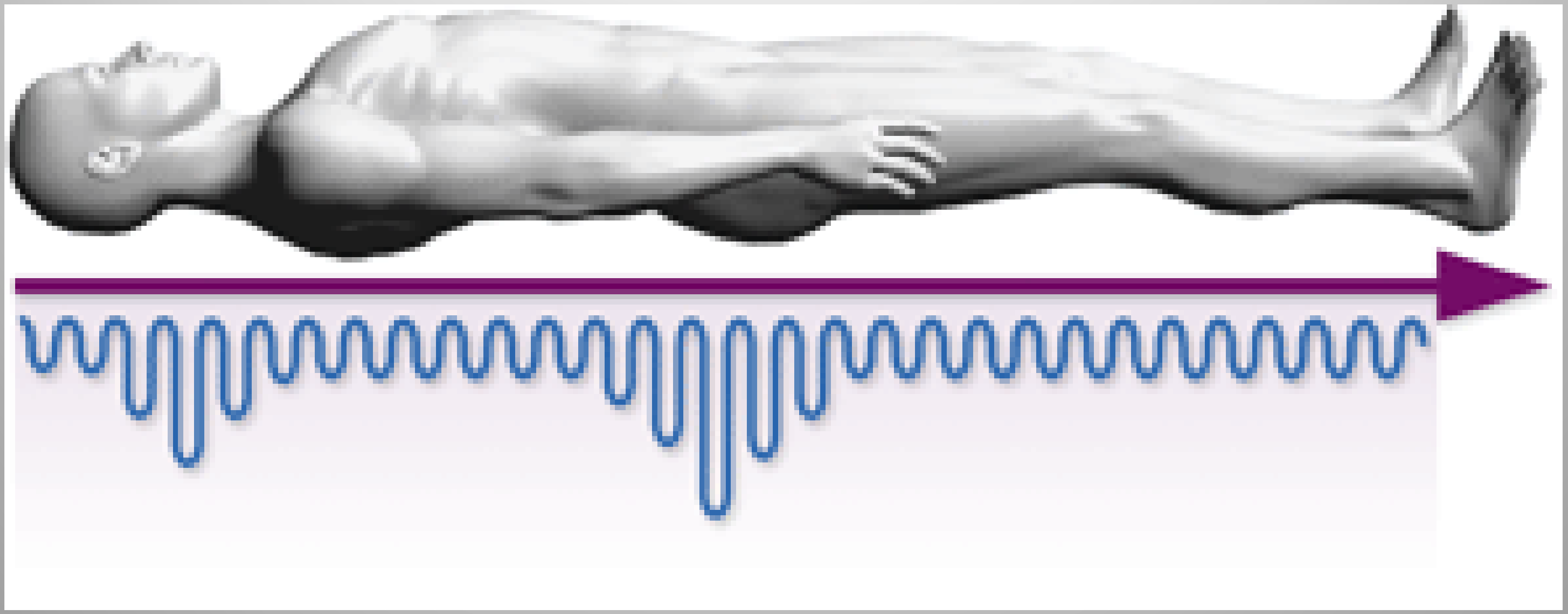
We need less energy to go through 40 kg than through 96 kg
Do not use the same kVp

Men vs Women

- Try to decrease the irradiation to the breast



Use more x-rays when you need them



Increase the mA to go through the shoulders and the pelvis

Dose concern ?

- Could x-rays be responsible for cancer?
  - In the general population
  - In the medical community

Chicago Tribune

March 17, 2011|By Cory Franklin

In the last 10 years, the use of CT scans has exploded. In 1980, 3 million CT scans were performed. The projection for 2011 is 72 million, nearly 20,000 every day.

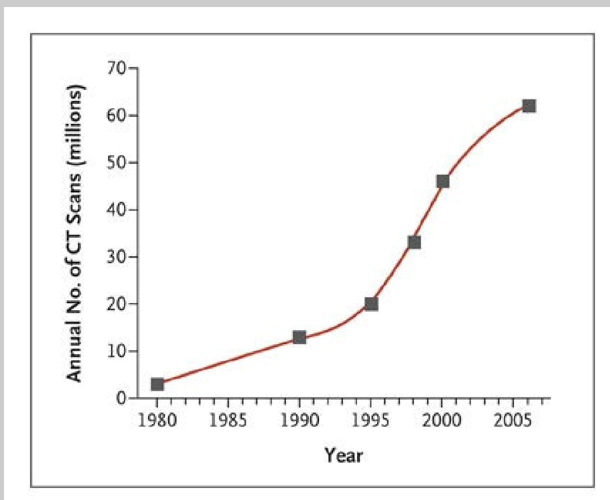


Figure 2. Estimated Number of CT Scans Performed Annually in the United States.

The most recent estimate of 62 million CT scans in 2006 is from an IMV CT Market Summary Report.[3]

Computed Tomography — An Increasing Source of Radiation Exposure. David J. Brenner, Ph.D., D.Sc., and Eric J. Hall, D.Phil., D.Sc. N Engl J Med 2007; 357:2277-2284 November 29, 2007

In the scientific community


NEWSFOCUS

Second Thoughts About CT Imaging

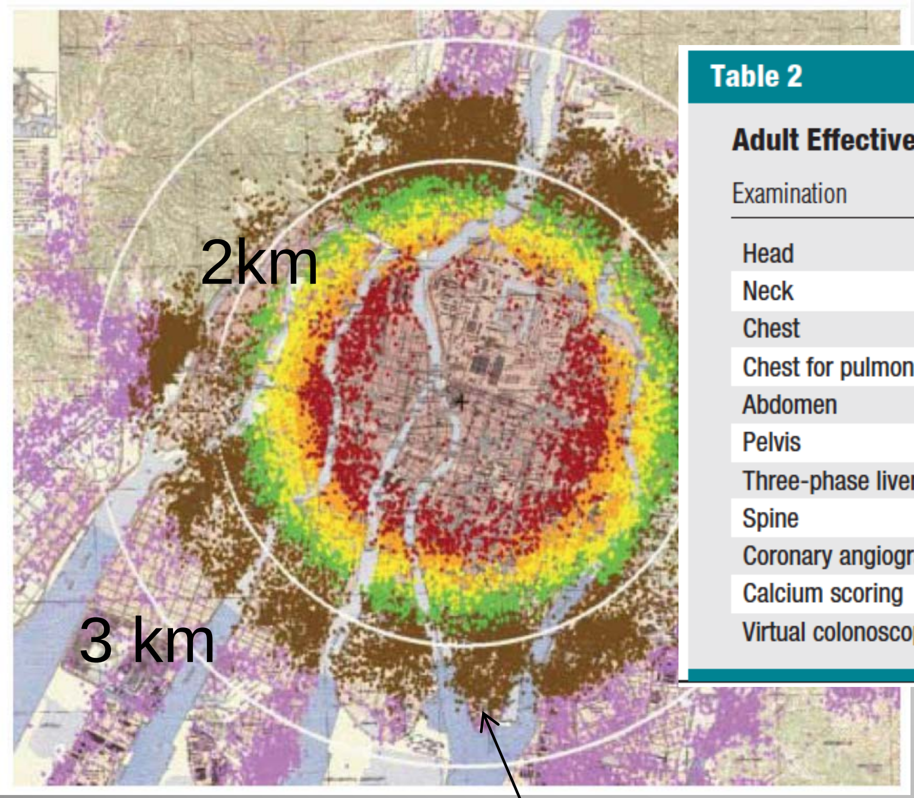
Concern that CT scan radiation is causing cancer has focused public scrutiny on radiologists and medical physicists—and riled up controversy among them. Can they find a solution?

25 FEBRUARY 2011 VOL 331 **SCIENCE** www.sciencemag.org
Published by AAAS

Controversy

- Based on
  - The majority of the model are based on Hiroshima/Nagasaki survivors
  - Could a nuclear blast be used to estimate the risk of cancer due to CT ?

Radiation dose - Hiroshima



5-100 mSv

Table 2

Adult Effective Doses for Various CT Procedures

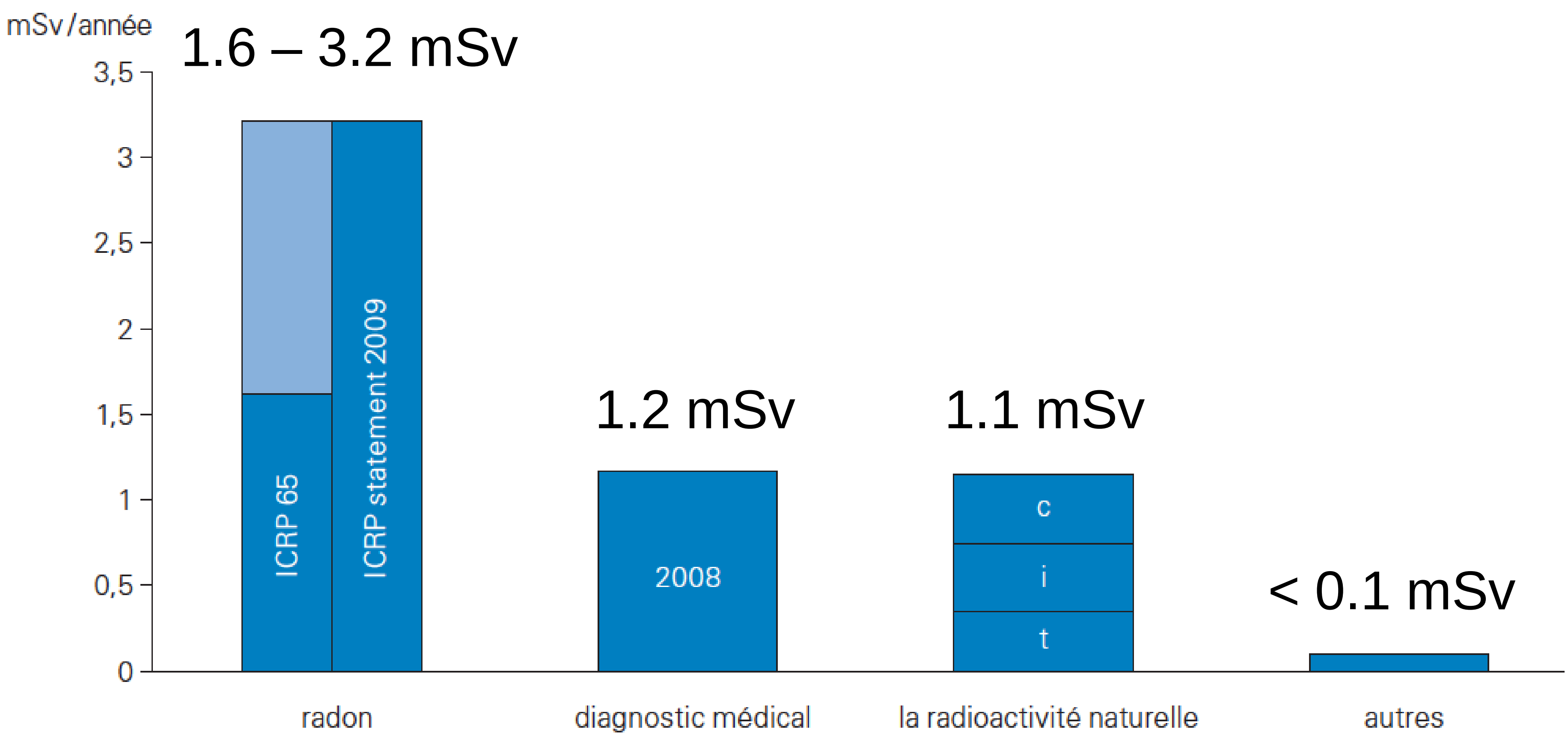
Examination	Average Effective Dose (mSv)	Values Reported in Literature (mSv)
Head	2	0.9–4.0
Neck	3	. . .
Chest	7	4.0–18.0
Chest for pulmonary embolism	15	13–40
Abdomen	8	3.5–25
Pelvis	6	3.3–10
Three-phase liver study	15	. . .
Spine	6	1.5–10
Coronary angiography	16	5.0–32
Calcium scoring	3	1.0–12
Virtual colonoscopy	10	4.0–13.2

Estimated radiation dose received in Switzerland by the general population

Mettler FA, Jr., Huda W, Yoshizumi TT, Mahesh M. Effective doses in radiology and diagnostic nuclear medicine: a catalog. Radiology. 2008;248(1):254-63.

Long-term Radiation-Related Health Effects in a Unique Human Population: Lessons Learned from the Atomic Bomb Survivors of Hiroshima and Nagasaki. Evan B. Douple, et al. *Disaster Med Public Health Prep*. 2011 March

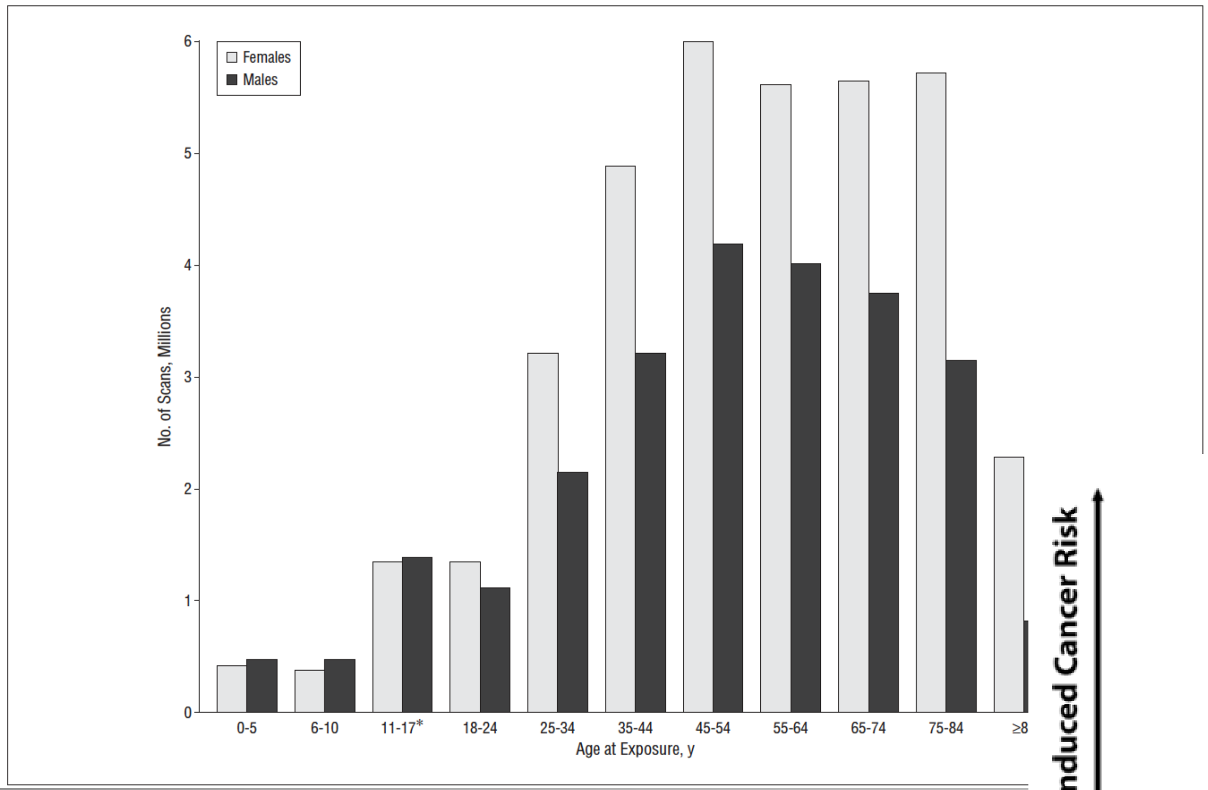
Radiation in Switzerland - 2010



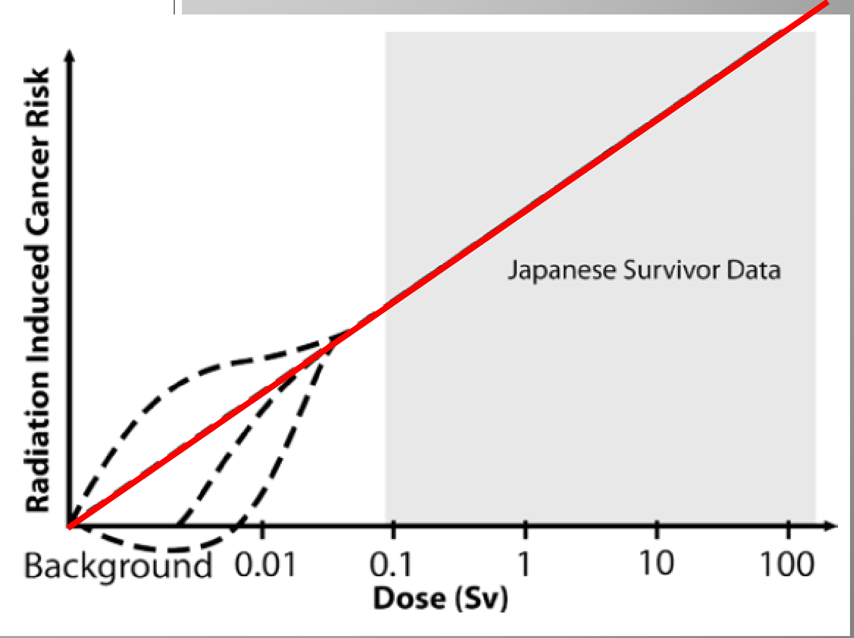
Total: 5.6 mSv

Radioprotection et surveillance de la radioactivité en Suisse **Résultats 2010**

Number of CT realized …



Linear non-threshold model



Radiation risks of medical imaging: separating fact from fantasy.
Hendee WR, O'Connor MK. Radiology. 2012 Aug;264(2):312-21.

Projected Cancer Risks From Computed Tomographic Scans Performed in the United States in 2007
Amy Berrington de Gonzalez. Arch Intern Med. 2009;169(22):2071-2077

… and estimated number of cancer

Table 2. Projected Number of Future Cancers That Could Be Related to CT Scans Performed in the United States in 2007, According to CT Scan Type[a]

		No. of Cancers					
		Females		Males		Total	
Type of CT Scan	No. of Scans,[b] Millions (%)	Mean (95% UL)	%	Mean (95% UL)	%	Mean (95% UL)	%
Head	18.7 (33)	1900 (500-4400)	11	2100 (600-4300)	19	4000 (1100-8700)	14
Chest	7.1 (12)	3100 (1400-6100)	17	1000 (500-2000)	9	4100 (1900-8100)	14
Cervical spine	1.8 (3)	700 (200-1700)	4	300 (100-600)	3	1000 (300-2300)	3
Thoracic spine	0.3 (<1)	200 (80-300)	1	50 (20-100)	<1	250 (10-400)	1
Lumbar spine	2.2 (4)	700 (300-1600)	4	500 (200-1100)	5	1200 (400-2700)	4
Abdomen/pelvis	18.3 (32)	8500 (4200-15 000)	47	5500 (2600-9600)	50	14 000 (6900-25 000)	48
CTA chest	2.3 (4)	2200 (1100-4200)	12	500 (200-900)	5	2700 (1300-5000)	9
CTA other[c]	1.6 (3)	400 (200-900)	2	500 (200-1100)	5	900 (300-1900)	3
Whole body	0.3 (<1)	300 (100-500)	2	100 (50-200)	1	400 (200-600)	1
Colonography	0.2 (<1)	70 (30-120)	<1	50 (20-100)	<1	120 (60-200)	<1
Calcium scoring	0.6 (1)	150 (70-300)	1	30 (10-60)	<1	180 (80-400)	<1
Other[d]	3.5 (6)	10 (3-20)	<1	20 (1-80)	<1	30 (4-100)	<1
Total[e]	56.9 (100)	18 000 (9000-28 000)	100	11 000 (6000-16 000)	100	29 000 (15 000-45 000)	100

Projected Cancer Risks From Computed Tomographic Scans Performed in the United States in 2007
Amy Berrington de Gonzalez. Arch Intern Med. 2009;169(22):2071-2077

Could the CT dose be lowered?

Table 2

Adult Effective Doses for Various CT Procedures

Examination	Average Effective Dose (mSv)	Values Reported in Literature (mSv)
Head	2	0.9–4.0
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Abdomen	8	3.5–25
Pelvis	6	3.3–10
Three-phase liver study	15	. . .
Spine	6	1.5–10
Coronary angiography	16	5.0–32
Calcium scoring	3	
Virtual colonoscopy	10	

Table 1

Adult Effective Doses for Various Diagnostic Radiology Procedures

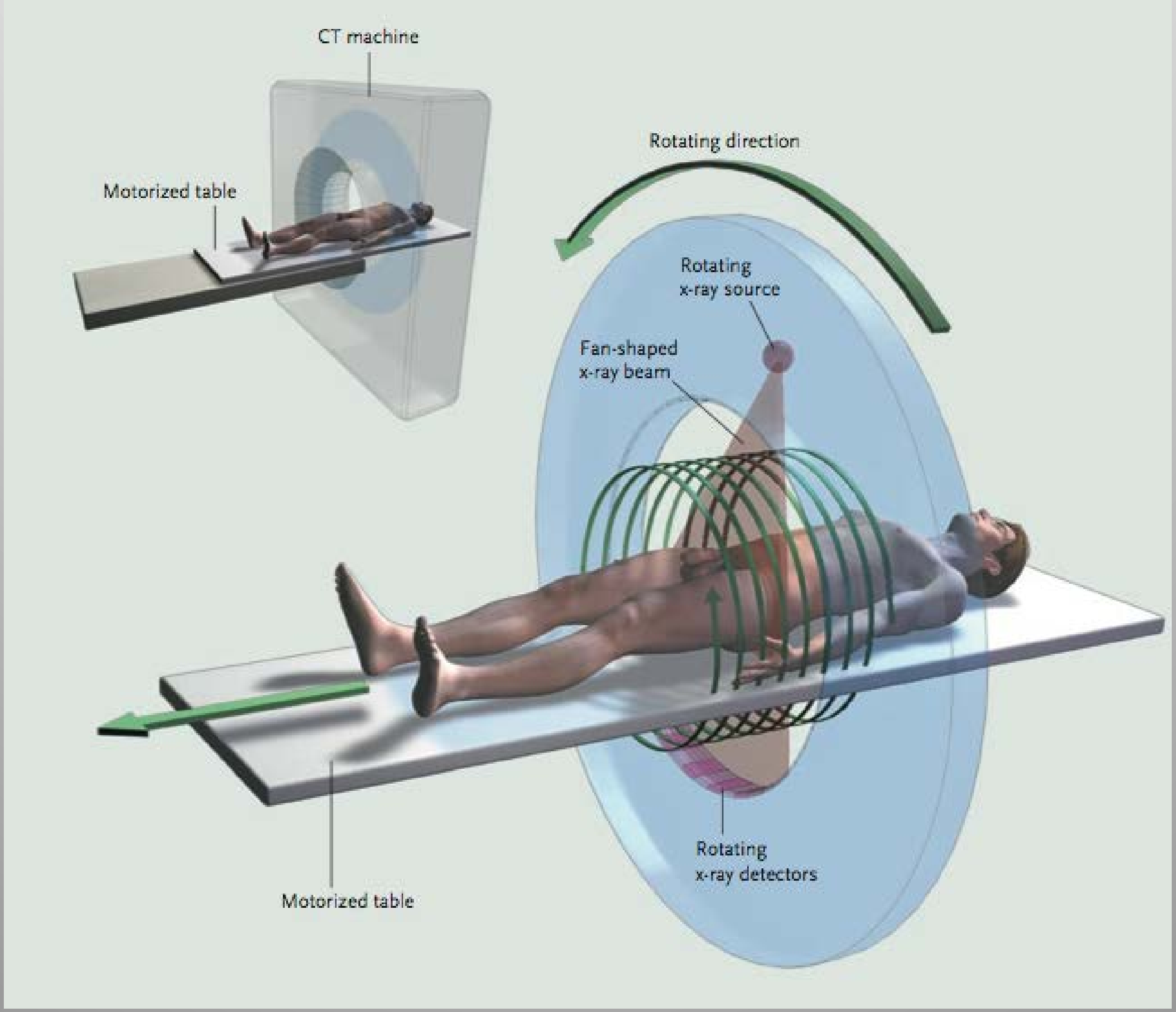
Examination	Average Effective Dose (mSv)	Values Reported in Literature (mSv)
Skull	0.1	0.03–0.22
Cervical spine	0.2	0.07–0.3
Thoracic spine	1.0	0.6–1.4
Lumbar spine	1.5	0.5–1.8
Posteroanterior and lateral study of chest	0.1	0.05–0.24
Posteroanterior study of chest	0.02	0.007–0.050
Mammography	0.4	0.10–0.60
Abdomen	0.7	0.04–1.1
Pelvis	0.6	0.2–1.2
Hip	0.7	0.18–2.71

Mettler FA, Jr., Huda W, Yoshizumi TT, Mahesh M. Effective doses in radiology and diagnostic nuclear medicine: a catalog. Radiology. 2008;248(1):254-63.

Chest CT with a X-ray dose close to a conventional Chest X-ray:

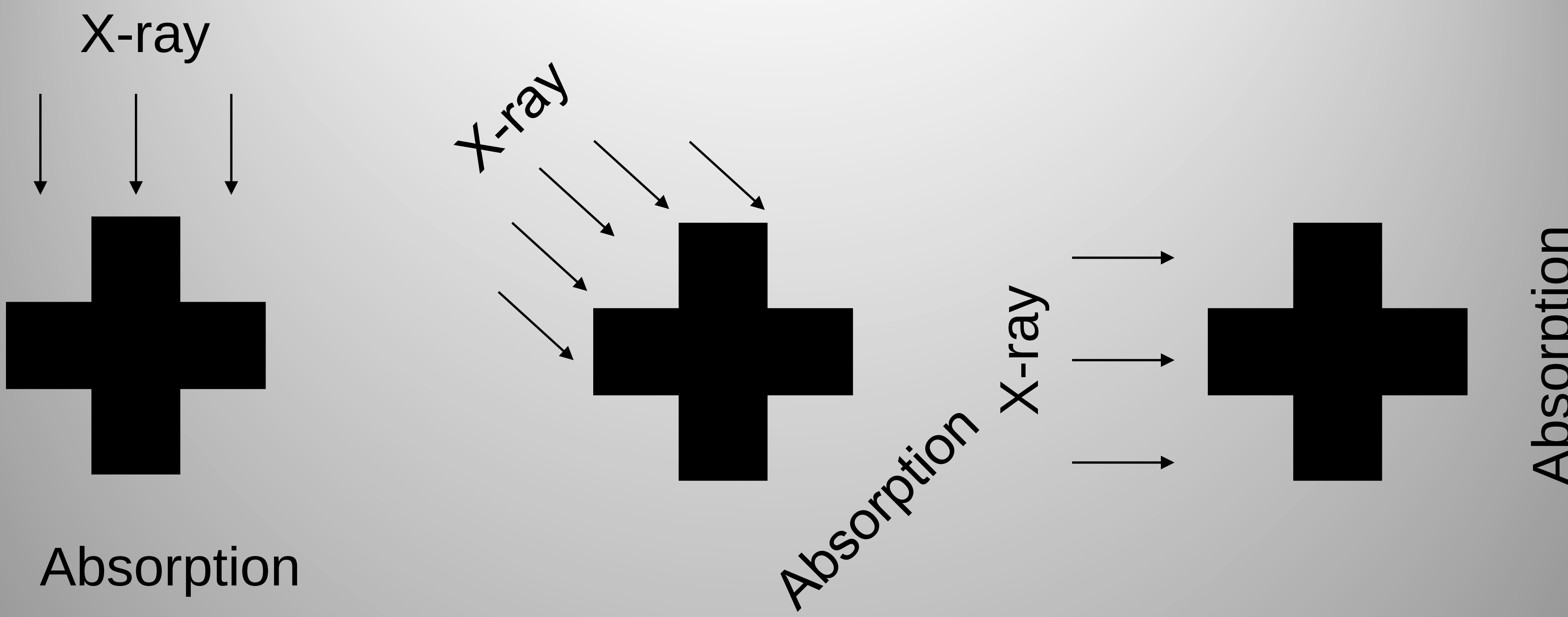
Iterative reconstruction

CT reconstructions



Computed Tomography — An Increasing Source of Radiation Exposure. David J. Brenner, Ph.D., D.Sc., and Eric J. Hall, D.Phil., D.Sc. N Engl J Med 2007; 357:2277-2284 November 29, 2007

CT Basic principle



1	3	1
1	3	1
1	3	1

(+)

1	2	0
2	1	2
0	2	1

(+)

1	1	1
3	3	3
1	1	1

CT basic principle - II

1	3	1
1	3	1
1	3	1

(+)

1	2	0
2	1	2
0	2	1

(+)

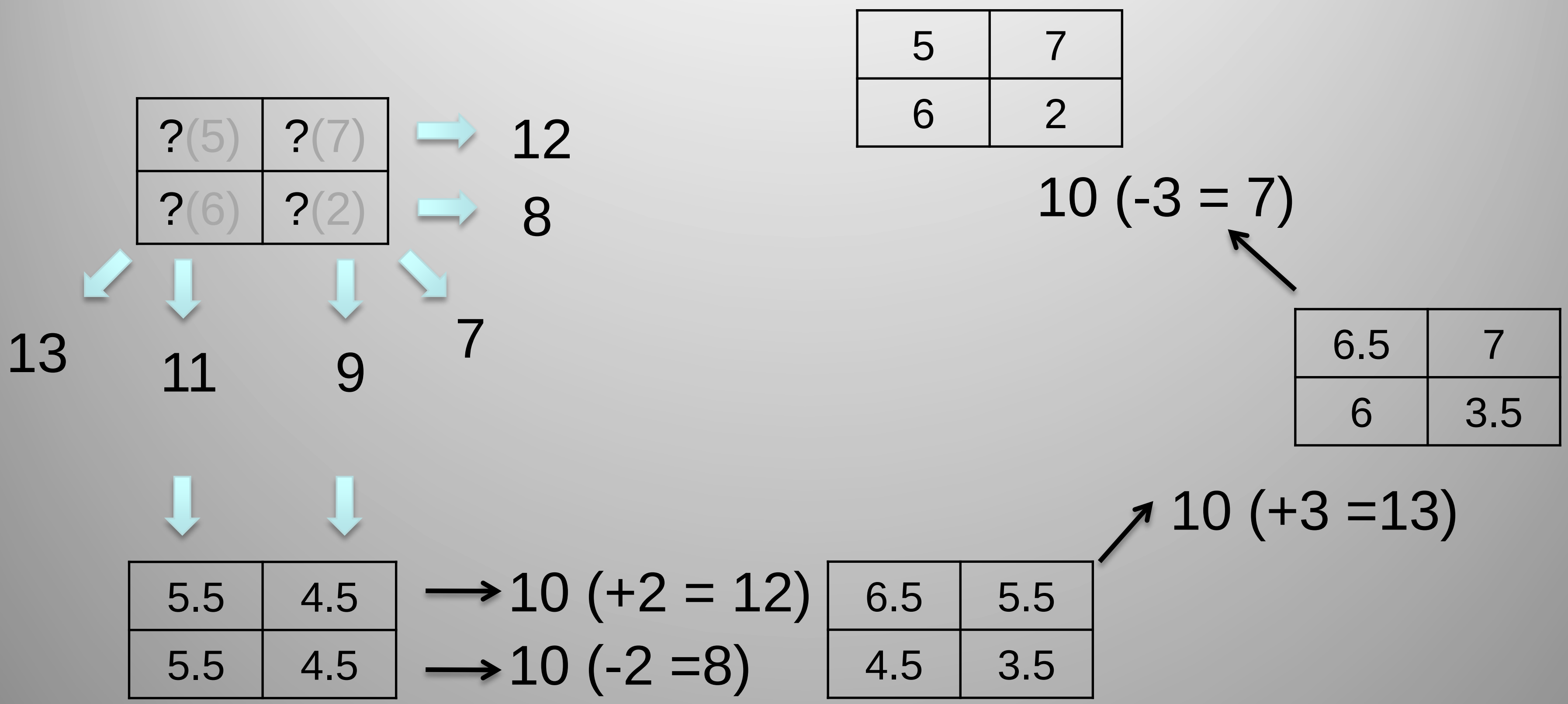
1	1	1
3	3	3
1	1	1

3	6	2
6	7	6
2	6	3

Apply a LUT: 7 = black
0 = white

2	6	2
6		6
2	6	2

Iterative reconstruction



Effects of iterative reconstruction

0.98 mSv

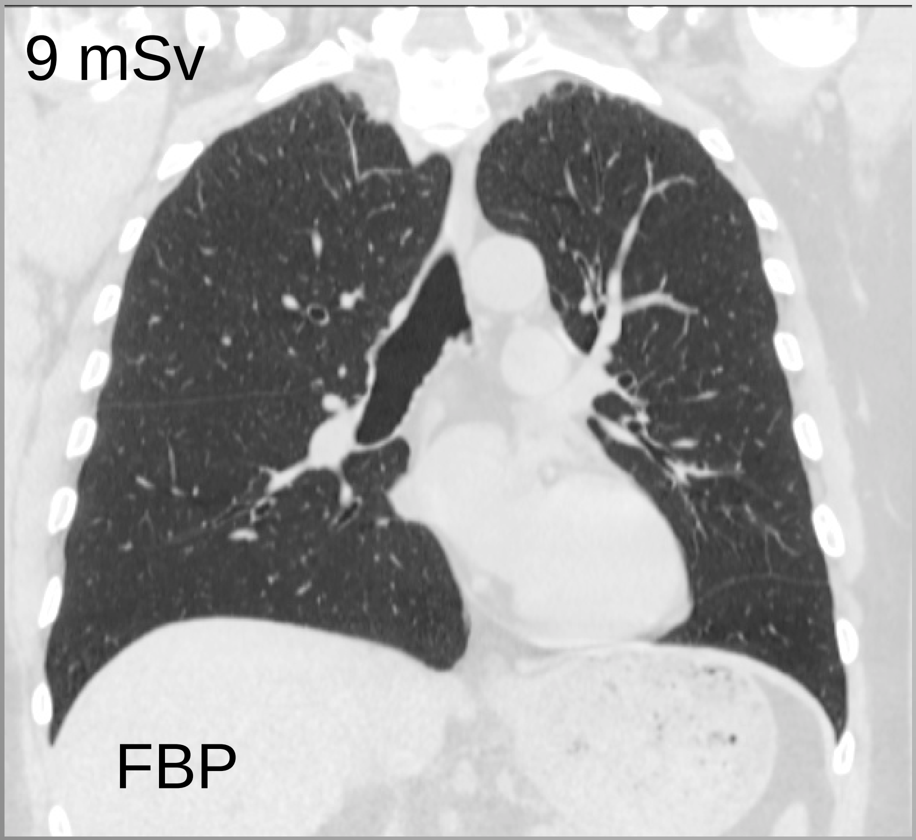
Ultra-low dose CT

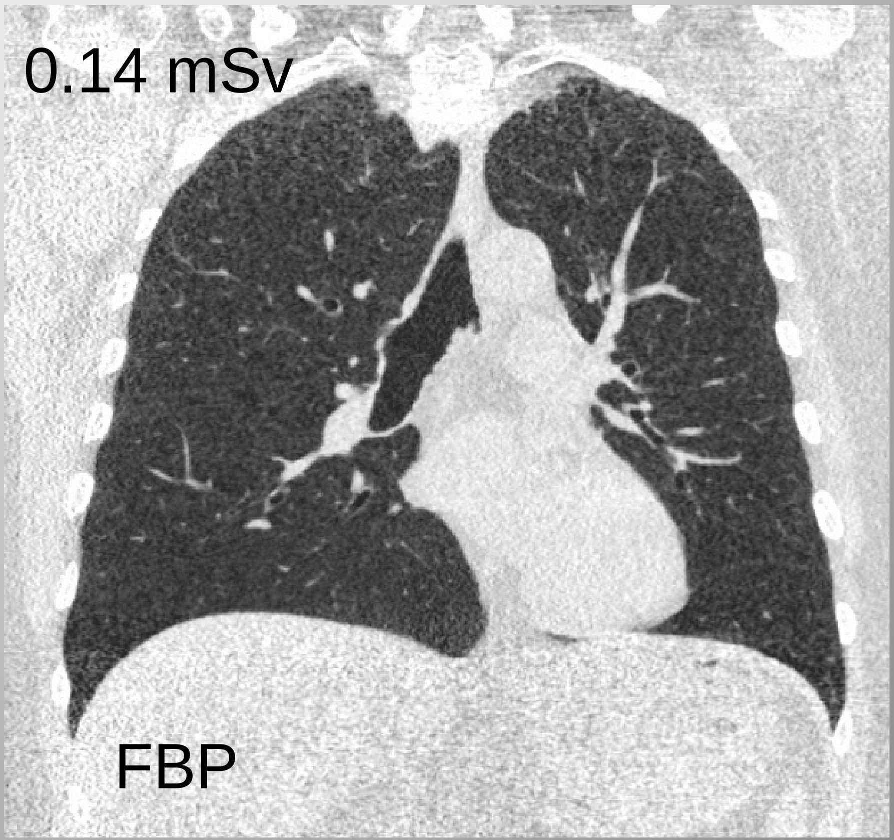
Model based iterative reconstruction

Dose reduction

To assess image quality and diagnostic information of chest CT acquired with the dose of a conventional radiography, i.e. with a dose of 0.1-0.15 mSv

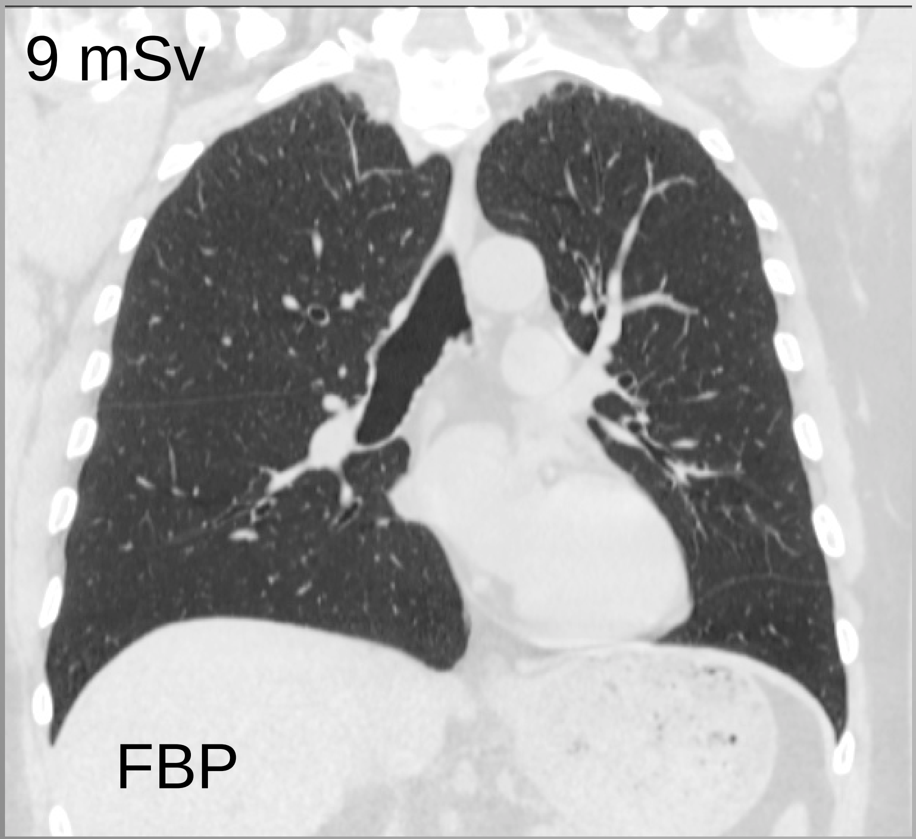
Using classical filtered back projection and new iterative reconstruction

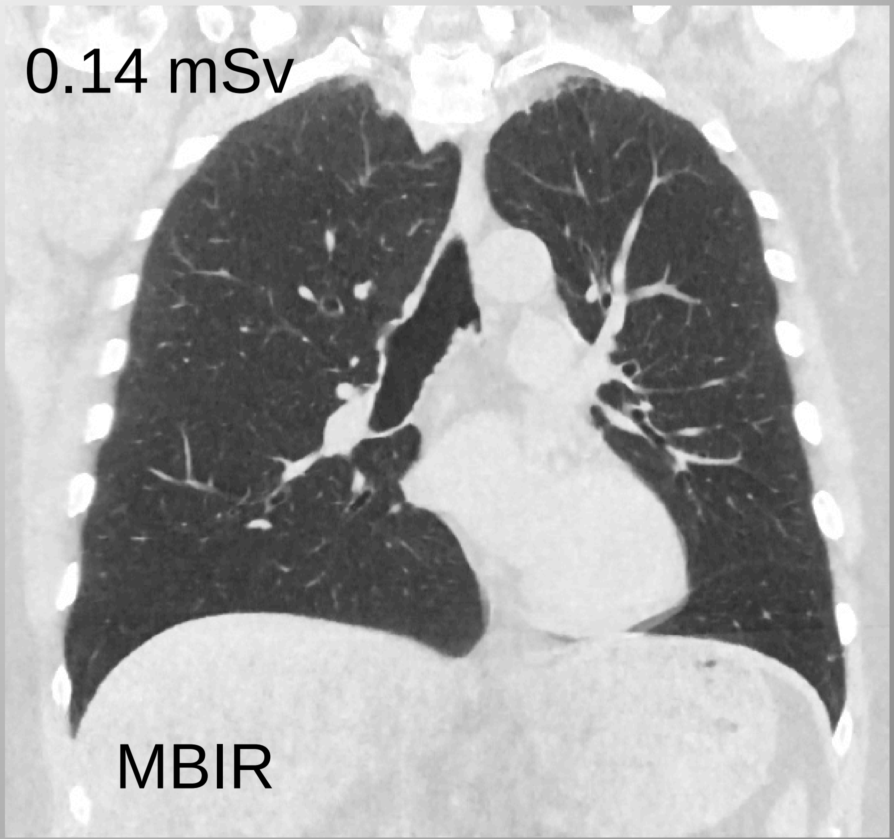




590 days of irradiation

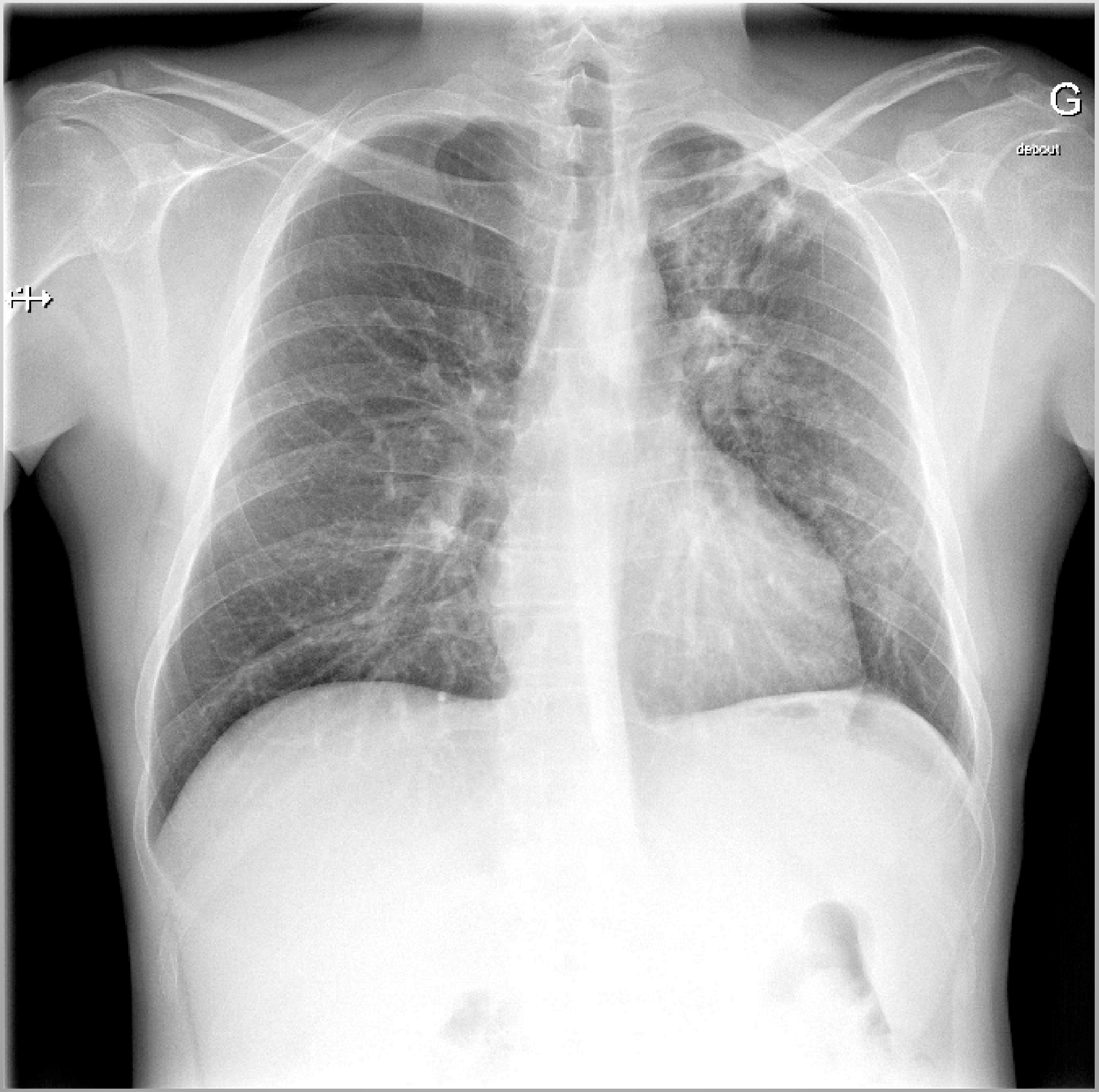
9 days of irradiation



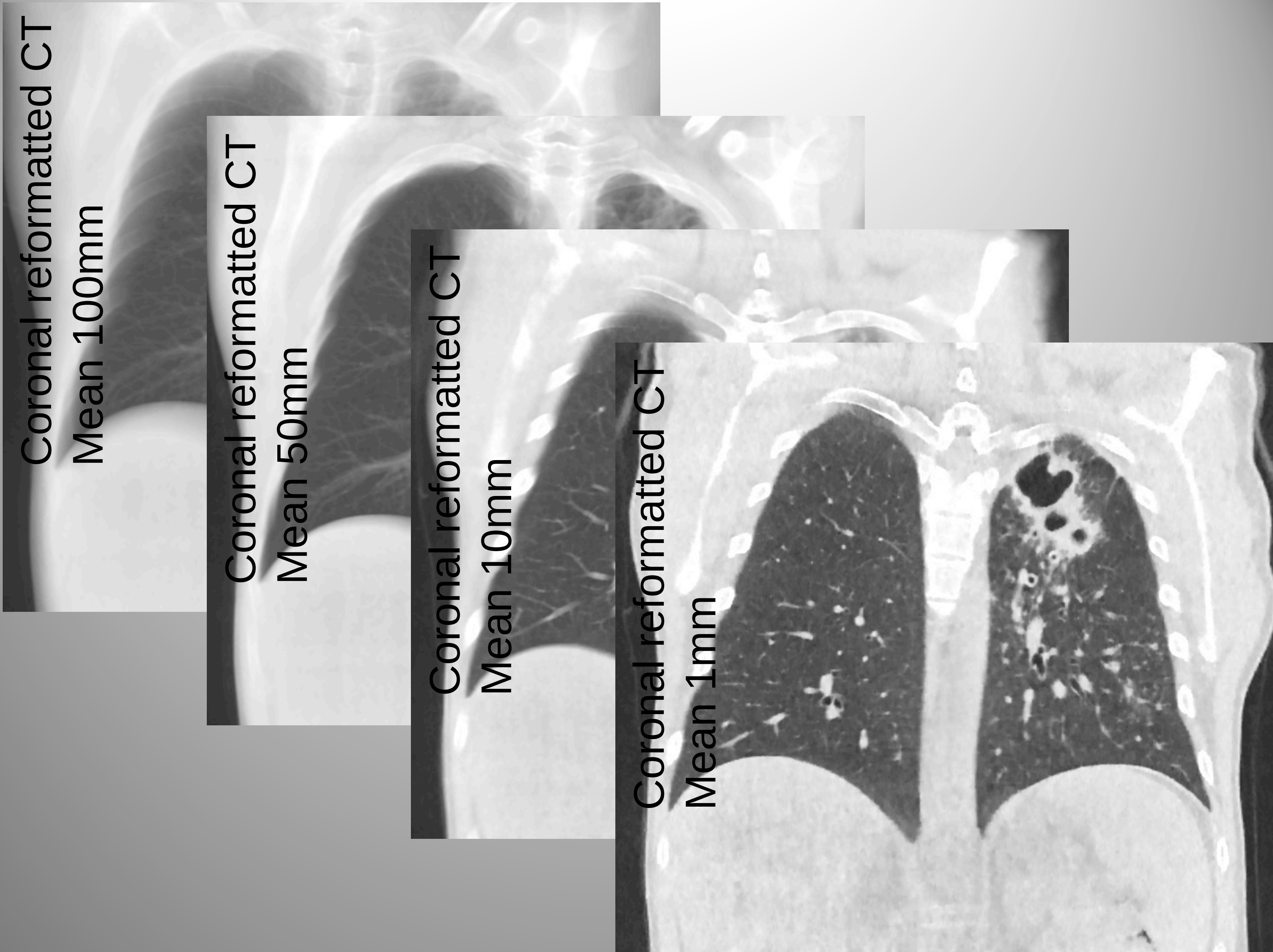


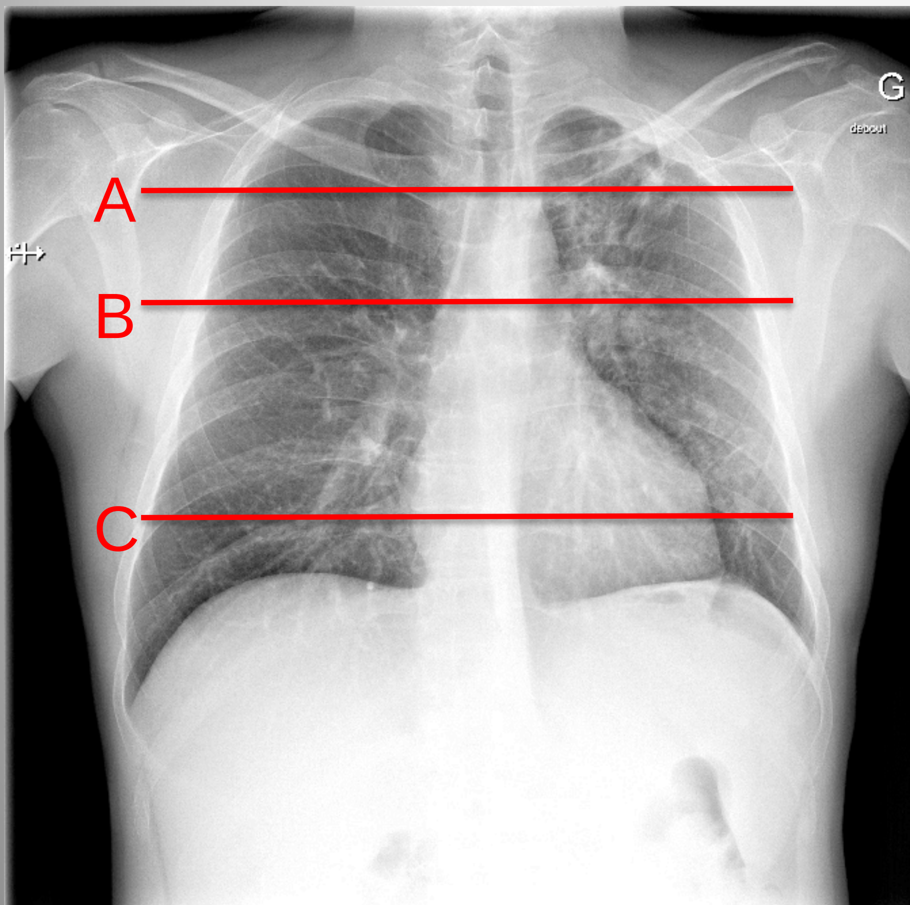
590 days of irradiation

9 days of irradiation

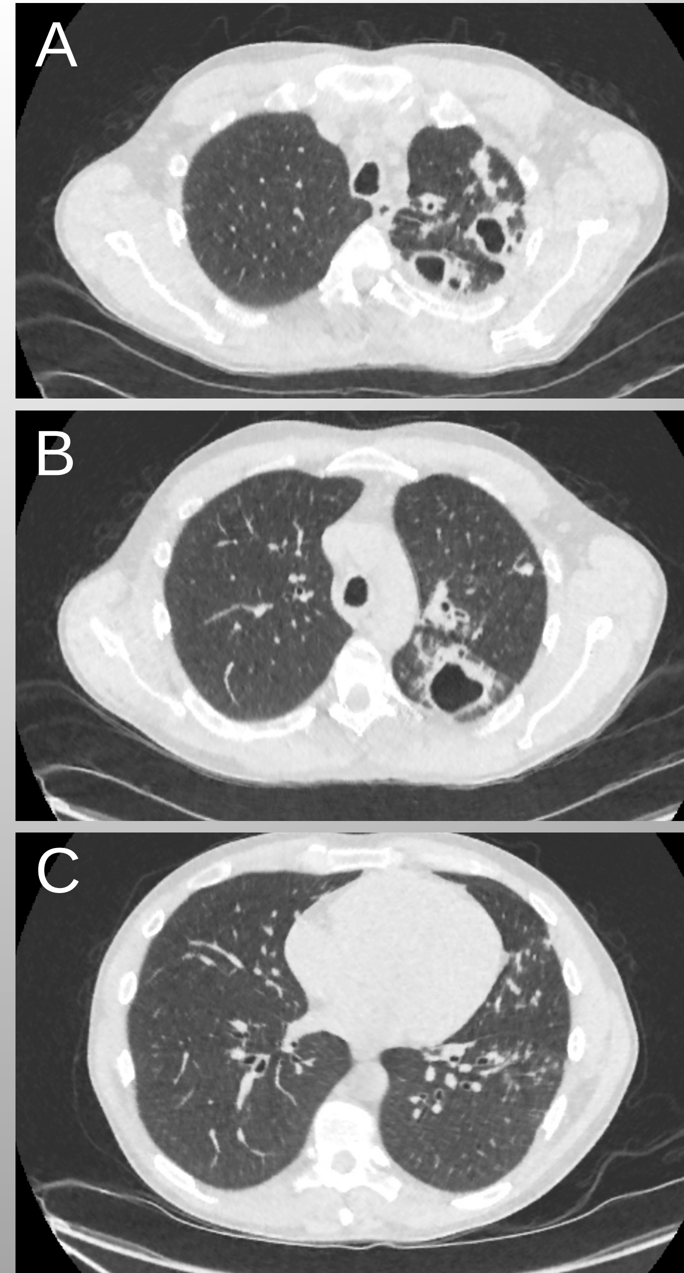


PA and lateral Chest X-ray : 0.1 – 0.15 mSv


Coronal reformatted CT
Mean 100mm
Coronal reformatted CT
Mean 50mm
Coronal reformatted CT
Mean 10mm
Coronal reformatted CT
Mean 1mm



Dose: 0.1 - 0.15 mSv



0.12 mSv

Nodules detection

		Number of nodules			
nodules		R1	R2	R3	Kappa
Diagnostic CT		28	29	29	0.815
Ultra-Low Dose	F.B.P.	25	24	19	0.684
	ASIR-40	27	28	18	0.578
	ASIR-80	28	29	20	0.654
	MBIR	28	29	29	0.815
Diagnostic CT vs ULD-CT		ns	ns	ns	

Computed tomography of the chest with model-based iterative reconstruction using a radiation exposure similar to chest X-ray examination: preliminary observations. Neroladaki A, Botsikas D, Boudabbous S, Becker CD, Montet X. Eur Radiol. 2013 Feb;23(2):360-6.

Subtle anomalies

Table 5 Number of patients having ground glass opacities

GGO		Kappa	Five-point scale (median)	Number of patients R1	R2	R3
Diagnostic CT (SDD/LDD)		0.694	1	11	11	12
ULD-CT	FBP	0.172	2	7	11	9
	ASIR-40	0.222	1.5	9	10	8
	ASIR-80	0.184	1	9	9	8
	MBIR	0.367	1	8	14	11

Table 6 Number of patients having emphysema

Emphysema		Kappa	Five-point scale (median)	Number of patients R1	R2	R3
Diagnostic CT (SDD/LDD)		1	1	9	9	9
ULD-CT	FBP	0.06	2	5	6	5
	ASIR-40	−0.125	1.5	4	5	3
	ASIR-80	−0.317	1	8	5	6
	MBIR	−0.144	2.2	11	16	6

Level of irradiation

Estimated effective dose

Full dose -CT	Low dose-CT	Ultra-low dose-CT
9.5 +/- 2.3 mSv	2.3+/- 0.7 mSv	**0.13** +/- 0.006 mSv

620 days of radiation

5 days of irradiation

150 days of irradiation

Ultra-low dose CT

- Could we combine ultra-low dose chest CT with iodinated contrast media?

A prospective study

164 patients underwent CTPA on a GE 750HD scanner after injection of 60 ml iohexol 350 at 3.5 ml/s

Standard dose CTPA (n=82)

- 100 kV
- 100-500 mA
- 0.984:1 Pitch
- 0.6s Gantry rotation time
- 28 noise index
- 64 x 0.625 detectors configuration

Ultra-low dose CTPA (n=82)

- 100 kV
- 20 mA
- 0.984:1 Pitch
- 0.6s Gantry rotation time
- --
- 64 x 0.625 detectors configuration

Purpose:

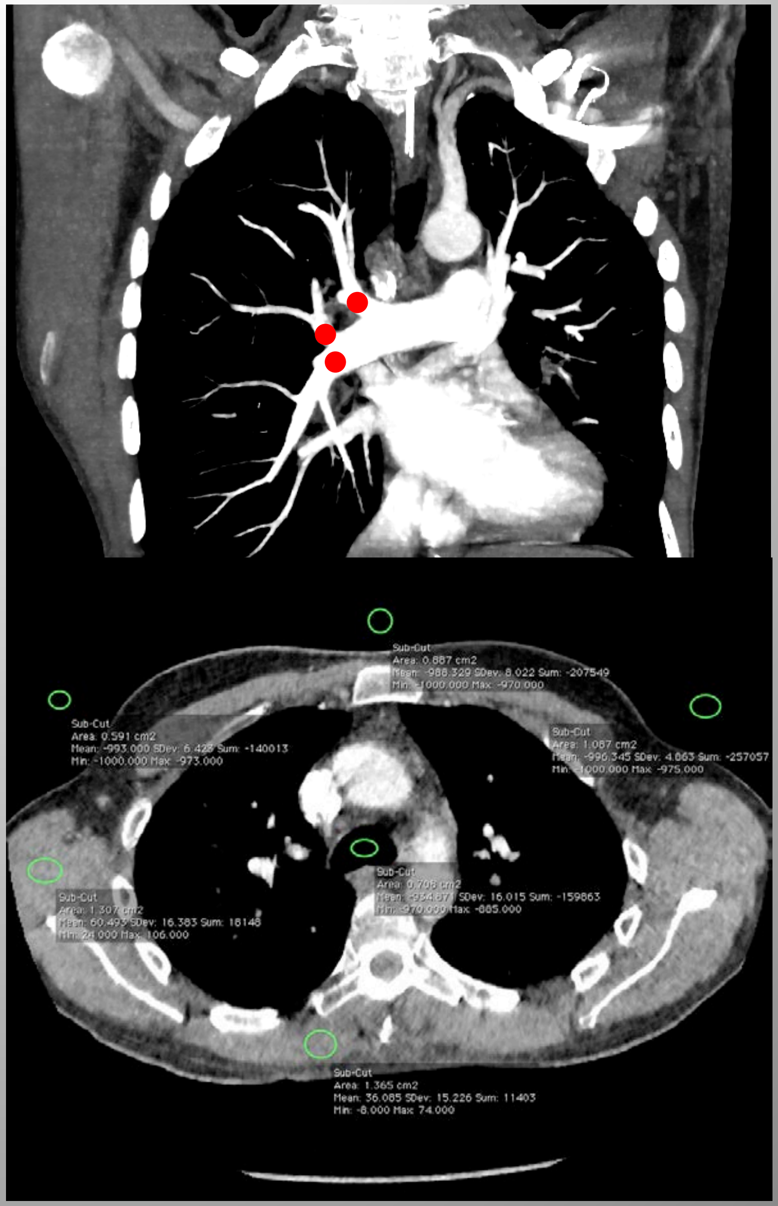
To compare image quality and radiation dose between CT pulmonary angiography (CTPA) reconstructed with filtered back projection (FBP) and ultra-low dose CTPA reconstructed with model-based iterative reconstruction (MBIR)

Objective image analysis

- ROIs were drawn in
  - 9 pulmonary vessels
  - 3 background noise
  - 2 muscle density

$$SNR = \frac{HU_{vessels}}{\text{background noise}}$$

$$CNR = \frac{(HU_{vessels} - HU_{muscle})}{\text{background noise}}$$



- Patients demographics

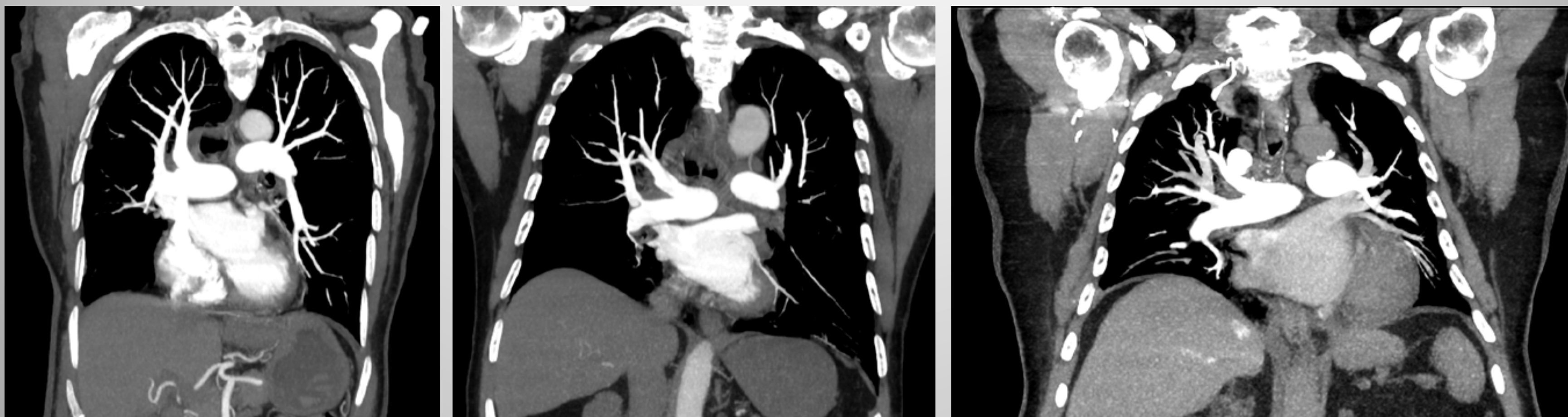
	Standard dose	Reduced dose	p
Men/Women	46/36	49/33	0.64
Age (year)	64±15	60 ± 14	0.08
Body mass index (kg/m^2)	26.1 ± 6.0	24.8 ± 4.8	0.12

	Ultra-low dose CTPA			Standard dose CTPA			
	Mean		SD	Mean		SD	
Pulmonary Arteries (HU)	340	±	80	356	±	84	0.22
MPA (HU)	361	±	81	376	±	93	0.26
RPA (HU)	349	±	82	368	±	88	0.16
LPA (HU)	342	±	78	364	±	85	0.09
RUA (HU)	356	±	95	366	±	96	0.52
RMA (HU)	331	±	79	339	±	86	0.56
RLA (HU)	340	±	89	352	±	94	0.42
LUA (HU)	326	±	88	341	±	84	0.27
LIA (HU)	327	±	89	342	±	82	0.27
LLA (HU)	340	±	85	357	±	88	0.21
Subscapular and paraspinal muscle	41	±	10	44	±	9	0.12
Background noise	6	±	1	10	±	4	< 0.0001
SNR	56	±	19	43	±	20	< 0.0001
CNR	50	±	17	38	±	18	< 0.0001
CTDIvol	0.59	±	0.003	8	±	1.8	< 0.0001
Effective dose (mSv)	0.31	±	0.03	4.23	±	0.96	< 0.0001

20 days of irradiation

275 days of irradiation

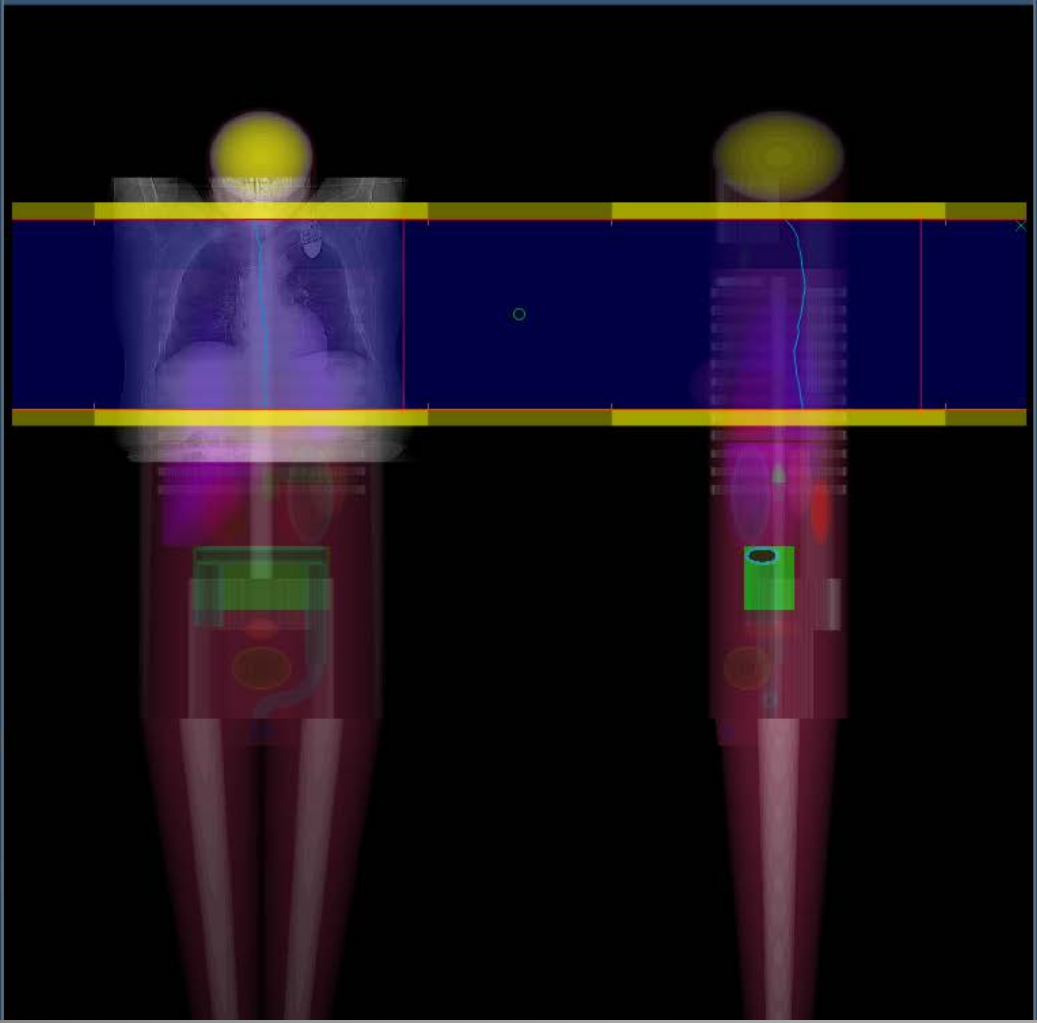
Routine FBP-CTPA



BMI < 20 kg/m^2 | 20 < BMI < 30 kg/m^2 | BMI > 30 kg/m^2

Ultra-low dose CTPA

Organ dose associated with CTPA



Value of Interest	Examination Dose [mSv]
Adrenals	0.0980
Brain	0.0600
Breasts	0.876
Colon	0.00335
Eye Lenses	0.0546
Esophagus	0.488
Gall Bladder	0.0249
Heart	0.678
Kidneys	0.0211
Liver	0.0783
Lungs	0.829
Muscle	0.26
Ovaries	0.00223
Pancreas	0.0729
Red Marrow	0.265
Remainder ICRP103	0.252
Remainder ICRP60	0.246
Salivary Glands	0.0600
Skeleton	0.687
Skin	0.267
Small Intestine	0.00364
Spleen	0.0642
Stomach	0.0518
Thymus	1.093
Thyroid	1.26
Urinary Bladder	0.000413
Uterus	0.000850
ICRP 103	0.357
ICRP 60	0.286

Ultra-low dose standard dose

Ultra-low dose

Organ Doses

Value of Interest	Examination Dose [mSv]
Adrenals	0.0980
Brain	0.0600
Breasts	0.876
Colon	0.00335
Eye Lenses	0.0546
Esophagus	0.488
Gall Bladder	0.0249
Heart	0.678
Kidneys	0.0211
Liver	0.0783
Lungs	0.829
Muscle	0.26
Ovaries	0.00223
Pancreas	0.0729
Red Marrow	0.265
Remainder ICRP103	0.252
Remainder ICRP60	0.246
Salivary Glands	0.0600
Skeleton	0.687
Skin	0.267
Small Intestine	0.00364
Spleen	0.0642
Stomach	0.0518
Thymus	1.093
Thyroid	1.26
Urinary Bladder	0.000413
Uterus	0.000850
ICRP 103	0.357
ICRP 60	0.286

0.876 mSv

0.00085 mSv

Standard dose

Organ Doses

Value of Interest	Examination Dose [mSv]
Adrenals	2.61
Brain	1.486
Breasts	21.789
Colon	0.0878
Eye Lenses	1.35
Esophagus	12.478
Gall Bladder	0.673
Heart	17.942
Kidneys	0.58
Liver	2.139
Lungs	21.319
Muscle	6.539
Ovaries	0.0753
Pancreas	1.962
Red Marrow	6.641
Remainder ICRP103	6.335
Remainder ICRP60	6.182
Salivary Glands	1.486
Skeleton	17.188
Skin	6.717
Small Intestine	0.0997
Spleen	1.754
Stomach	1.426
Thymus	27.12
Thyroid	31.17
Urinary Bladder	0.0102
Uterus	0.0243
ICRP 103	9.018
ICRP 60	7.239

21.789 mSv

0.0243 mSv

Conclusion

- CT protocols have to be tailored to your patient, i.e. personalized CT protocols

- CT dose reduction is only possible with clear indications/questions
  - We may be able to image PE with a dose of 0.2 mSv
  - Whereas we may not be able to image interstitial pneumonia with this dose

Thank you

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