Background

- deterministic and stochastic effects of ionizing radiations
- increased sensitivity of children to radiations
- principles : justification and optimization
- increasing use of CT :
  - epidemiological data
  - risk projection

Judicious use of radiations (1)

- first effective measure to minimize radiation

    NOT TO DO UNNECESSARY EXAMINATIONS

- good communication between radiologist and referring doctor
- no examination performed for questionable indication
- no repetition without clinical justification
- check for previous examinations

Judicious use of radiations (2)

- periodic review of patterns of requests ⇒ recommendations
- guidelines (Royal College of Radiologists : London)

  (Consilium Radiologicum : Belgium)

  « Making the best use of a department of clinical radiology »
- substitution : alternative techniques ⇒ US & MR

Dose optimization > dose reduction

- image noise = $\frac{1}{beam\ energy}$
- dose reduction must not compromise diagnostic outcome
- diagnostic standards to maintain

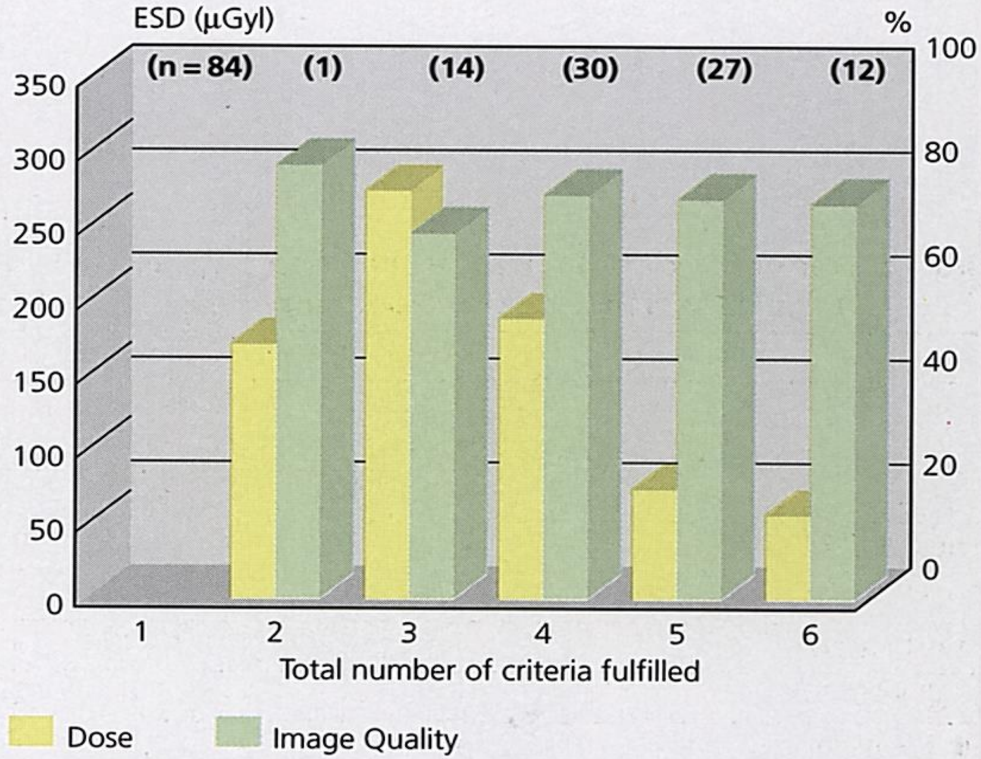


Figure 9 Impact of good radiographic technique on entrance surface dose and image quality: Chest AP/PA examination for 10 year old child; n = number of X-ray departments

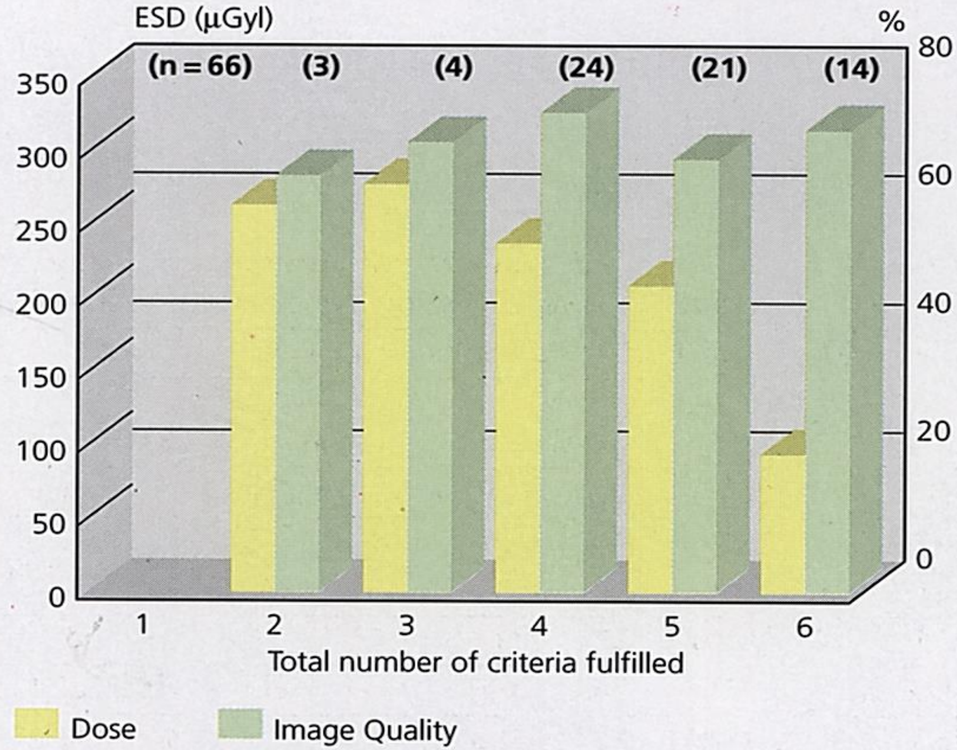
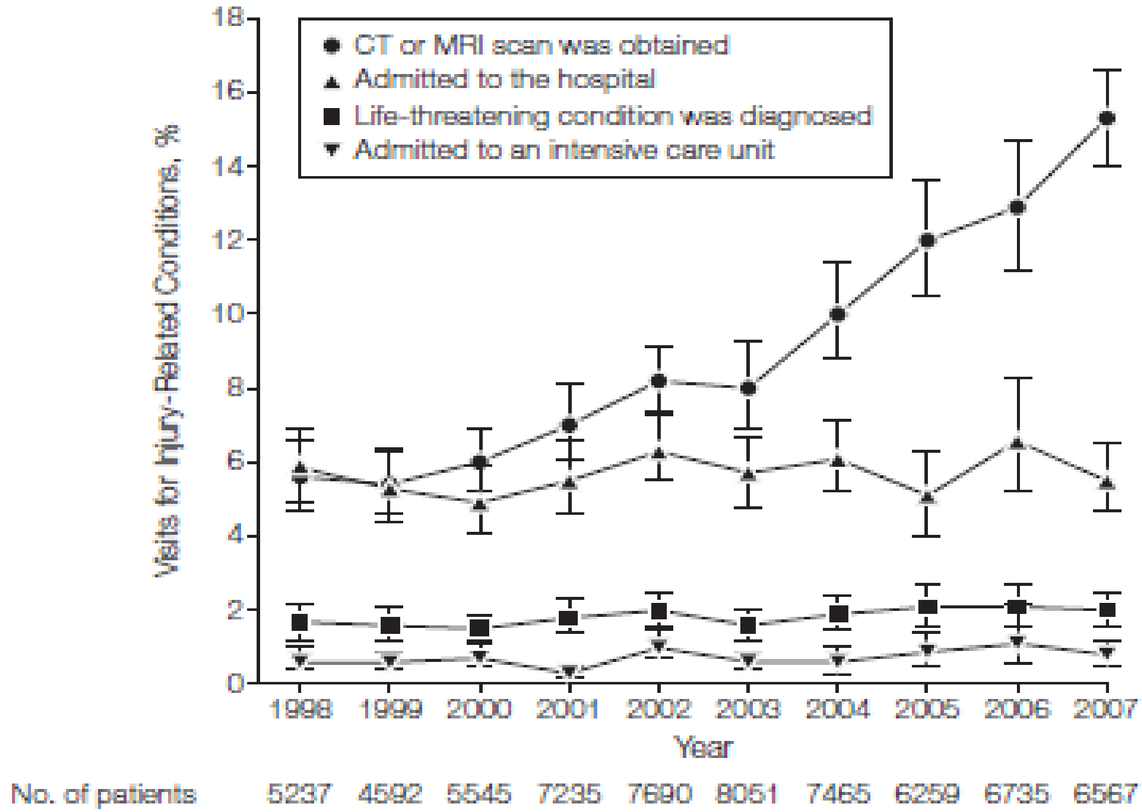


Figure 8 Impact of good radiographic technique on entrance surface dose and image quality: Chest lateral examination for 5 year old child; n = number of X-ray departments

Figure. Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) Obtained in the Diagnosis of Life-Threatening Conditions During Emergency Department Visits

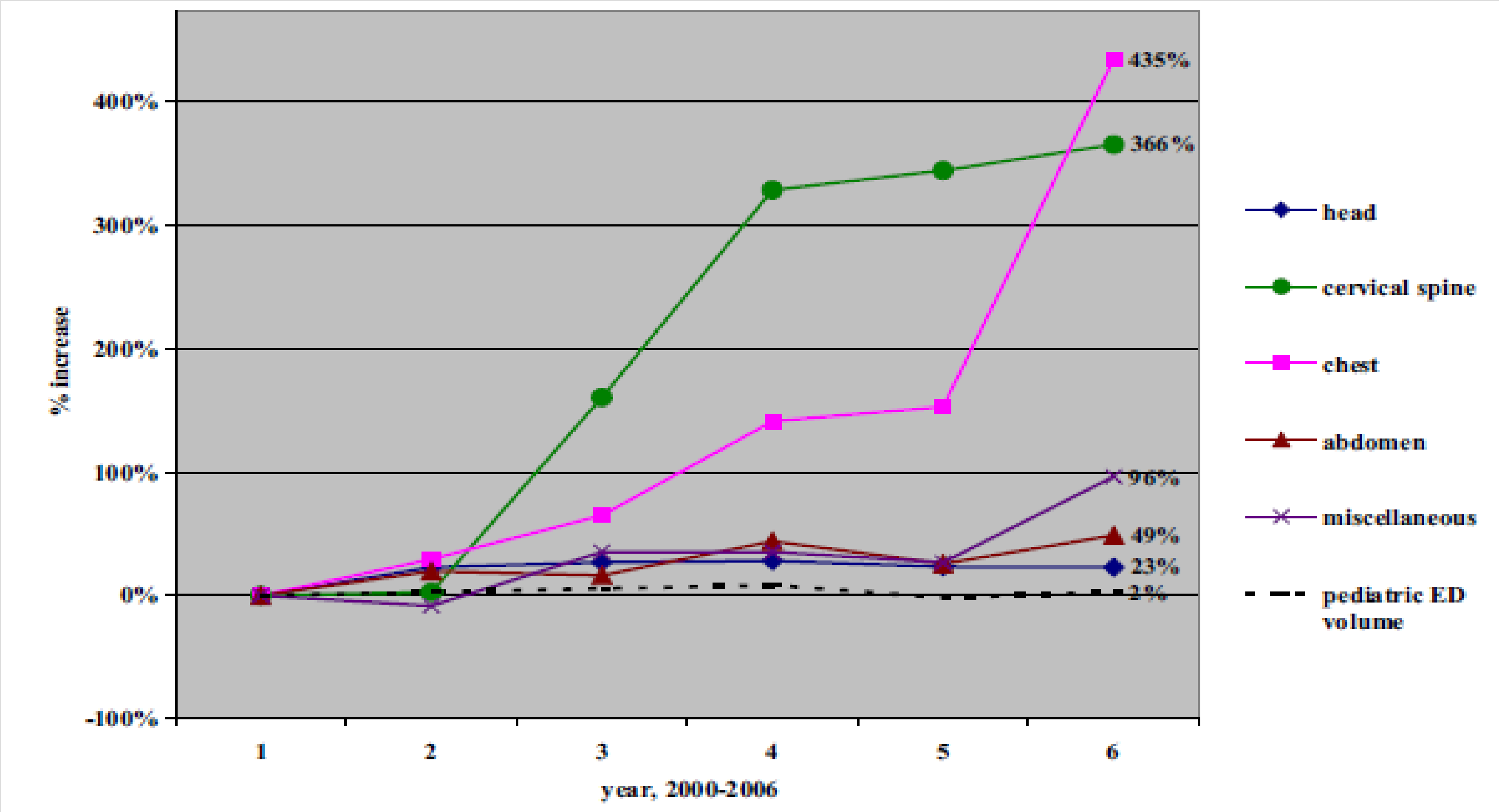


F. Korley et al. JAMA October 2010

Table 3. Length of Stay for Emergency Department (ED) Visits for Injury-Related Conditions

	2001 (n = 7235)	2002 (n = 7690)	2003 (n = 8051)	2004 (n = 7465)	2005 (n = 6259)	2006 (n = 6735)	2007 (n = 6567)
Length of stay for ED visits for injury-related conditions, mean (95% CI), min							
CT or MRI	296 (273-319)	308 (284-332)	312 (296-328)	315 (291-338)	304 (290-319)	310 (294-325)	314 (297-331)
No CT or MRI	170 (161-179)	182 (169-195)	183 (174-192)	179 (172-187)	182 (174-190)	184 (173-196)	190 (180-201)
Mean difference (CT or MRI obtained vs not obtained)	126 (105-146)	126 (104-148)	129 (116-143)	135 (113-158)	122 (110-135)	125 (112-138)	124 (110-138)

F. Korley et al.   JAMA   October 2010



J. Broder et al. *Emerg. Radiol.* *2007*

Facteurs d'augmentation

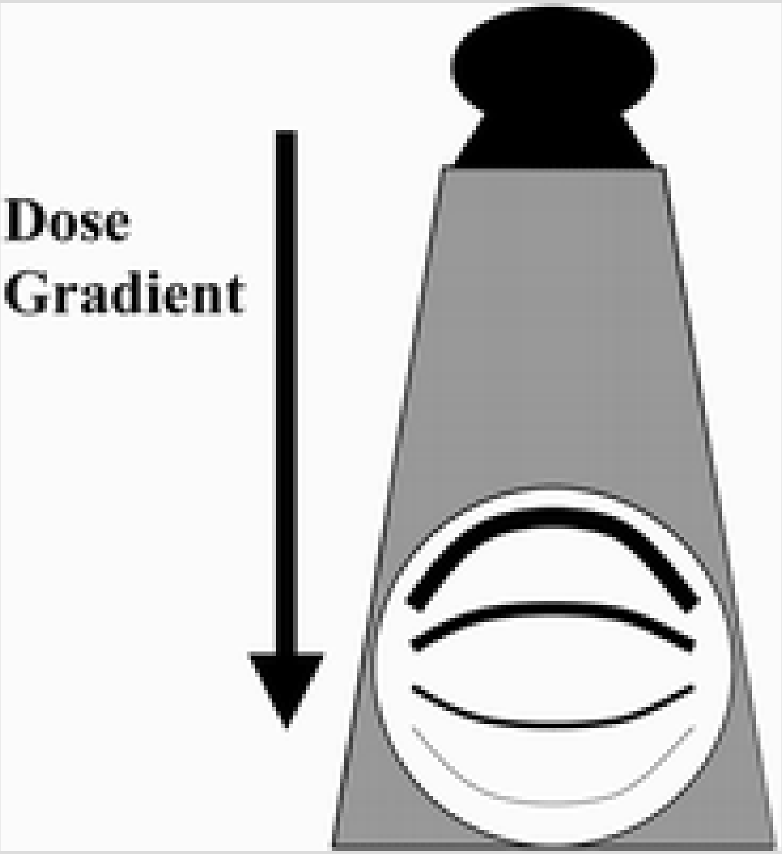
- quantité information TDM >> RX
- utilisation en routine dans 'trauma center'
- augmentation disponibilité TDM
- proximité de la machine par rapport aux S.U.
- vitesse d'acquisition des images (pas de sédation)
- procédures juridiques pour mauvaise pratique

Conventional radiography

- decreasing dose from entrance to exit

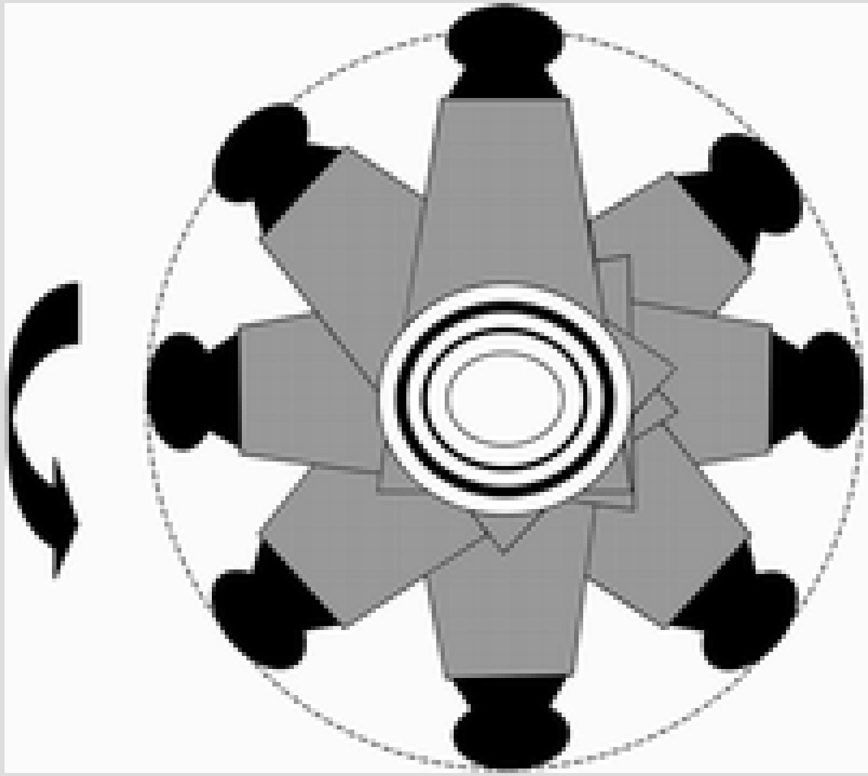
Conventional radiography

- decreasing dose from entrance to exit



Computed tomography

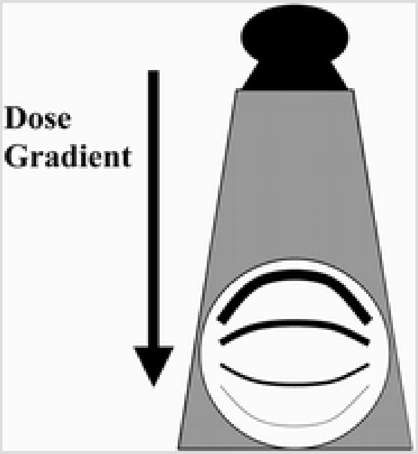
- more uniform distribution of dose around patient
- radiation energy not fully contained within volume



Computed tomography

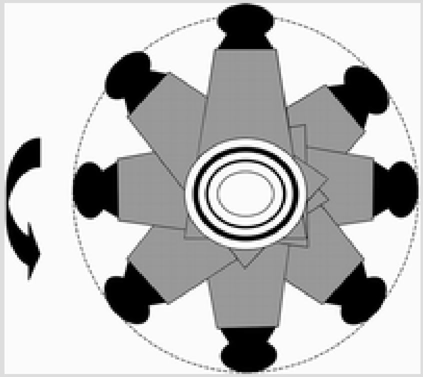
- more uniform distribution of dose around patient
- radiation energy not fully contained within volume

Conventional radiography



- decreasing dose from entrance to exit

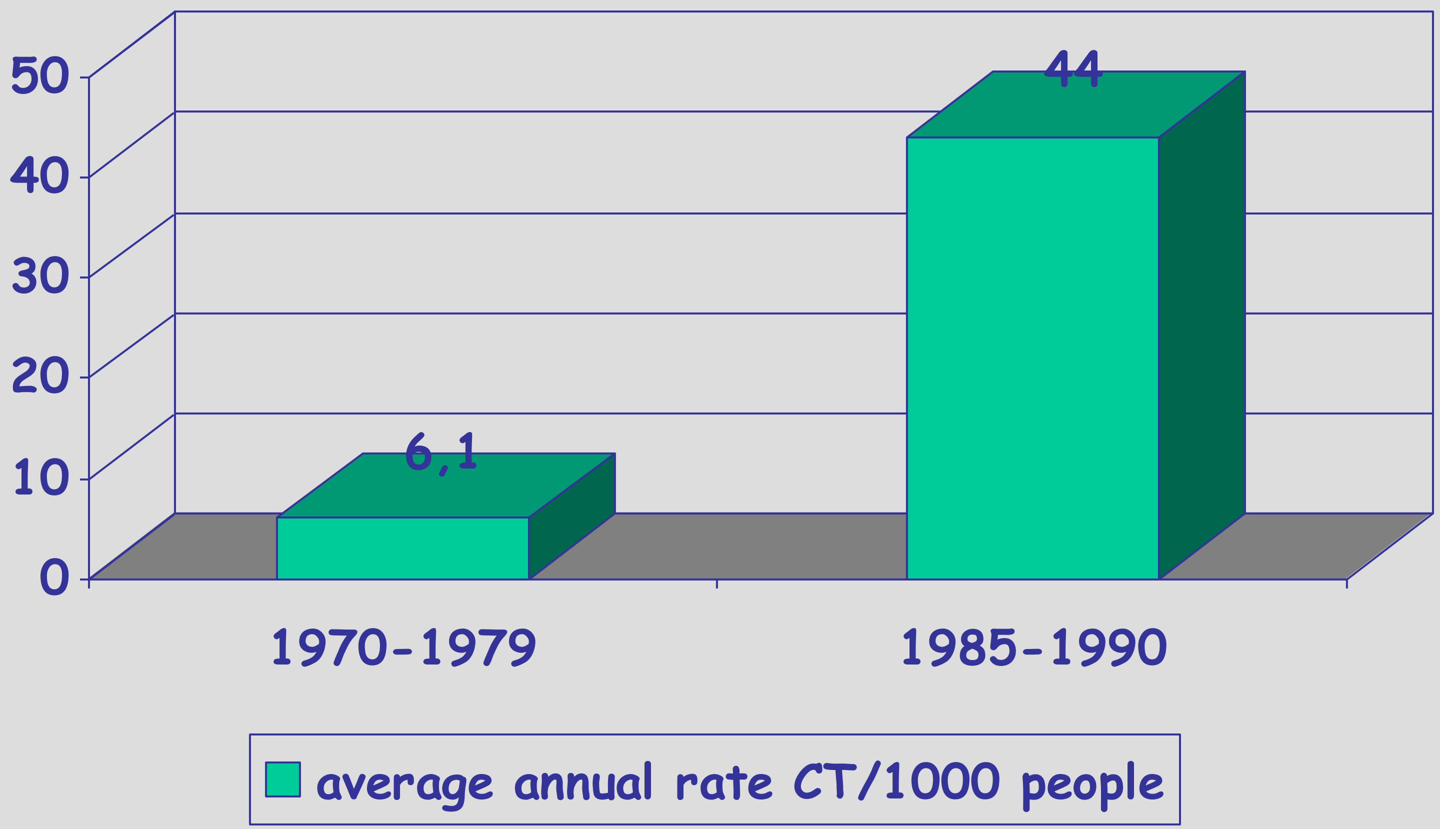
Computed tomography

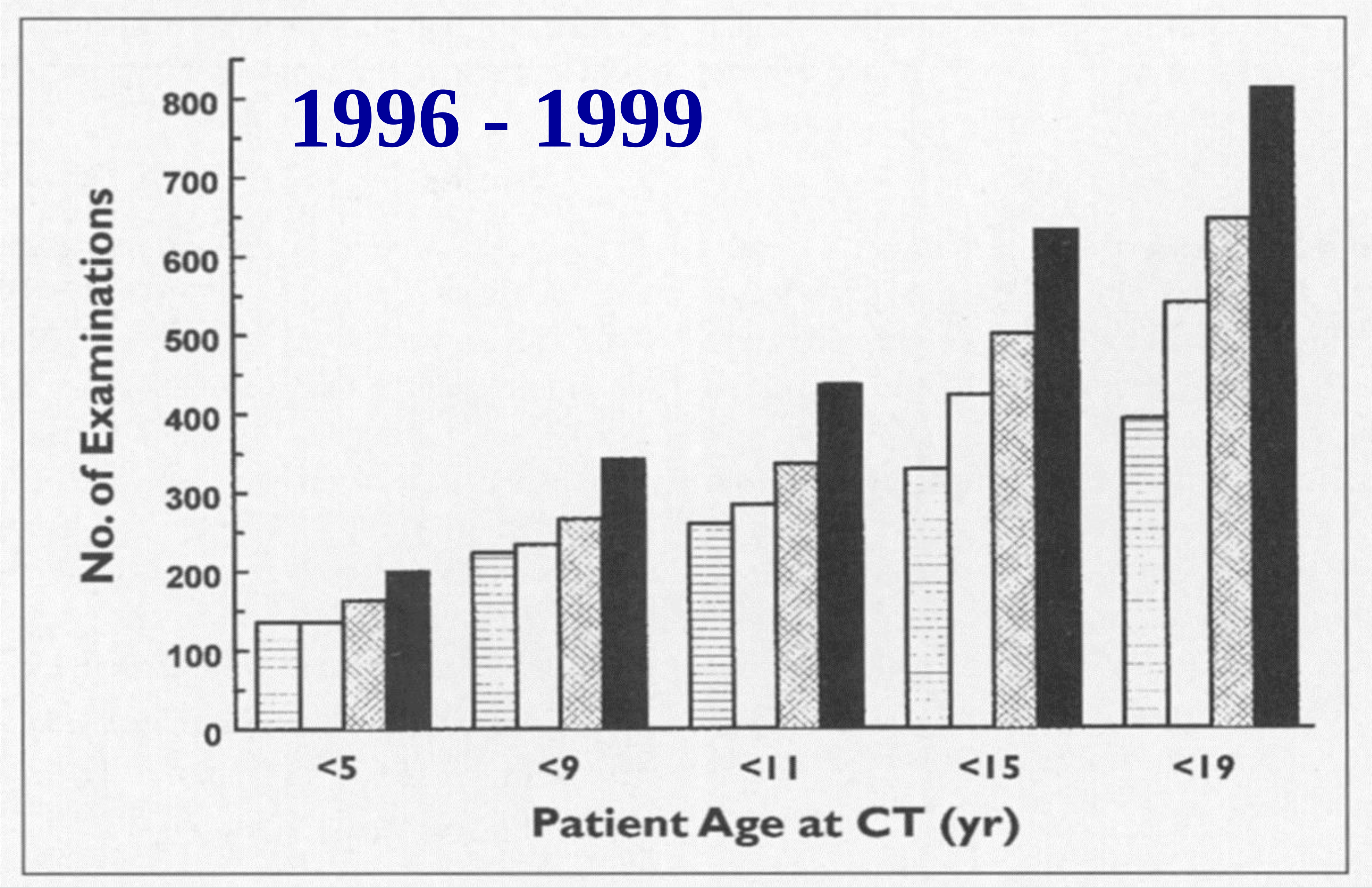


- more uniform distribution of dose around patient
- radiation energy not fully contained within volume

Table 2. CT is a high-dose procedure

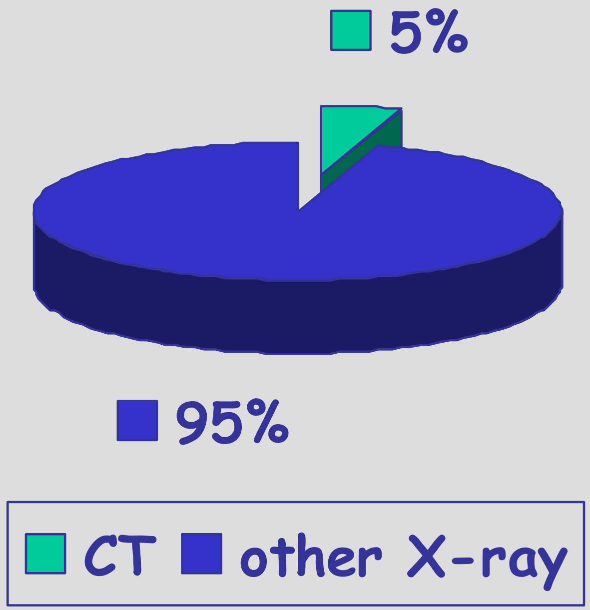
Procedure	Effective dose in Sv	Chest surveys equivalent (*n*)	Equivalent background radiation time
Chest PA	0.02	1	2.4 days
Chest CT	8	400	2.7 years
Abdomen CT	10	500	3.3 years


50
40
30
20
10
0
6,1
44
1970-1979
1985-1990
average annual rate CT/1000 people



D. J. Brenner AJR feb. 2001

UNSCEAR 2000 report
radiologic examinations



UNSCEAR 2000 report
collective dose

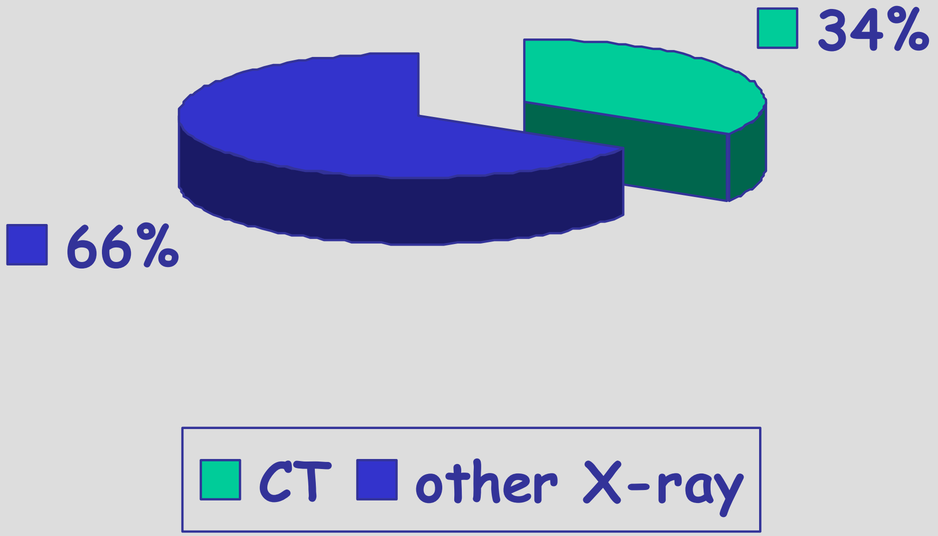


Figure XII. Annual per caput effective dose (mSv) for the United States population in 1980 [M37]

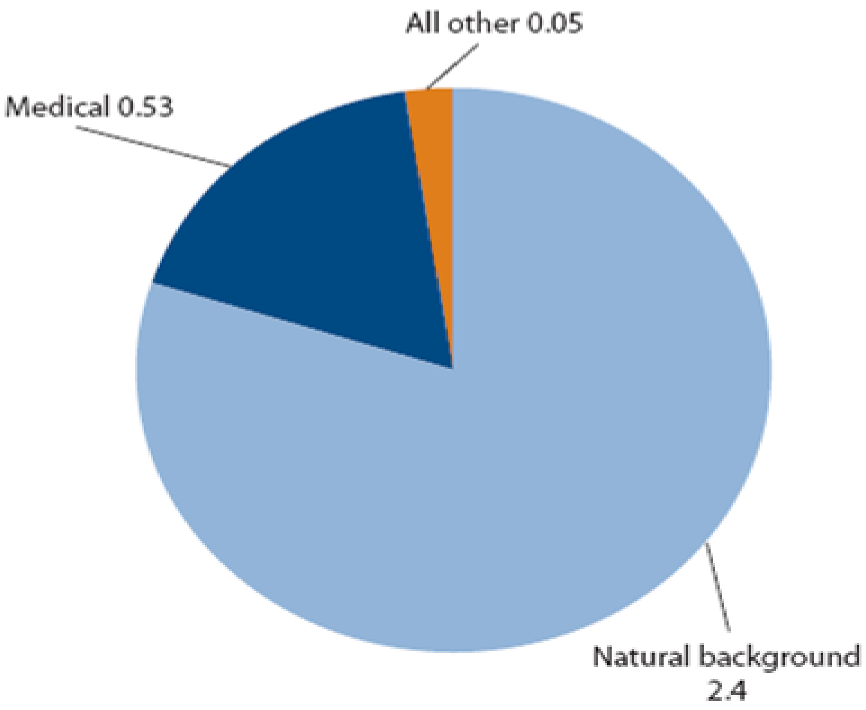
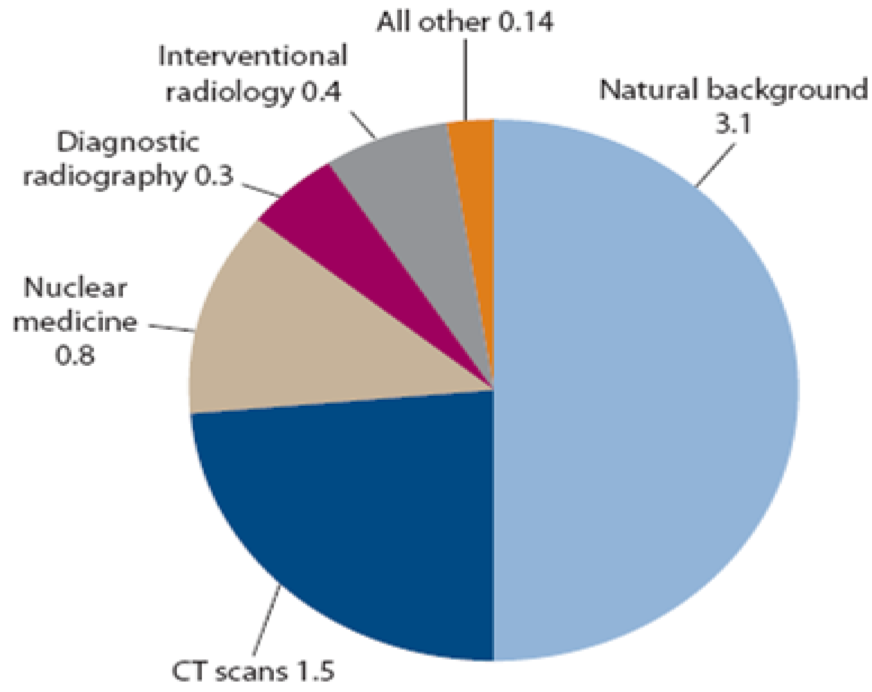


Figure XIII. Annual per caput effective dose (mSv) for the United States population in 2006 [N26]



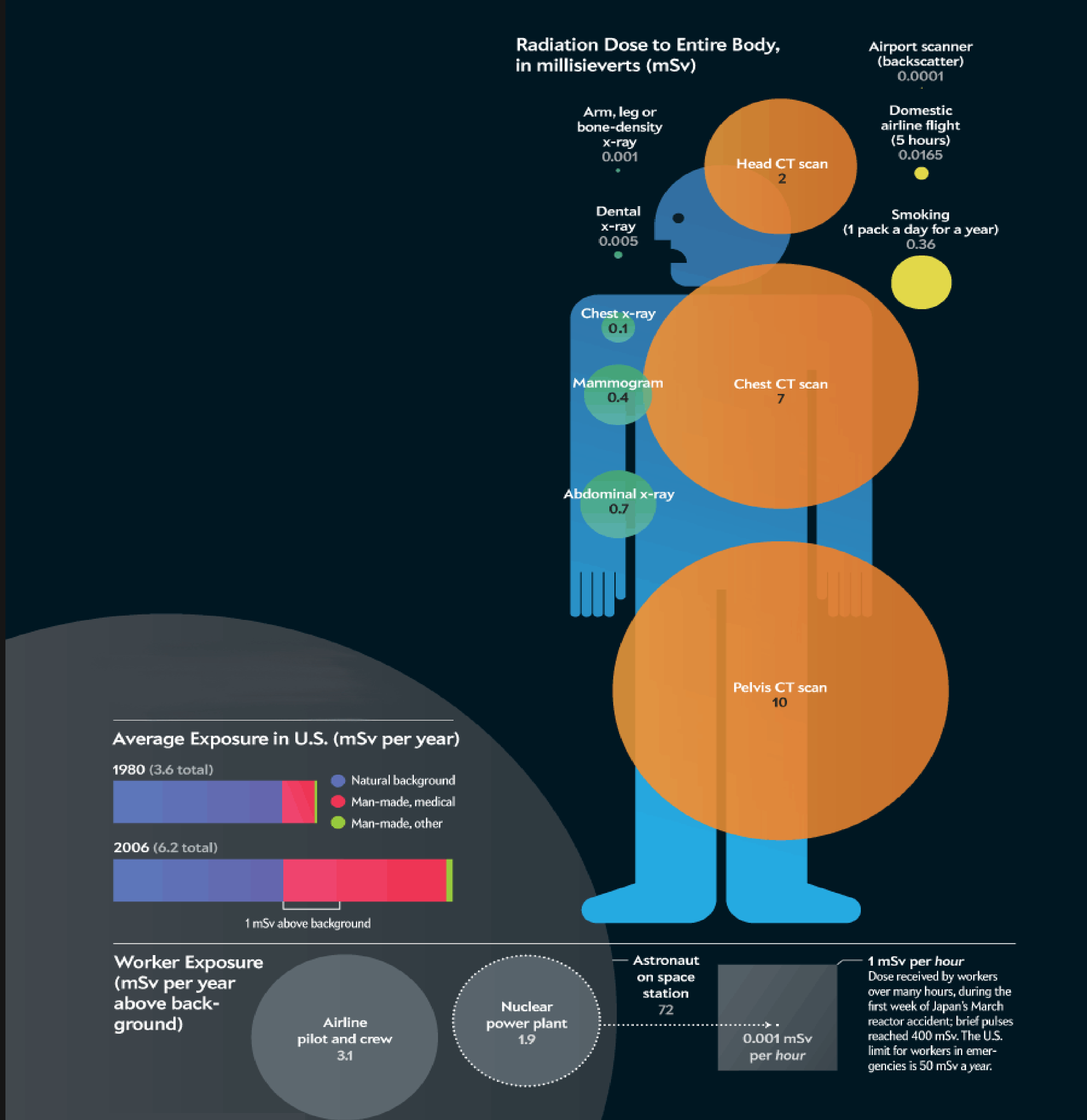
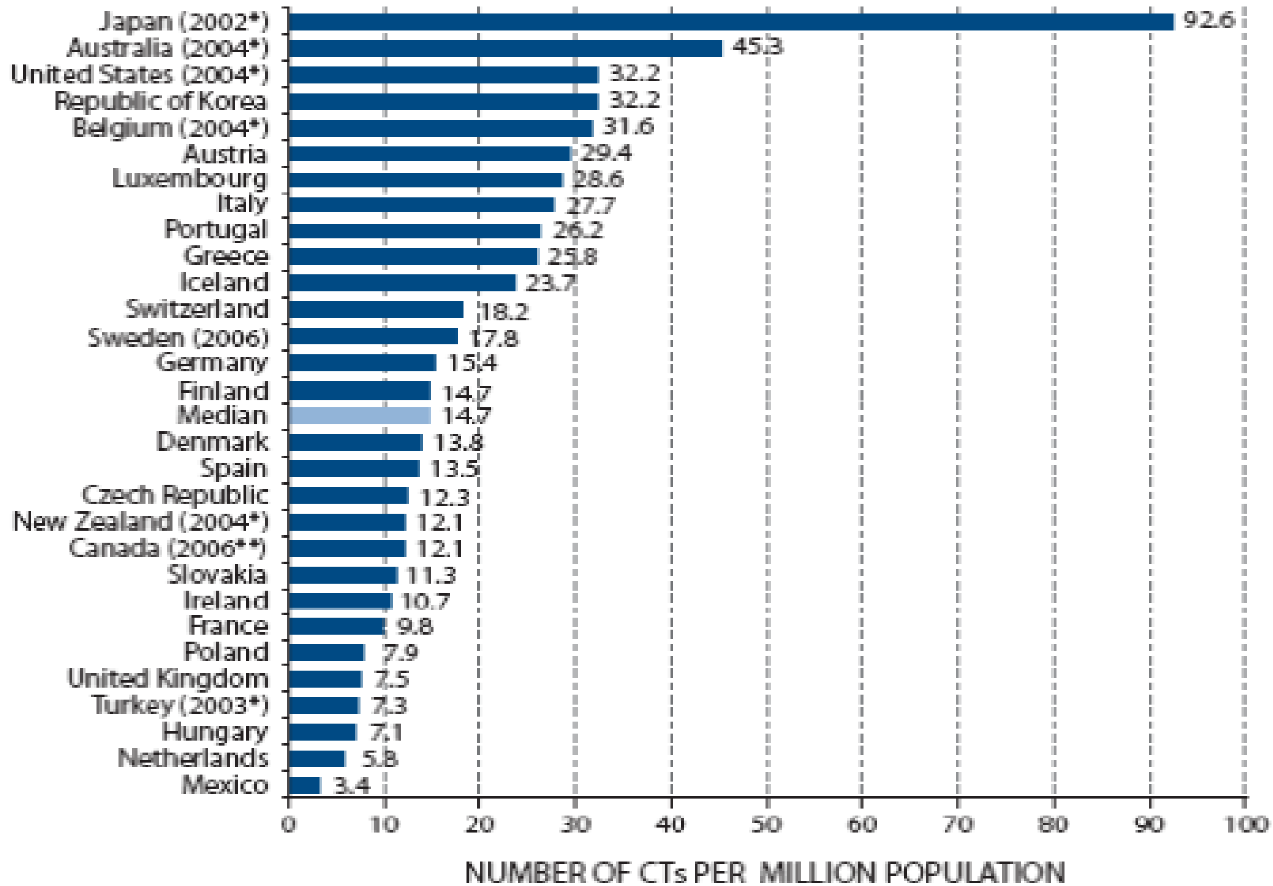

Radiation Dose to Entire Body, in millisieverts (mSv)
Airport scanner (backscatter) 0.0001
Arm, leg or bone-density x-ray 0.001
Domestic airline flight (5 hours) 0.0165
Head CT scan 2
Dental x-ray 0.005
Smoking (1 pack a day for a year) 0.36
Chest x-ray 0.1
Mammogram 0.4
Chest CT scan 7
Abdominal x-ray 0.7
Pelvis CT scan 10
Average Exposure in U.S. (mSv per year)
1980 (3.6 total)
Natural background
Man-made, medical
Man-made, other
2006 (6.2 total)
1 mSv above background
Worker Exposure (mSv per year above back-ground)
Airline pilot and crew 3.1
Nuclear power plant 1.9
Astronaut on space station 72
0.001 mSv per hour
1 mSv per hour
Dose received by workers over many hours, during the first week of Japan's March reactor accident; brief pulses reached 400 mSv. The U.S. limit for workers in emergencies is 50 mSv a year.

Figure B-II. Number of CT scanners per million population in OECD countries [C25]

Sources: OECD Health Data 2007, OECD, for all countries except Sweden and Canada; Belgian Health Care Knowledge Centre, *HTA of Diagnostic Resonance Imaging*, KCE report vol. 37C, 2006, for Sweden; National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information, for Canada. Reproduced with permission from the Canadian Institute for Health Information



*Latest year for which data are available.

**As of January 1, 2006.

Risk and radiation dose from CT

- increased risk of cancer mortality in children CT
- lifetime cancer mortality risks in a 1-year old
  - 0,18% : abdominal CT
  - 0,07% : head CT
- extrapolation :
  - USA : 600 000 abdominal and head CT annually
    in children younger than 15 years
  - 500 may die of cancer attributable to CT radiation

D.Brenner AJR 2001; 176 : 289-296

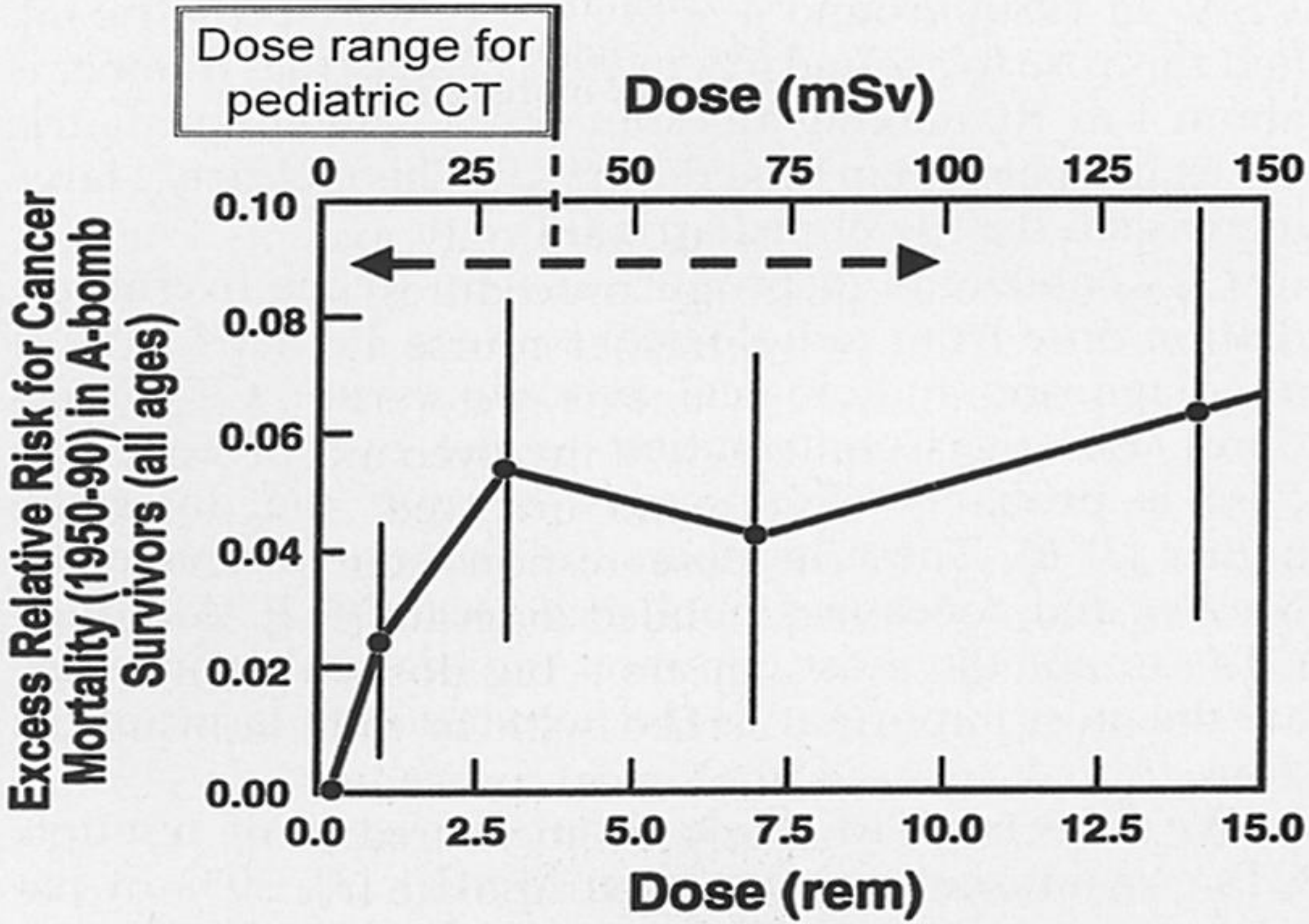
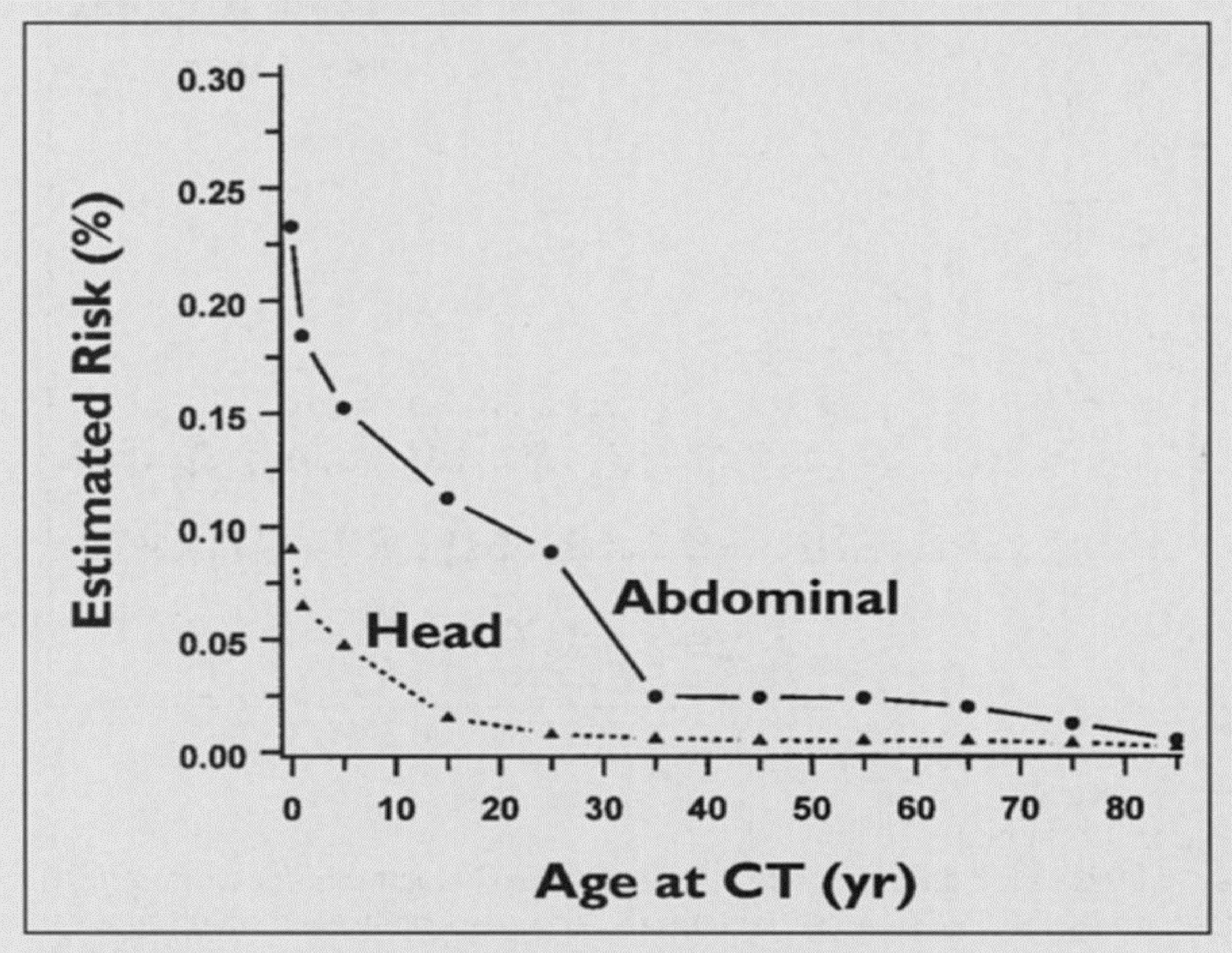


Fig. 3. The 35,000 A-bomb survivors who were exposed to doses below 15 rem and who have been followed for over 55 years show a small, but statistically significant, excess cancer incidence. This dose range is comparable to that applicable to helical CT studies in children



D. J. Brenner AJR feb. 2001

Radiation dose descriptor in CT

- CTDI = CT dose index
  - dose within and beyond scan volume
- $CTDI_W$ = average dose in scan volume for contiguous slices
- $CTDI_{vol}$ = average dose within a scan volume
  - not dose to any specific patient
  - standardized index of average dose delivered from scanning series
  - ! phantom : adult vs. child

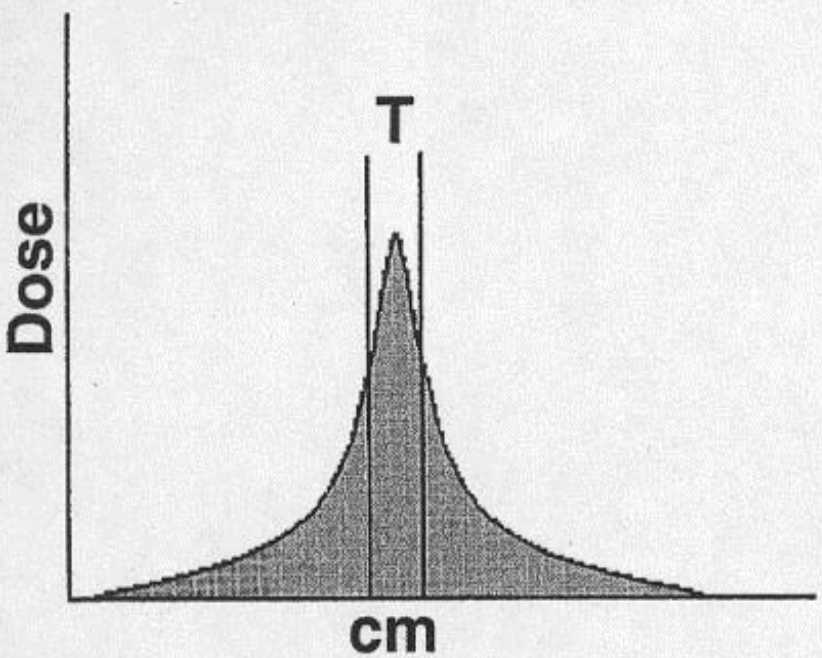
- DLP = $CTDI_{vol}$ X scan length (cm)

- CTDI = $$\frac{surface\ sous\ courbe \int_{-7T}^{7T} D(z)dz}{T}$$

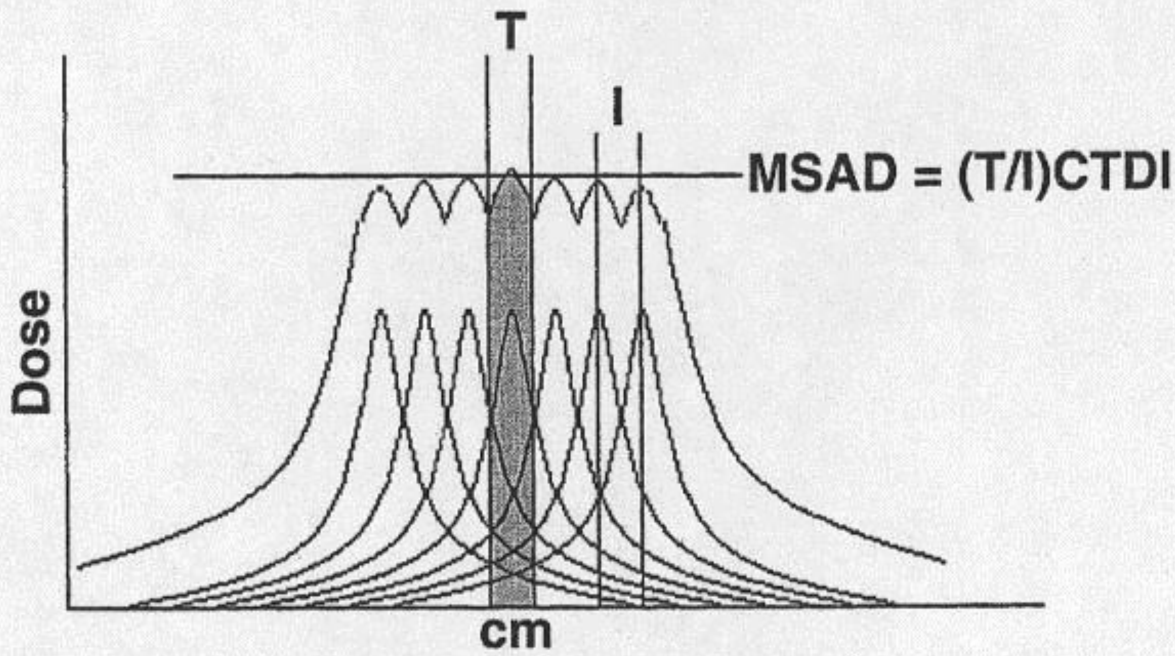
- MSAD = $$\left(\frac{T}{I}\right) CTDI$$

T = épaisseur de coupe

I = intervalle entre 2 coupes



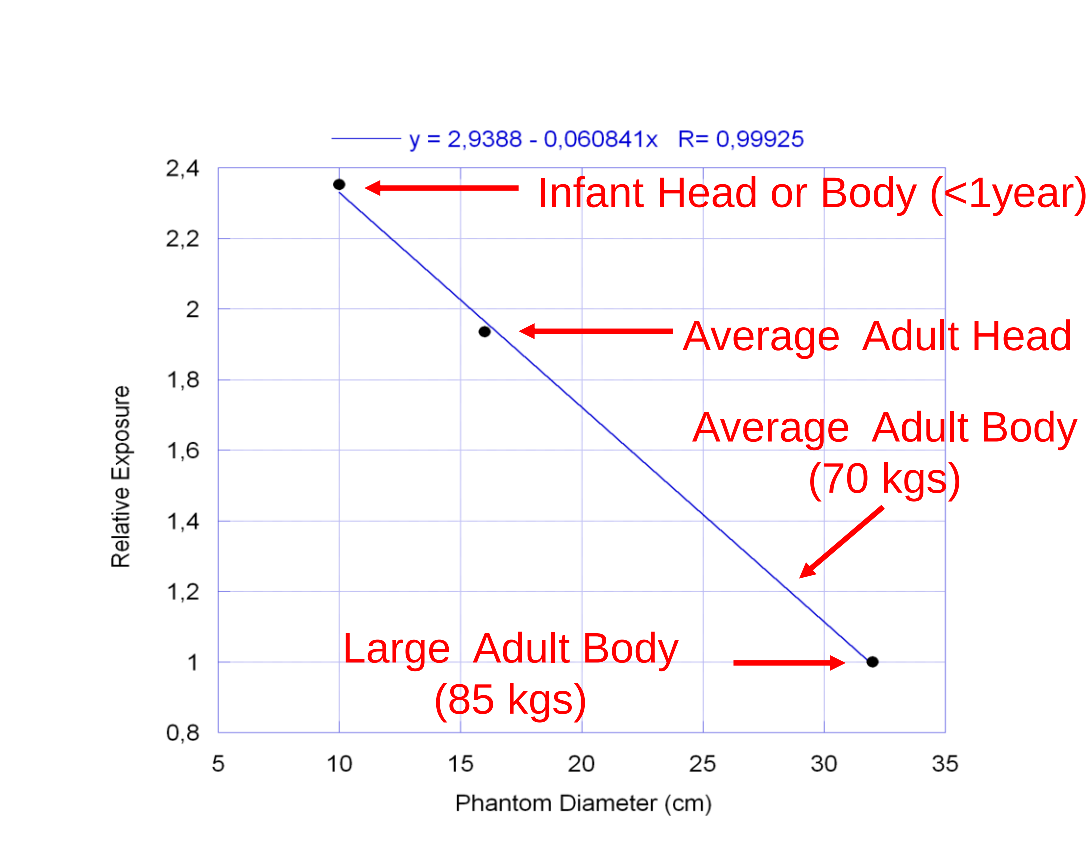
1.



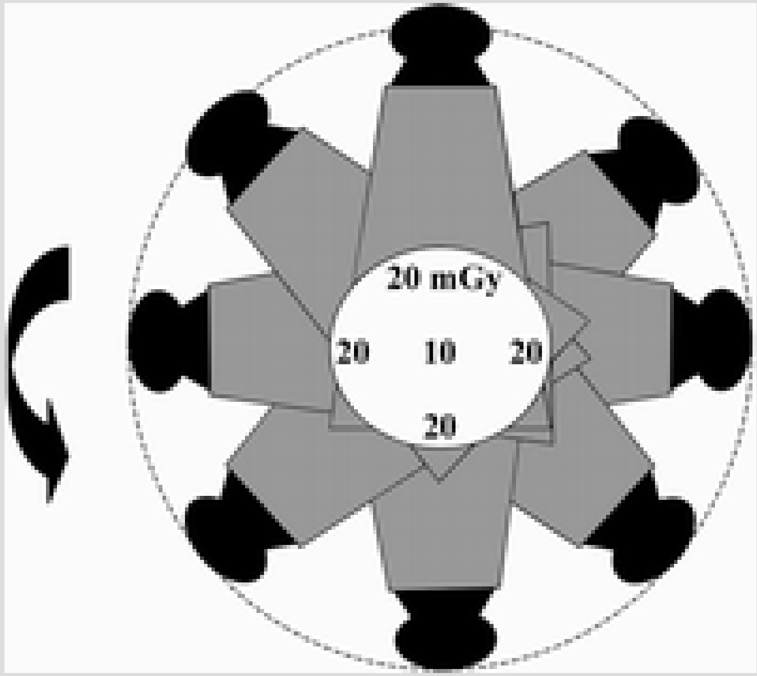
2.

Relative CTDI and phantom size

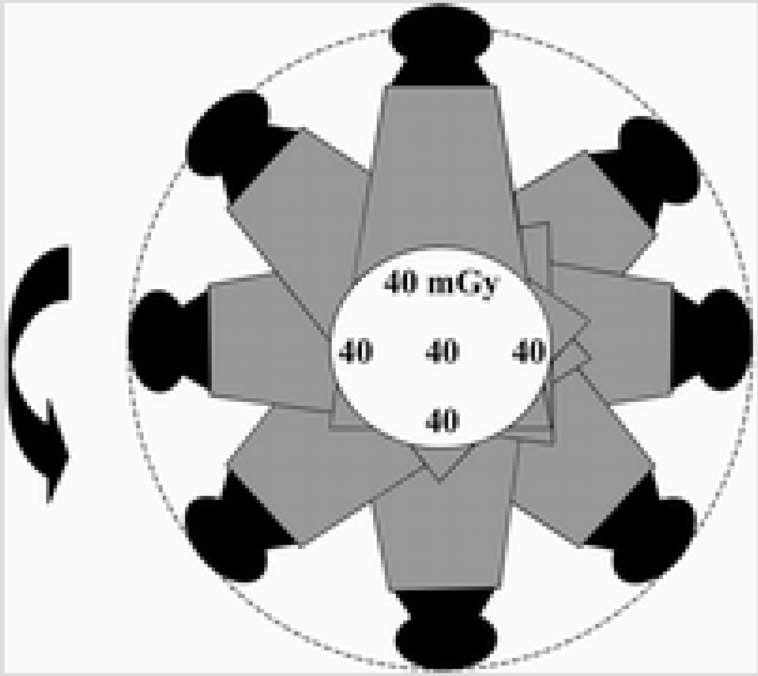
at 120 kV and 100 mAs



	Φ32cm	Φ16cm	Φ10cm
90 kV	1.0	1.95	**2.42**
120 kV	1.0	1.94	**2.35**
140 kV	1.0	1.88	**2.29**



fantôme 32 cm.



fantôme 16 cm.

Factors influencing dose with CT

1. intrinsic : cannot be modified by users

   - tube (focal spot, ...)
   - geometry : distance between focal spot and isocenter (inverse square law)
   - filtration
   - collimation

Factors influencing dose with CT

2. extrinsic : can be modified by users

- scanning modes
- scanning length
- tube current and potential
- collimation, table speed, pitch
- gantry rotation time
- shielding

Factors influencing dose with CT

2. extrinsic : can be modified by users

- scanning modes
- scanning length
- tube current and potential
- collimation, table speed, pitch
- gantry rotation time
- shielding

Scanning modes

- sequential scanning $\Rightarrow$ head CT
- single helical scan > multiple helical scan
- high resolution CT of chest : low dose slices performed at intervals
- ? necessity for multiphase examinations ?

Factors influencing dose with CT

2. extrinsic : can be modified by users

- scanning modes
- scanning length
- tube current and potential
- collimation, table speed, pitch
- gantry rotation time
- shielding

Scanning length

- protocol to restrict the examination to what is absolutely necessary
- do not increase the area of coverage

Factors influencing dose with CT

2. extrinsic : can be modified by users

- scanning modes
- scanning length
- tube current and potential
- collimation, table speed, pitch
- gantry rotation time
- shielding

are settings adjusted for pediatric patients?

TABLE I **Helical Body CT of 32 Neonates, Infants, and Children: Tube Current and Kilovoltage Settings**

Patient Group (Age Range)	Body Region	No. of Examinations	Tube Current (mA)			Kilovoltage (kVp)		
			Mean	Range	Median	Mean	Range	Median
A (0–4 yr)	Chest	5	184	100–280	170	122	120–130	120
	Abdomen[a]	5	220	140–280	200	122	120–130	120
B (5–8 yr)	Chest	3	210	200–220	210	123	120–130	120
	Abdomen	5	225	200–240	225	125	120–133	120
C (9–12 yr)	Chest	6	229	200–280	223	123	120–130	120
	Abdomen	15	196	140–240	200	127	120–140	120
D (13–16 yr)	Chest	4	225	160–260	240	125	120–140	120
	Abdomen	15	204	160–300	180	128	120–140	120
Total no. of examinations		58						
Chest		18	213	100–300	220	123	120–140	120
Abdomen		40	206		200	127		

[a]Abdominal CT included examinations of the abdomen and examinations of the abdomen and pelvis.

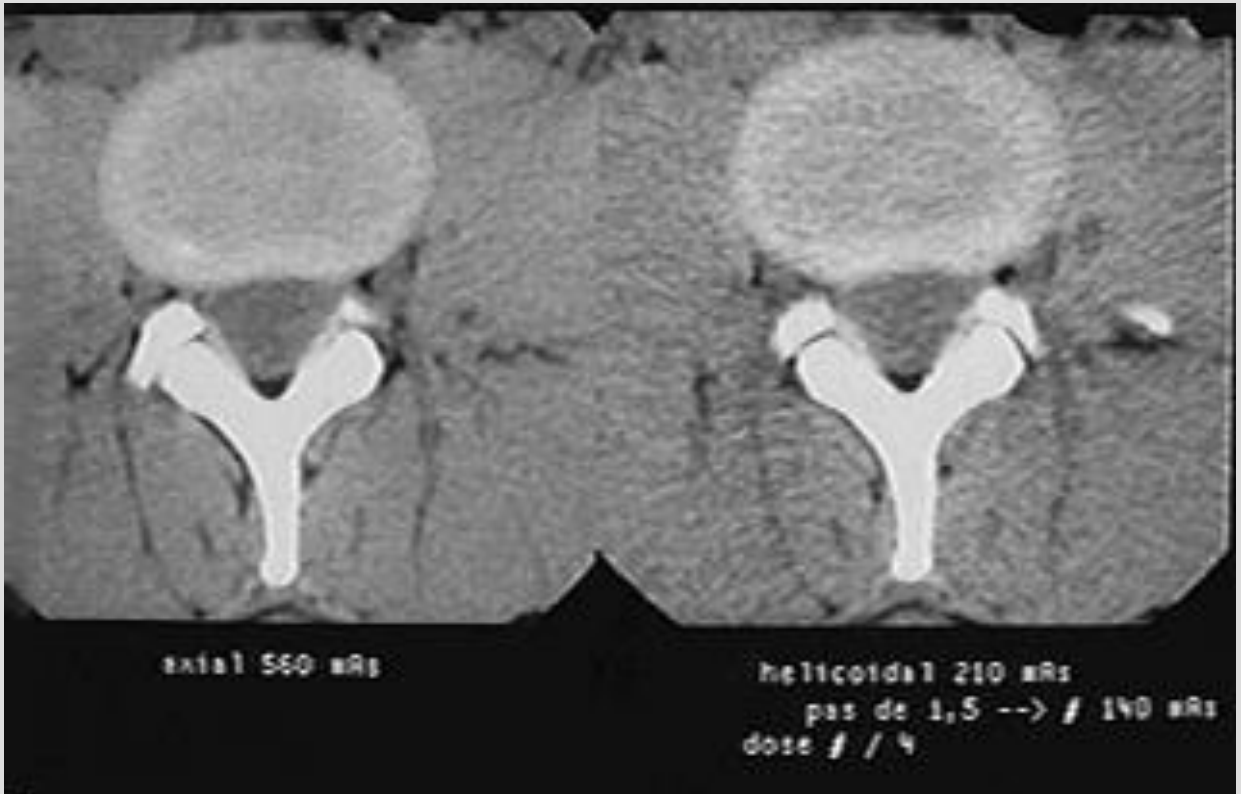
A. Paterson AJR feb. 2001

Tube current and potential

- current = mA
  - proportionality between dose and current
  - noise is affected
- potential = kV
  - ~ proportionality to square of tube voltage change
  - noise change ~ inversly proportional to tube voltage change
  - tissue contrast is also affected
- modulation in children on the basis of weight

pediatric protocols !

mA settings : lumbal spine



Acquisition séquentielle 3mm jointives, 560 mAs, angulation dans le plan du disque.	Héliscan, 3mm, pas de 1,5, 210 mAs, reconstruction dans le plan du disque. **Dose /4**

pediatric protocols

TABLE I Suggested Tube Current (mA) by Weight of Pediatric Patients for Single-Detector Helical CT

Weight		mA	
lb	Kg	Chest	Abdomen or Pelvis
10–19	4.5–8.9	40	60
20–39	9.0–17.9	50	70
40–59	18.0–26.9	60	80
60–79	27.0–35.9	70	100
80–99	36.0–45.0	80	120
100–150	45.1–70.0	100–120	140–150
>150	>70	≥140	≥170

Beam Energy (kVp)	$CTDI_w$ in Head Phantom (mGy)	$CTDI_w$ in Body Phantom (mGy)
80	14	5.8
100	26	11
120	40	18
140	55	25

Tube Current–Time Product (mAs)	$CTDI_w$ in Head Phantom (mGy)	$CTDI_w$ in Body Phantom (mGy)
100	13	5.7
200	26	12
300	40	18
400	53	23

Factors influencing dose with CT

2. extrinsic : can be modified by users

- scanning modes
- scanning length
- tube current and potential
- collimation, table speed, pitch
- gantry rotation time
- shielding

Collimation – Table speed - Pitch

- Pitch : ratio of table feed per gantry rotation to nominal width of X-ray beam

  $\uparrow$ pitch $\Rightarrow$ $\downarrow$ duration of radiation

- ! Effective mA.s settings : $\frac{mAs}{pitch}$

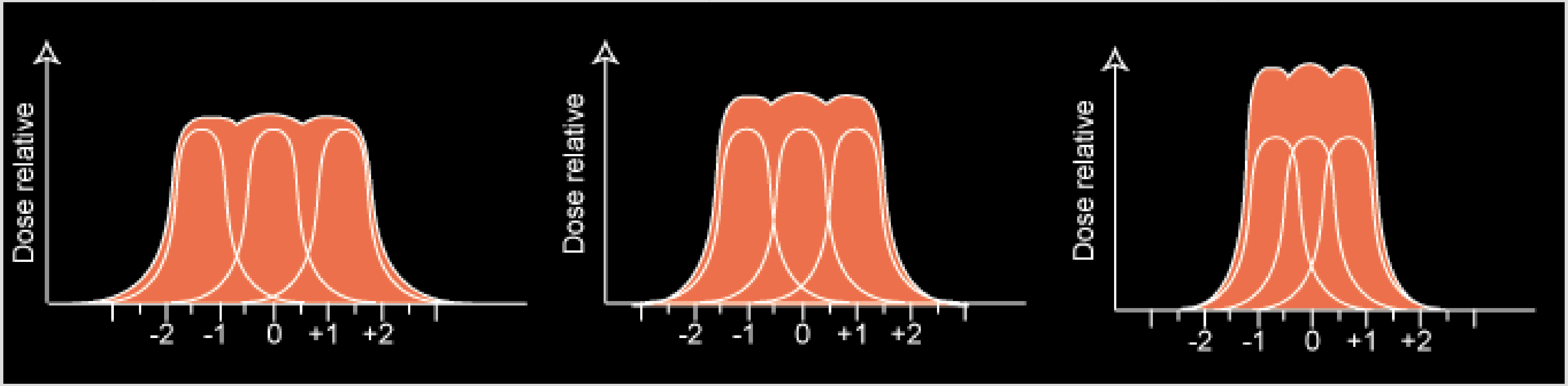
  – no influence of pitch on radiation dose

- $\uparrow$ pitch - helical artifacts

  - decrease spatial resolution

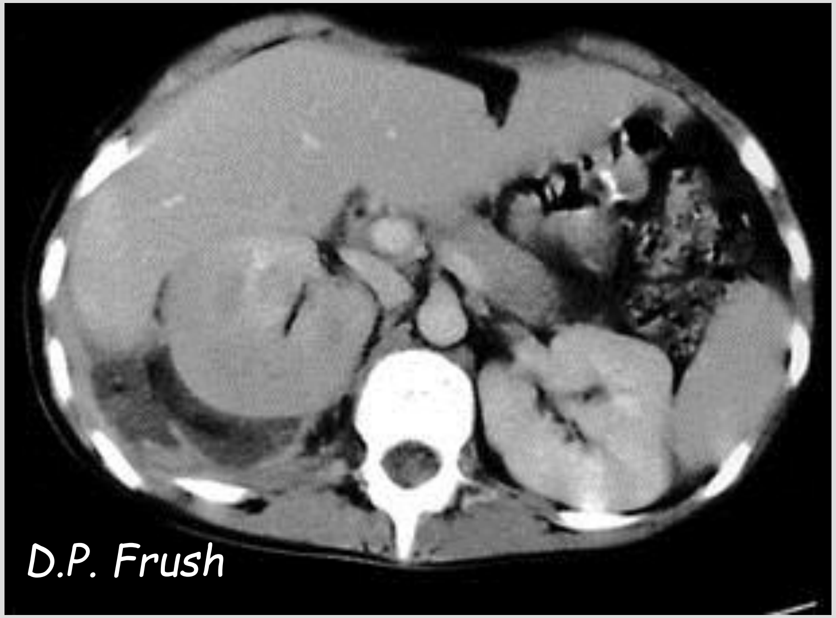
PITCH and dose

pitch = 1,5 pitch = 1 pitch = 0,5



pitch = 1

Pitch	$CTDI_{vol}$ in Head Phantom (mGy)	$CTDI_{vol}$ in Body Phantom (mGy)
0.5	80	36
0.75	53	24
1.0	40	18
1.5	27	12
2.0	20	9



pitch = 2

Collimation – Table speed - Pitch

- thicker beam collimation : more dose efficient examination
  - overbeaming = smaller proportion of detected X-ray beam
  - more difficult for reconstruction of thinner sections

Collimation (mm)	$CTDI_w$ in Head Phantom (mGy)	$CTDI_w$ in Body Phantom (mGy)
1	45	19
3	41	18
5	40	18
7	40	18
10	40	18

Collimation (mm)	Total Beam Width (mm)	$CTDI_w$ in Head Phantom (mGy)	$CTDI_w$ in Body Phantom (mGy)
4 × 1.25	5	62	33
2 × 2.5	5	62	33
1 × 5	5	62	33
4 × 2.5	10	46	24
2 × 5	10	46	24
4 × 5	20	40	20

Factors influencing dose with CT

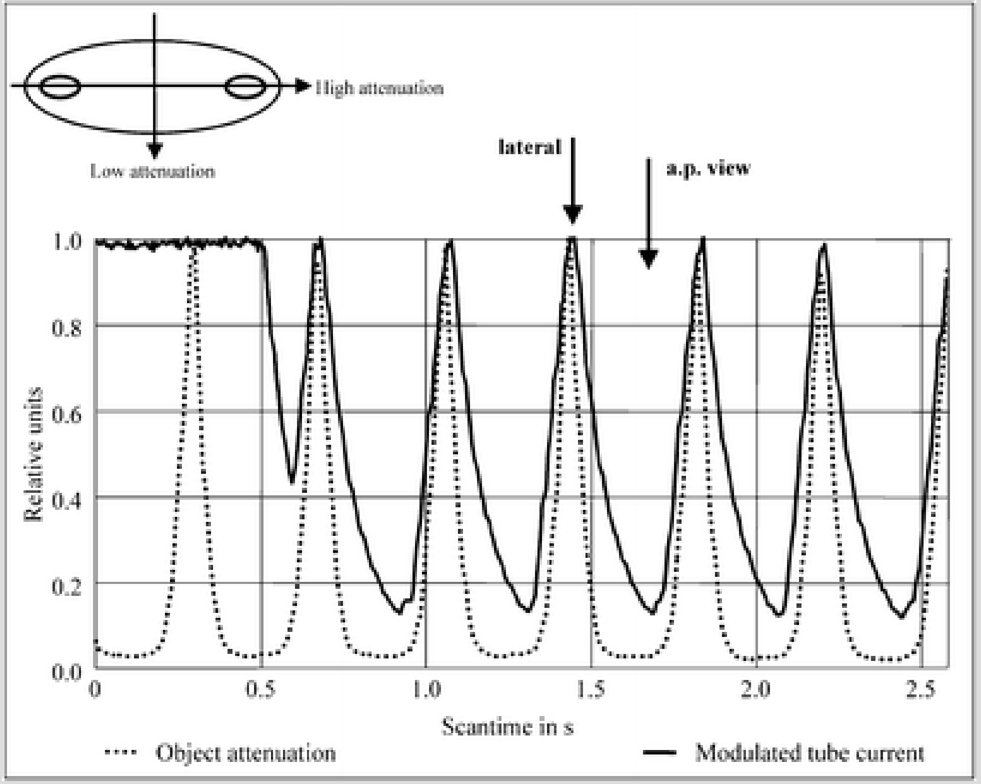
2. extrinsic : can be modified by users

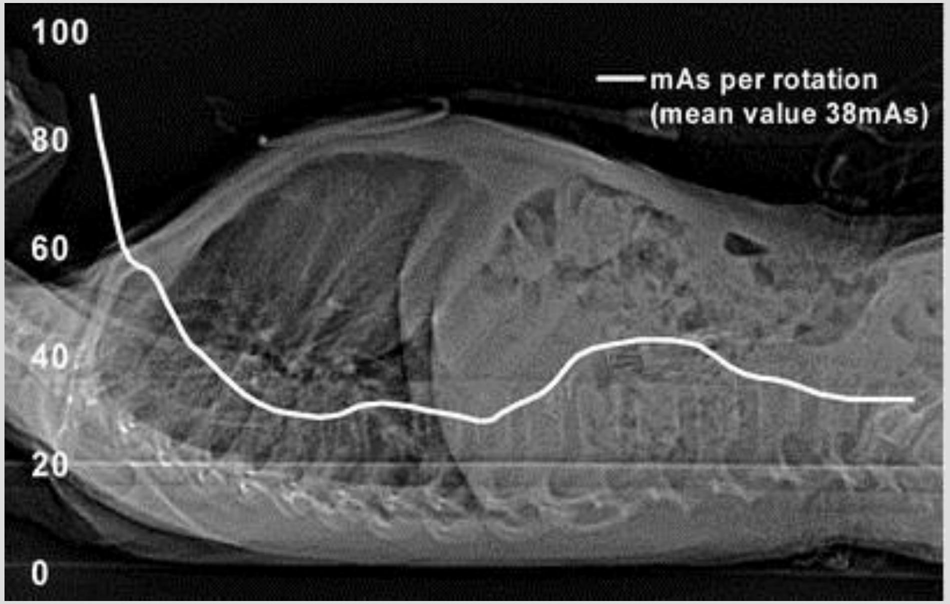
- scanning modes
- scanning length
- tube current and potential
- collimation, table speed, pitch
- gantry rotation time
- shielding

Gantry rotation time

- dose reduction is proportional to reduction of cycle time
- less motion artifact

Automatic modulation of tube current





C. Suess & X. Chen   Pediatr. Radiol. oct. 2002

take-home messages

- work in consensus with the referring clinician
- avoid unnecessary radiologic procedure
- use alternative methods when possible
- perform according to guidelines
- focus on region of interest
- remember: large amount of radiation from CT
  - very simple ways to reduce radiation : *dedicated pediatric protocols*
    - decrease current (mA) and potential (kV)
    - rarely multiphase examinations
  - work together with physicist for ultimate optimization

TABLE 1

Effective Radiation Doses

Examination	Effective Dose (mSv)	Equivalent Number of Chest Radiographs	Equivalent Dose of Natural Background Radiation
Background radiation	3.0	150	—
Transatlantic airline flight (New York to London)	3.6	180	1 year, 85 days
Skull x-ray	0.07	3.5	9 days
2-view chest radiograph	0.02	—	3 days
Abdomen radiograph	1.0	50	125 days
Pelvic radiograph	0.7	35	86 days
Barium swallow	1.5	75	188 days
Barium enema	7	350	2 years, 145 days
Head CT	2	100	250 days
Chest CT (pediatric parameters)	Up to 3	150	1 year, 10 days
Chest CT (adult parameters)	8	400	2 years, 270 days
Abdomen/pelvis CT (pediatric parameters)	Up to 5	250	1 year, 260 days
Abdomen/pelvis CT (adult parameters)	15 to 20	750 to 1,000	5.1 to 6.8 years
Radionuclide renal scan (99m-Tc)	1	50	125 days
Radionuclide bone scan (99m-Tc)	4	200	1 year, 135 days

Data sources[illegible]

dose	équivalent irradiation naturelle
1mSv 40 µSv 5 µSv 0,25 µSv	6 mois 1 semaine 1 jour 1 heure