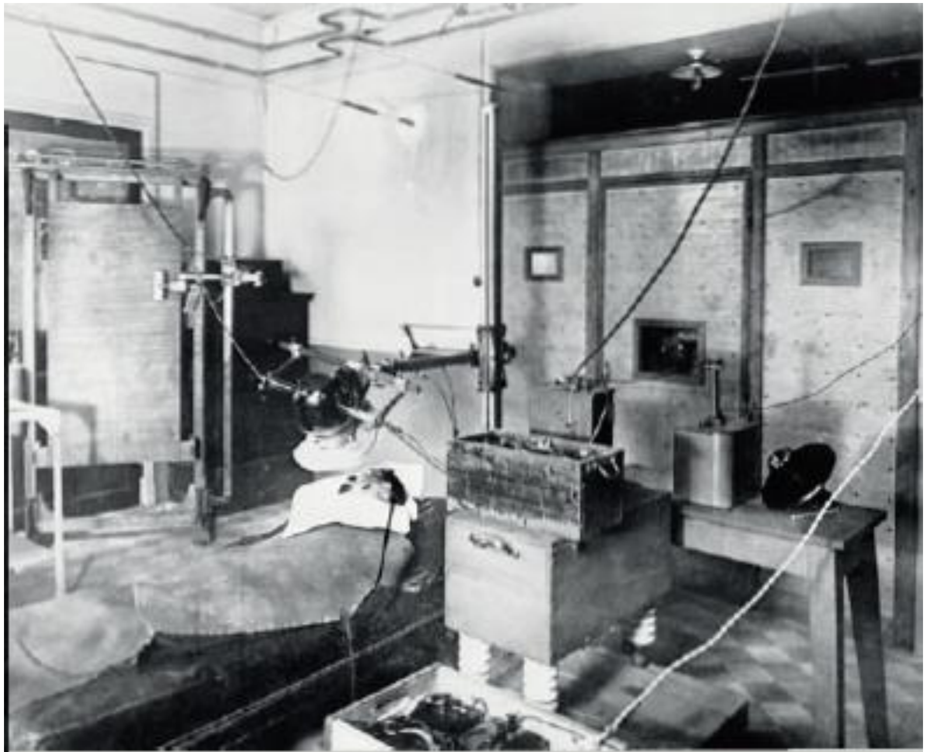
Cancers radio-induits

F. Jamar

Cours RPR 2002, 23 avril 2019

- Tout commence par un paradoxe!



Patient atteint d'un cancer traité au rayons X (1928)

Cancers radio-induits

- Est-ce que ça existe?
- OUI!
  - Cancers secondaires en radiothérapie
  - Cancers secondaires après thérapie métabolique
  - Exposition de travailleurs
  - Survivants des grandes catastrophes nucléaires, p.ex. HN, Chernobyl, essais nucléaires
  - Imagerie médicale (d’aujourd’hui)?

Cancers radio-induits

- Est-ce que ça existe?
- OUI! Exemples historiques
  - Cancers de la peau chez les radiologues, techniciens RX,… (+leucémies?)
  - Exposition de travailleurs dans les mines d’uranium (poumon)
  - Ostéosarcomes chez les peintres de cadrans de montres (radium)
  - Tumeurs hépatiques après Thorotrast

- Ces exemples sont anecdotiques car aucune forme de dosimétrie solide n’est disponible

Cancers radio-induits: exemples historiques

Figure 10.2. Hand of a dentist who for 35 years held x-ray films in place in patients' mouths. The thumb has been partially amputated. Damaged skin on the fingers has been replaced by grafts. The lesion on the finger is a skin cancer subsequently removed. (Courtesy of Dr. Victor Bond, Brookhaven National Laboratory.)

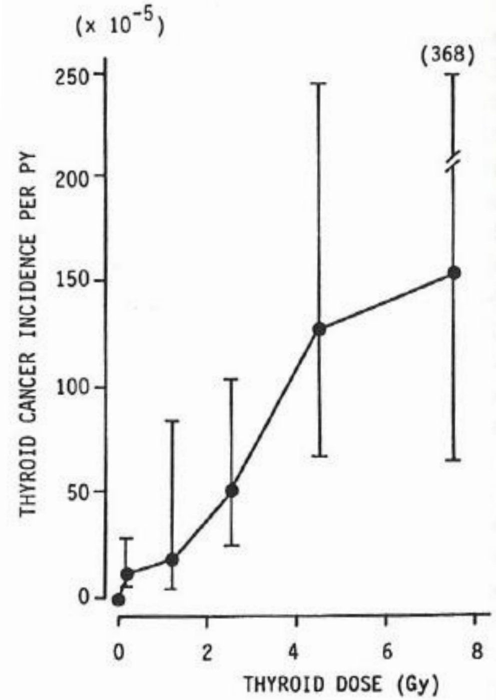
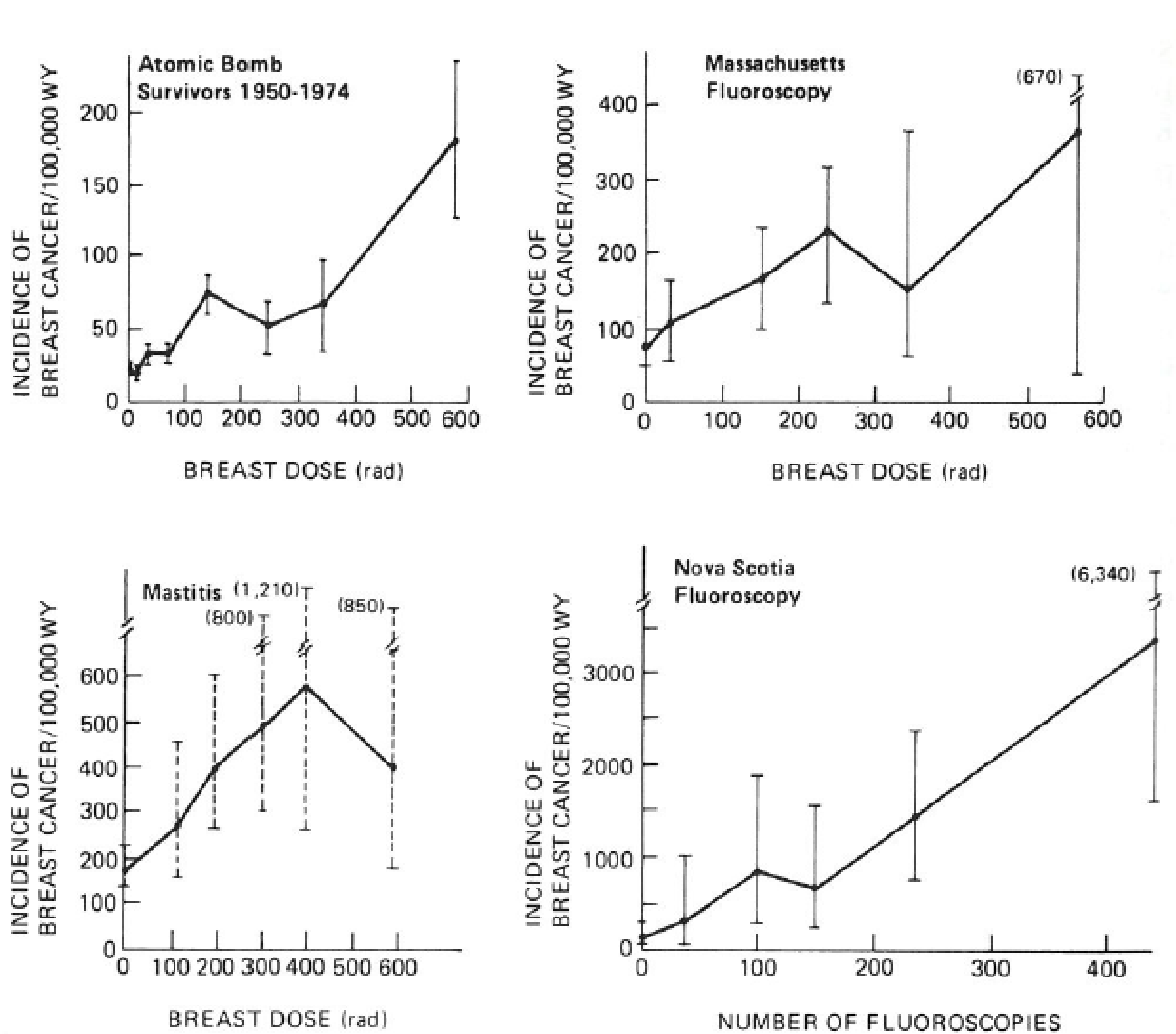
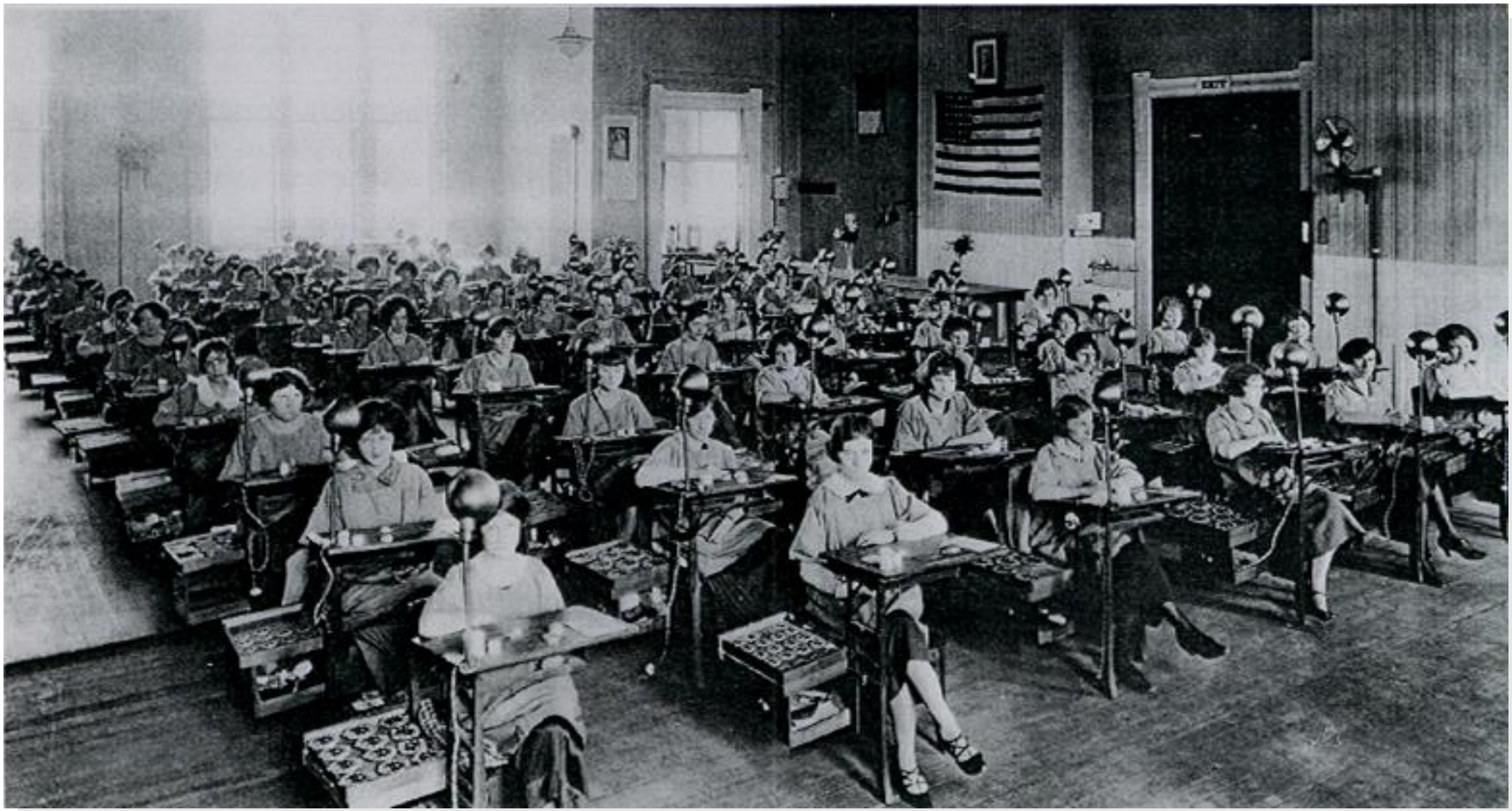


Figure 10.4. Thyroid cancer incidence per person-year (PY) as a function of the radiation dose in the thyroid. Rates adjusted for sex, ethnicity, and interval after irradiation. *Error bars* represent 90% confidence limits. (From Shore RE, Woodard E, Hildreth N, et al.: JNCI 74: 1177–1184, 1985, with permission.)

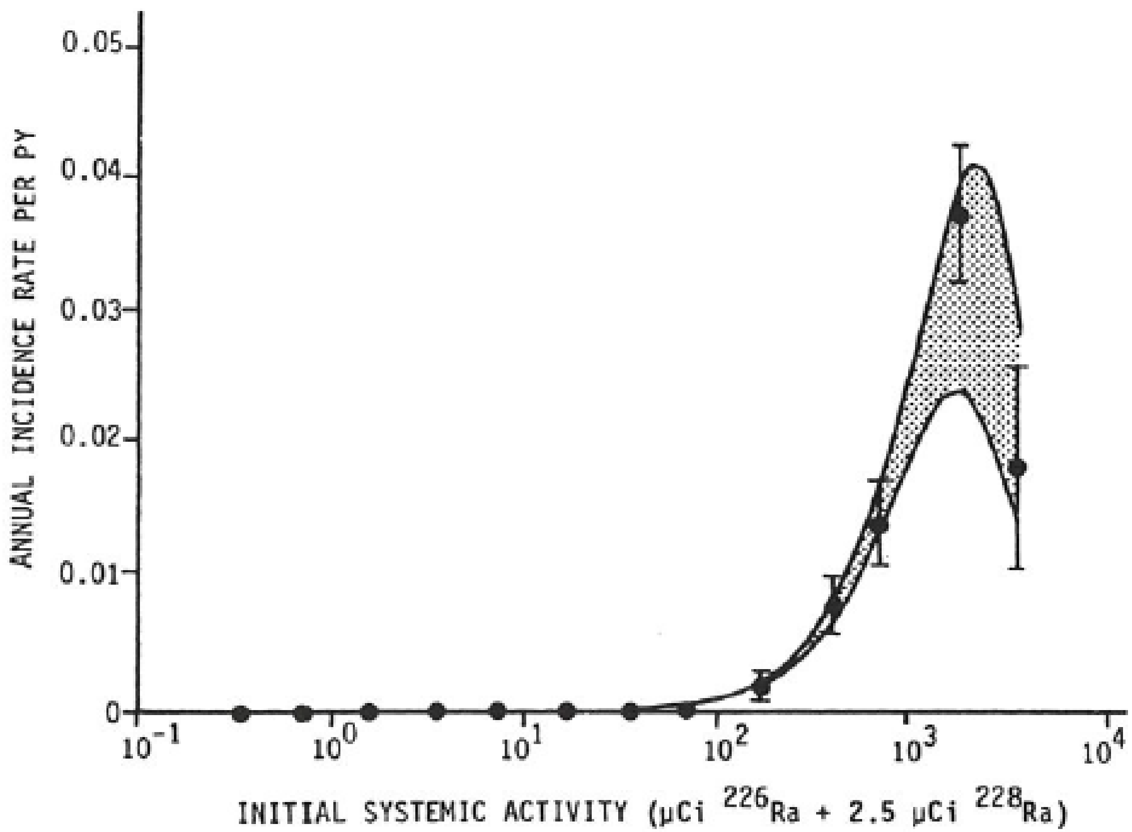
Cancers radio-induits: cancer du sein



Cancer radio-induits: radium et sarcome



Cancer radio-induits: sarcomes



Cancers radio-induits

- Est-ce que ça existe?
- OUI! Exemples plus récents
  - Survivants japonais de Hiroshima-Nagasaki
  - Radiothérapie pour SPA en UK: leucémies
  - Cancer thyroïdien après irradiation du thymus chez l'enfant (+sein)
  - Cancer salivaire, du cerveau, de la peau, leucémie après épilation pour pédiculose
  - Cancer du sein après fluoroscopie pour Tbc/scoliose
  - Cancer du sein après irradiation pour mastite du post-partum

- Dans ces cas, des données dosimétriques sont disponibles et conduisent à des modèles de risque.

Cancers radio-induits

- ~~EFFETS DETERMINISTES~~
  - Sévérité augmente avec la dose
  - Existence d'un seuil (100 voire 500 mGy)
  - (latence généralement courte)

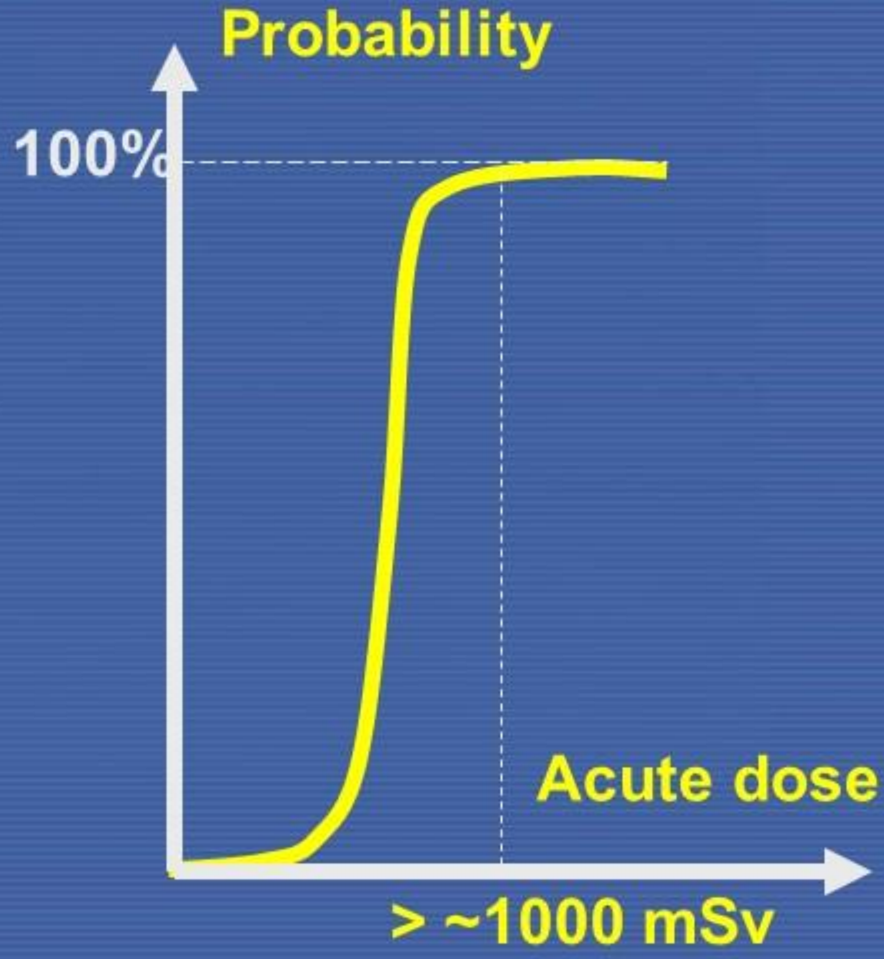
- EFFETS STOCHASTIQUES
  - Sévérité indépendante de la dose
  - Pas de seuil
  - (latence généralement longue)

Cancers radio-induits = stochastique

Sunburn	deterministic
Melanoma	stochastic

Deterministic Health Effects

- A radiation effect for which generally a threshold level of dose exists above which the severity of the effect is greater for a higher dose
  - many cells die or have function altered
  - occurs when the dose is above given threshold (characteristic for the given effect)
  - severity increases with the dose

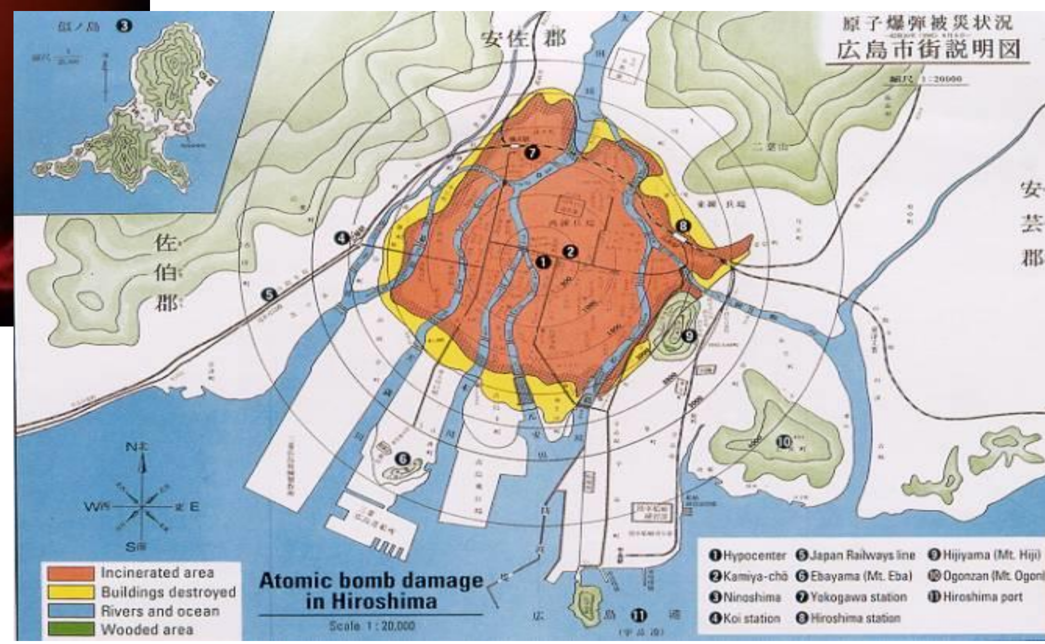


Stochastic Health Effects

- A radiation-induced health effect, occurring without a threshold level of dose:
  - probability is proportional to the dose
  - severity is independent of the dose
- Stochastic health effects:
  - Radiation-induced cancers
  - Hereditary effects
- Late appearance (years)
- Latency period:
  - Several years for cancer
  - Hundreds of years for hereditary effects

IAEA

Cancer radio-induits: Hiroshima-Nagasaki



Cancers radio-induits: Hiroshima-Nagasaki

- Life Span Study, (LSS) Cohort
- Source primaire d'information:
  - 86,500 individus:
    - Des deux sexes
    - De tous les âges
  - Données dosimétriques sur une gamme de doses étendue
    - Dose moyenne – 0.27 Sv
    - ~ 6,000 individus exposés à des doses > 0.1 Sv
    - ~ 700 individuals exposés à des doses > 1 Sv

Cancers radio-induits: Hiroshima-Nagasaki

- Life Span Study, (LSS) Cohort
- 47 ans de suivi (1950-1997)
- Observés: 9,335 cas fatals de cancer solide
- Attendus: ~8,895 cas fatals de cancer solide

DONC: ~440 cancers (5%) attribuables aux radiations ionisantes

(Preston et al, *Radiat Res* 160:381-407, 2003)

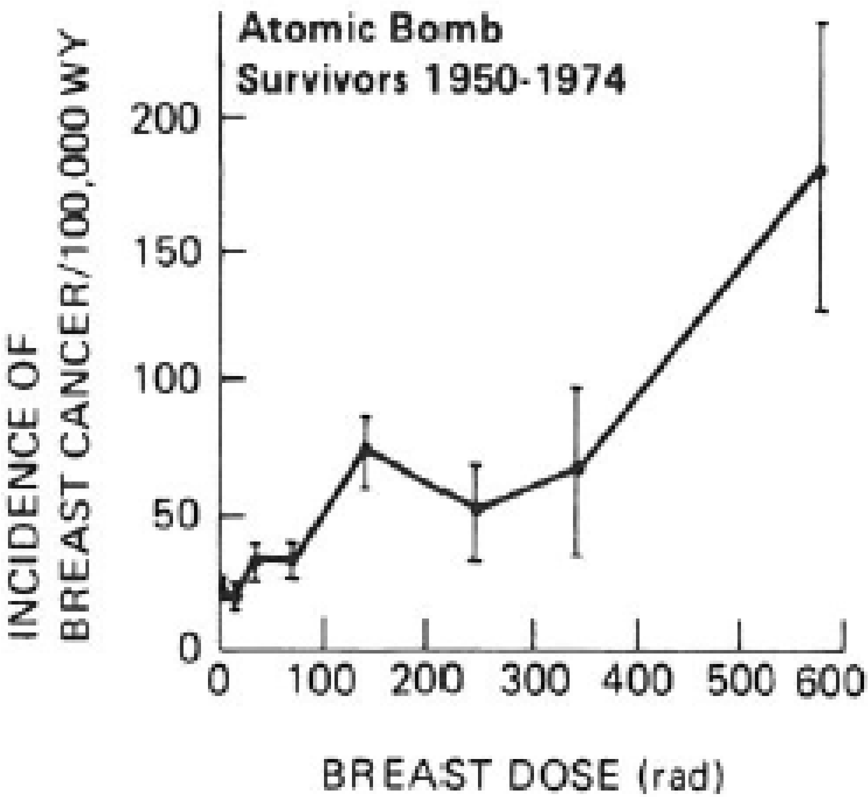
Cancers radio-induits: Hiroshima-Nagasaki

- Résumé du risque épidémiologique de cancer induit
- Risque de mortalité par cancer solide

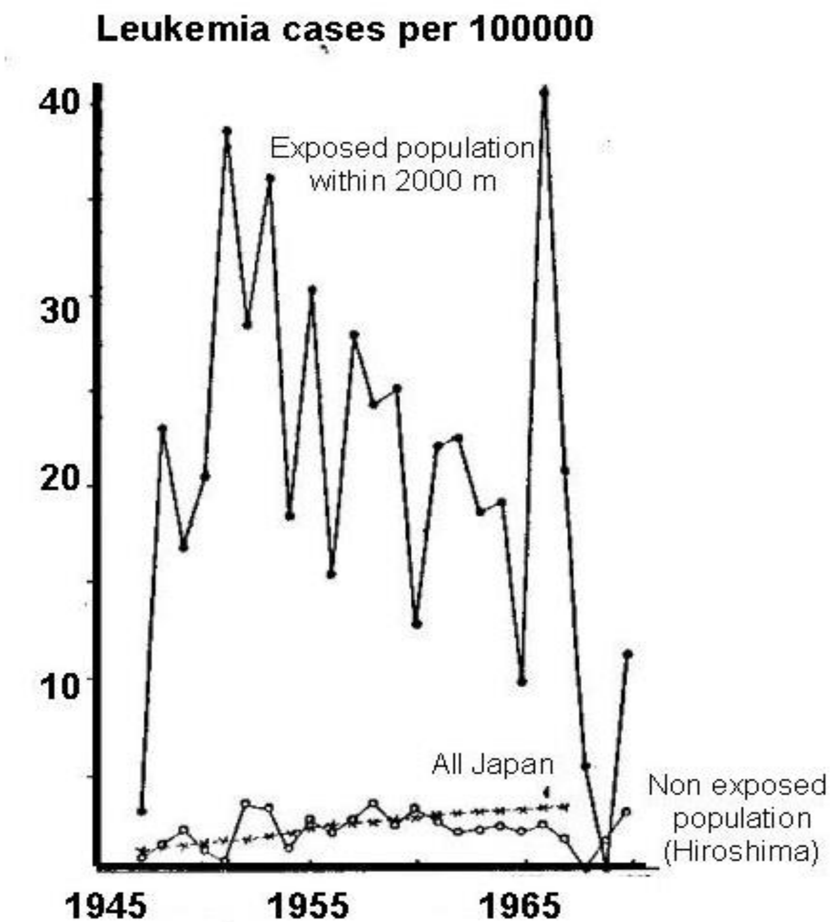
$$\boxed{\sim 0.005\% \text{ per mSv}}$$

(Preston et al, *Radiat Res* 160:381-407, 2003)

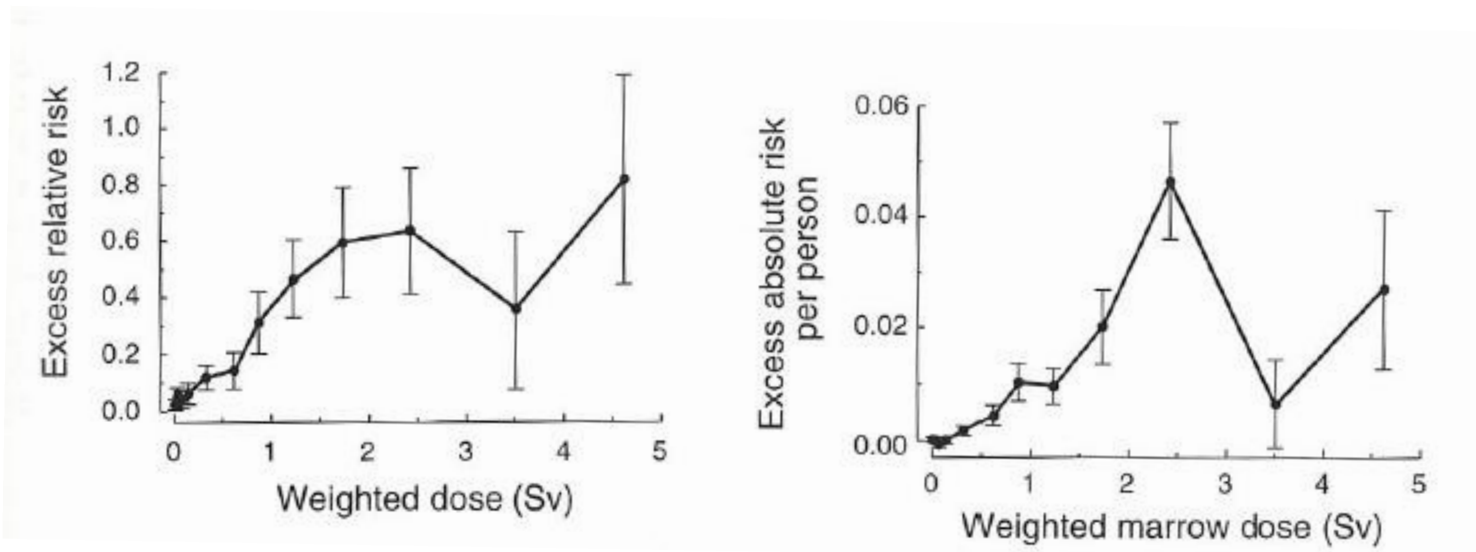
Cancers radio-induits: Hiroshima-Nagasaki



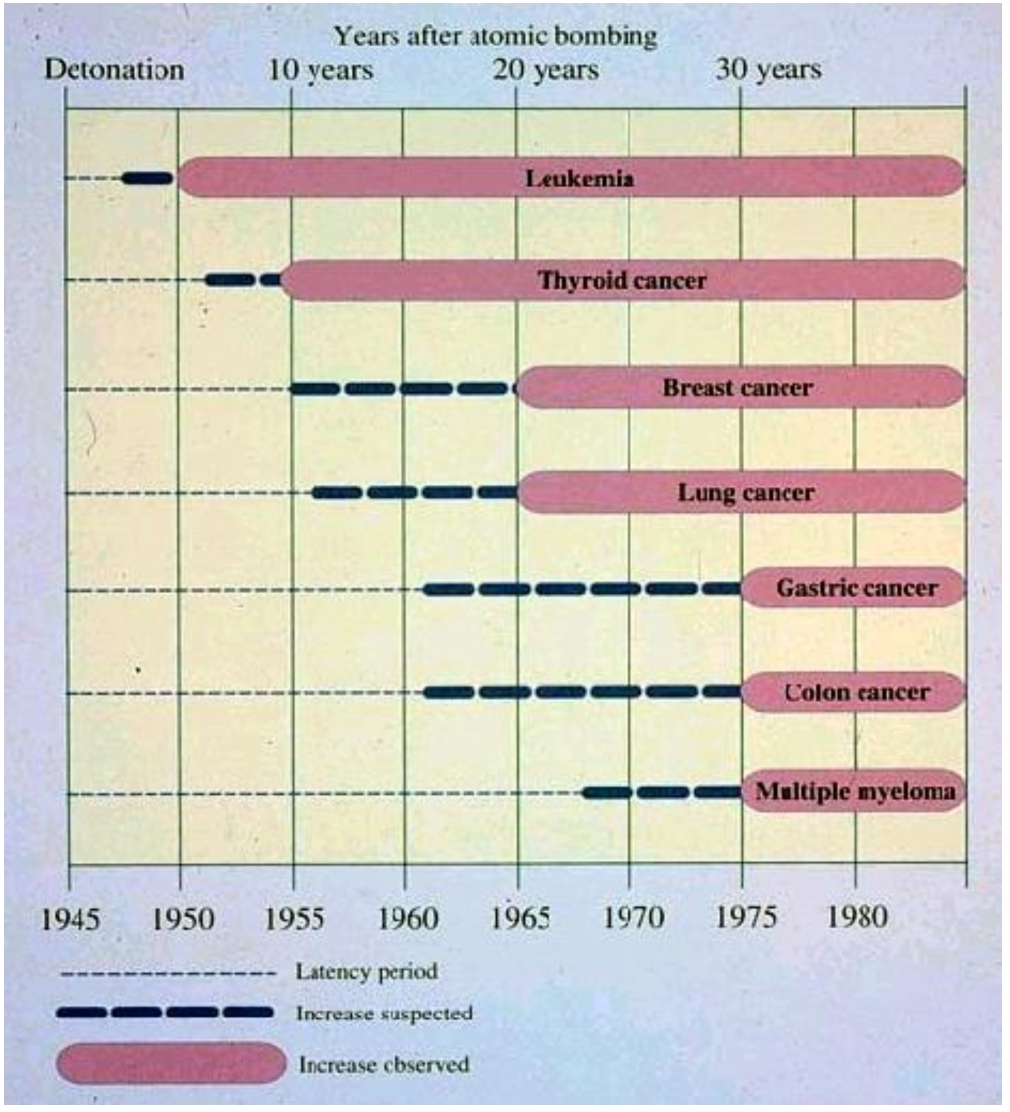
Cancers radio-induits: Hiroshima-Nagasaki



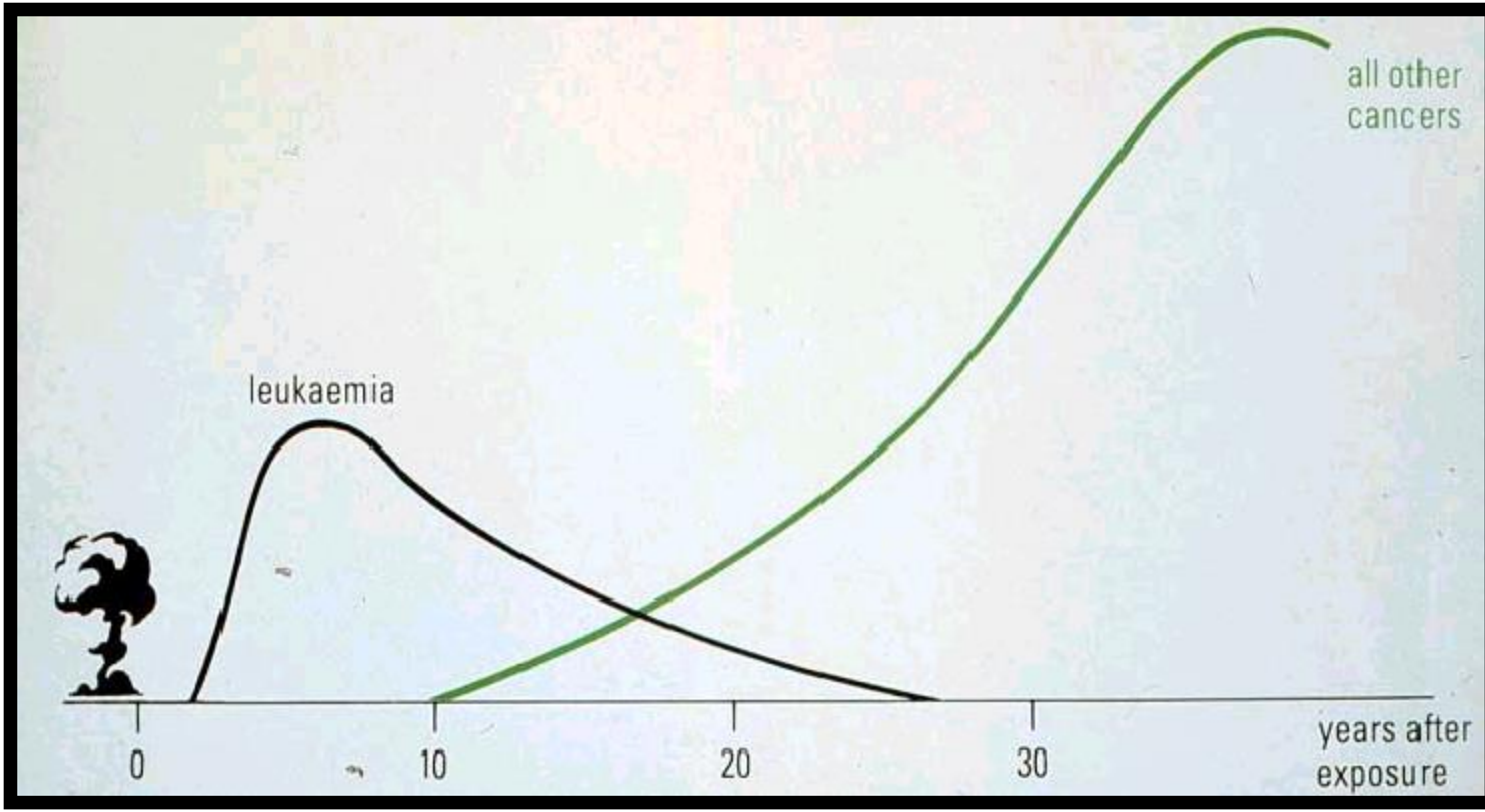
Cancers radio-induits: Hiroshima-Nagasaki



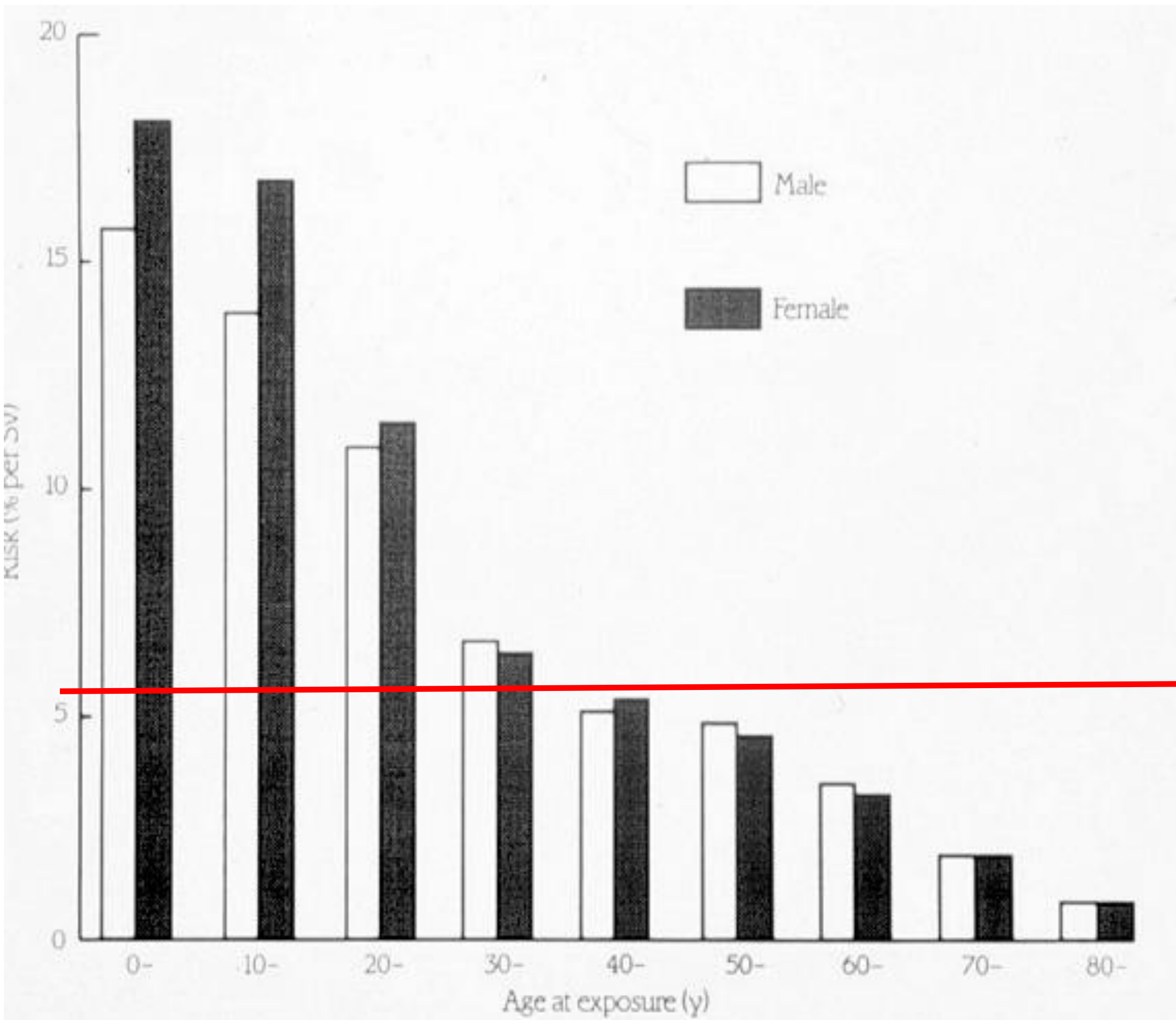
Cancers radio-induits: Hiroshima-Nagasaki



Cancers radio-induits: Hiroshima-Nagasaki



Cancers radio-induits: Hiroshima-Nagasaki

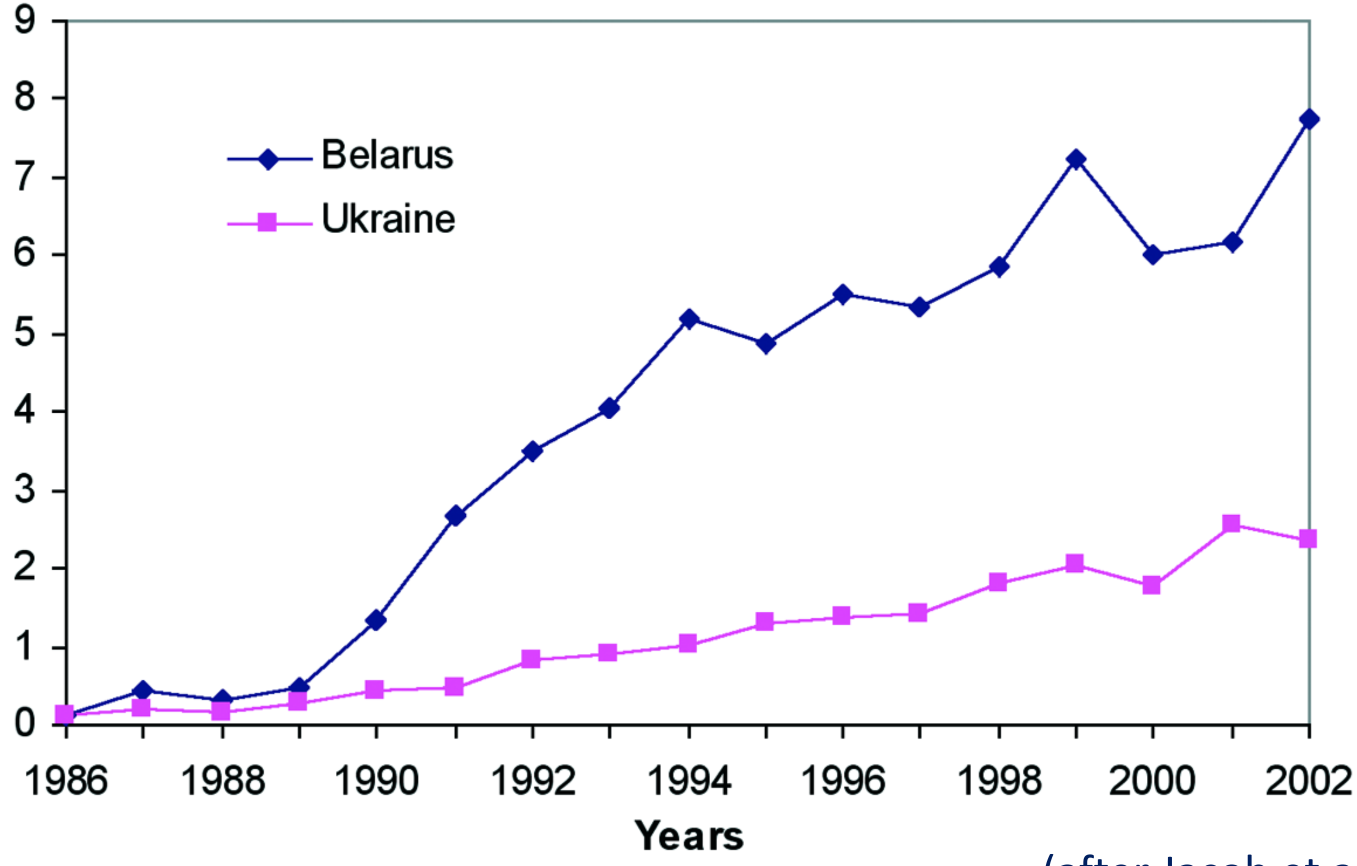


Cancers radio-induits: Chernobyl

- “Liquidators”
  - Doublement du risque de leucémie chez les travailleurs avec des doses >150 mGy
  - Discrète augmentation de la mortalité par cancer solide (~5%) et les maladies cardiovasculaires
  - Augmentation de la fréquence de la cataracte
  - Les doses enregistrées dans les registres sont en moyenne de 100 mGy avec des valeurs jusque 500 mGy
- Public
  - Pas d’augmentation du risque de leucémie
  - Pas d’augmentation des cancers solides à l’exception de celui de la thyroïde (enfants et adolescents)
  - Les doses efficaces entre 1986-2005 vont de quelques mSv à quelques centaines de mSv avec une moyenne de 10 - 20 mSv

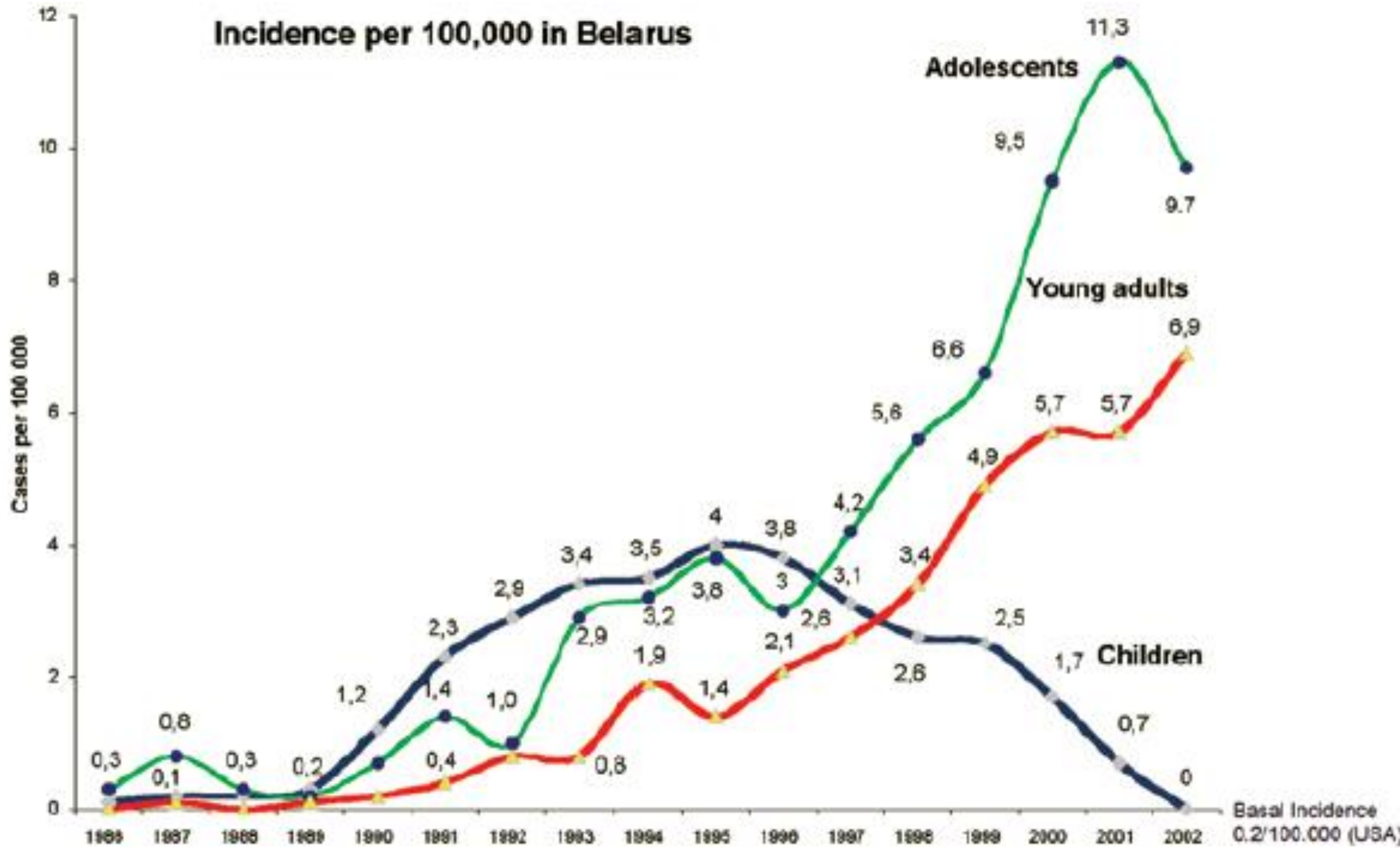
Cancers radio-induits: thyroïde

Incidence Rate of Thyroid Cancer per 100,000 Children and Adolescents as of 1986
1800 additional thyroid cancers in children



(after Jacob et al., 2005)

Cancers radio-induits: Chernobyl - thyroïde

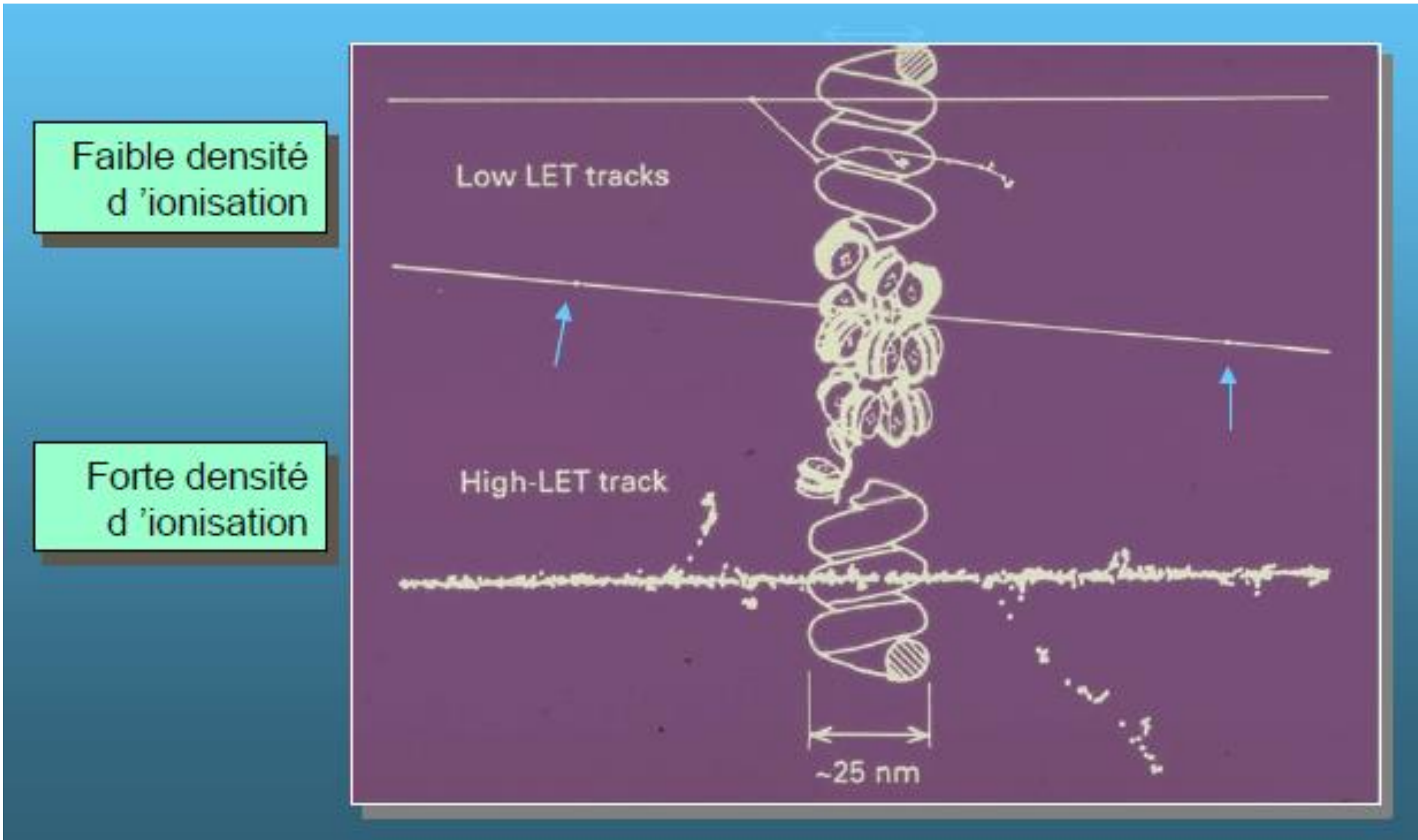


Cancers radio-induits: numbers and facts

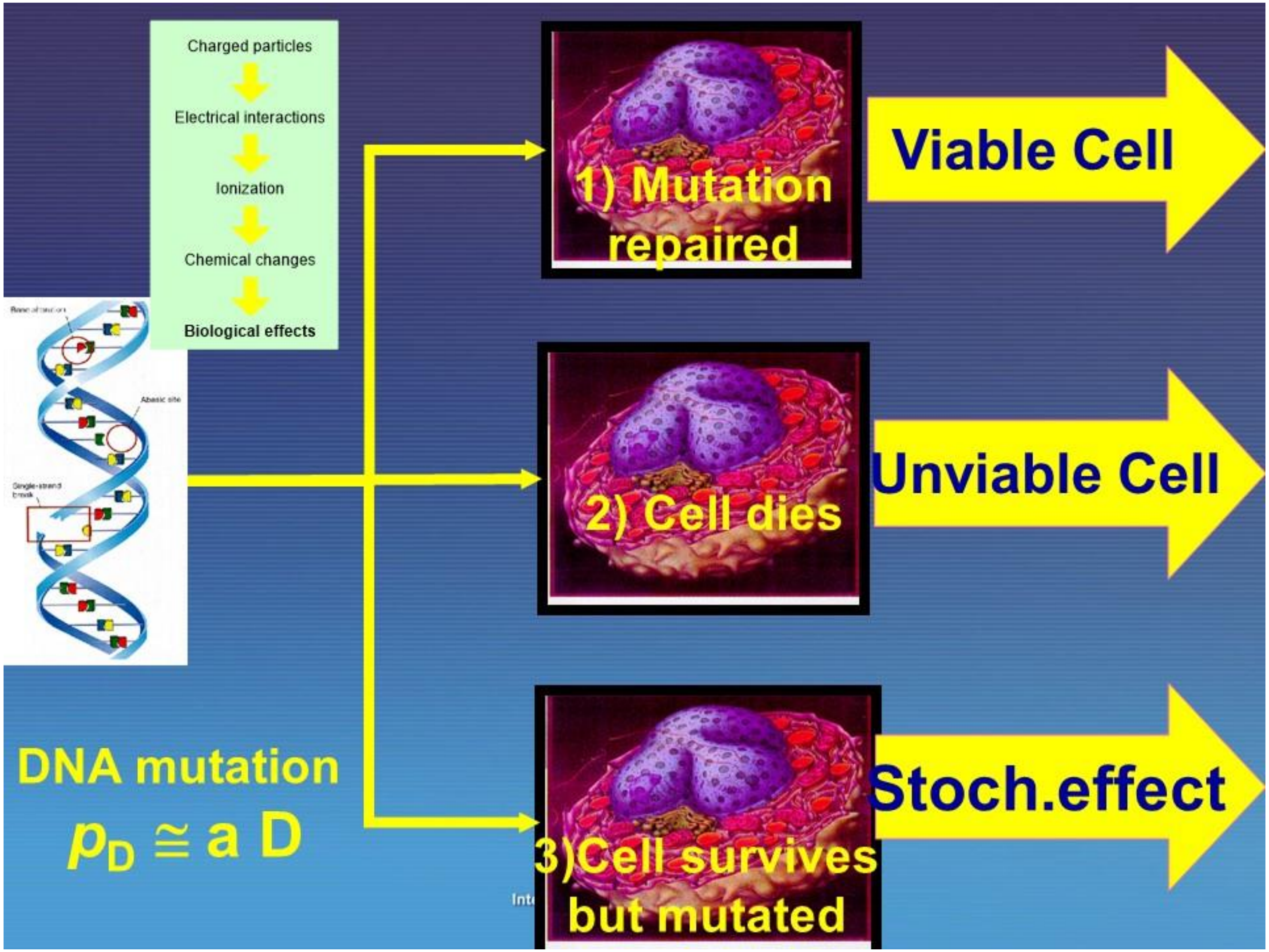
Comparison of mortality rates for human carcinogenesis (UNSCEAR 1977) at high doses and dose rates

Cancer Type	Data Source	Risk Coefficient (Mortality/person-Sv)
Leukaemia	Hiroshima and Nagasaki	30×10^{-4}
	Ankylosing spondylitis	11 to 25×10^{-4}
	Pelvic irradiation (not in utero examinations)	17×10^{-4}
Thyroid cancer	Hiroshima and Nagasaki	0.5 to 2×10^{-4}
	Marshall Islanders	6×10^{-4}
	Radiotherapy of children	1 to 5×10^{-4}
Lung cancer	Hiroshima and Nagasaki	10 to 25×10^{-4}
	Uranium mining	40 to 180×10^{-4}
Breast cancer	Hiroshima and Nagasaki	13×10^{-4}
	Multiple fluoroscopy	110×10^{-4}
	Radiotherapy	210×10^{-4}
Bone cancer	Radiotherapy	3 to 5×10^{-4}
	Treatment with ^{224}Ra	20 to 25×10^{-4}

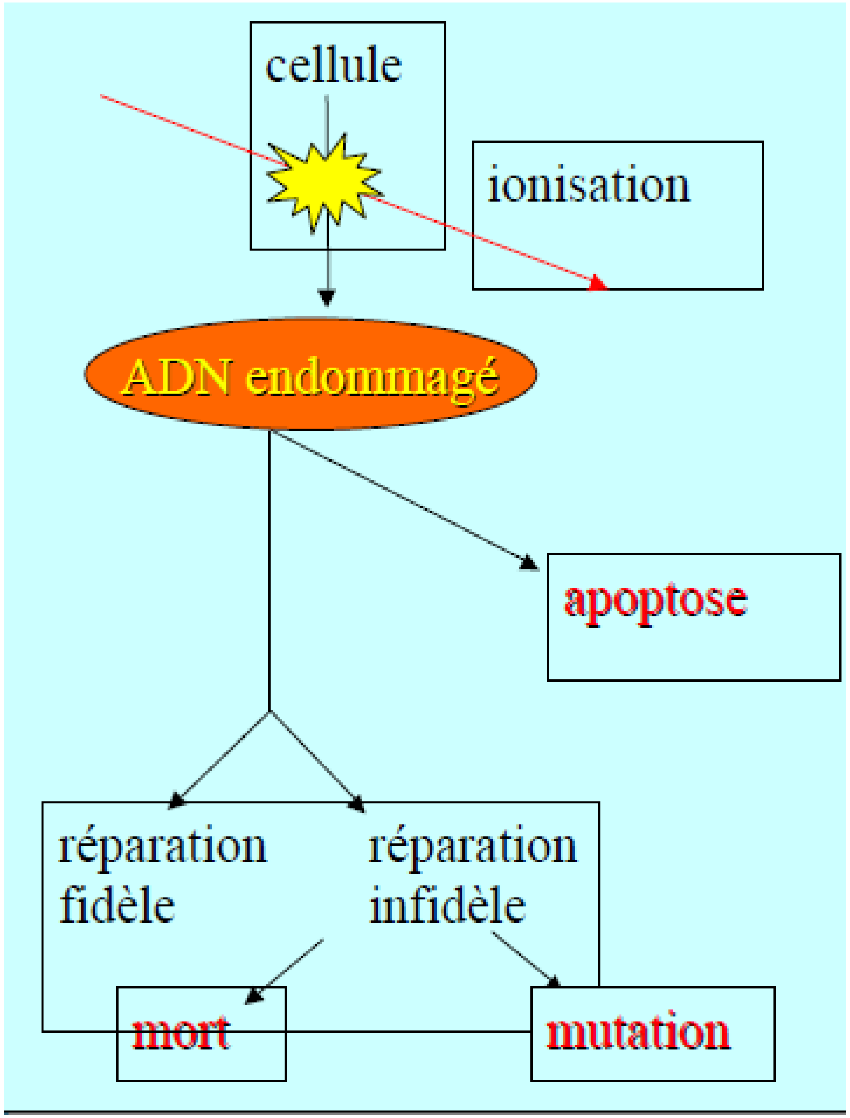
Cancers radio-induits: pourquoi et comment?



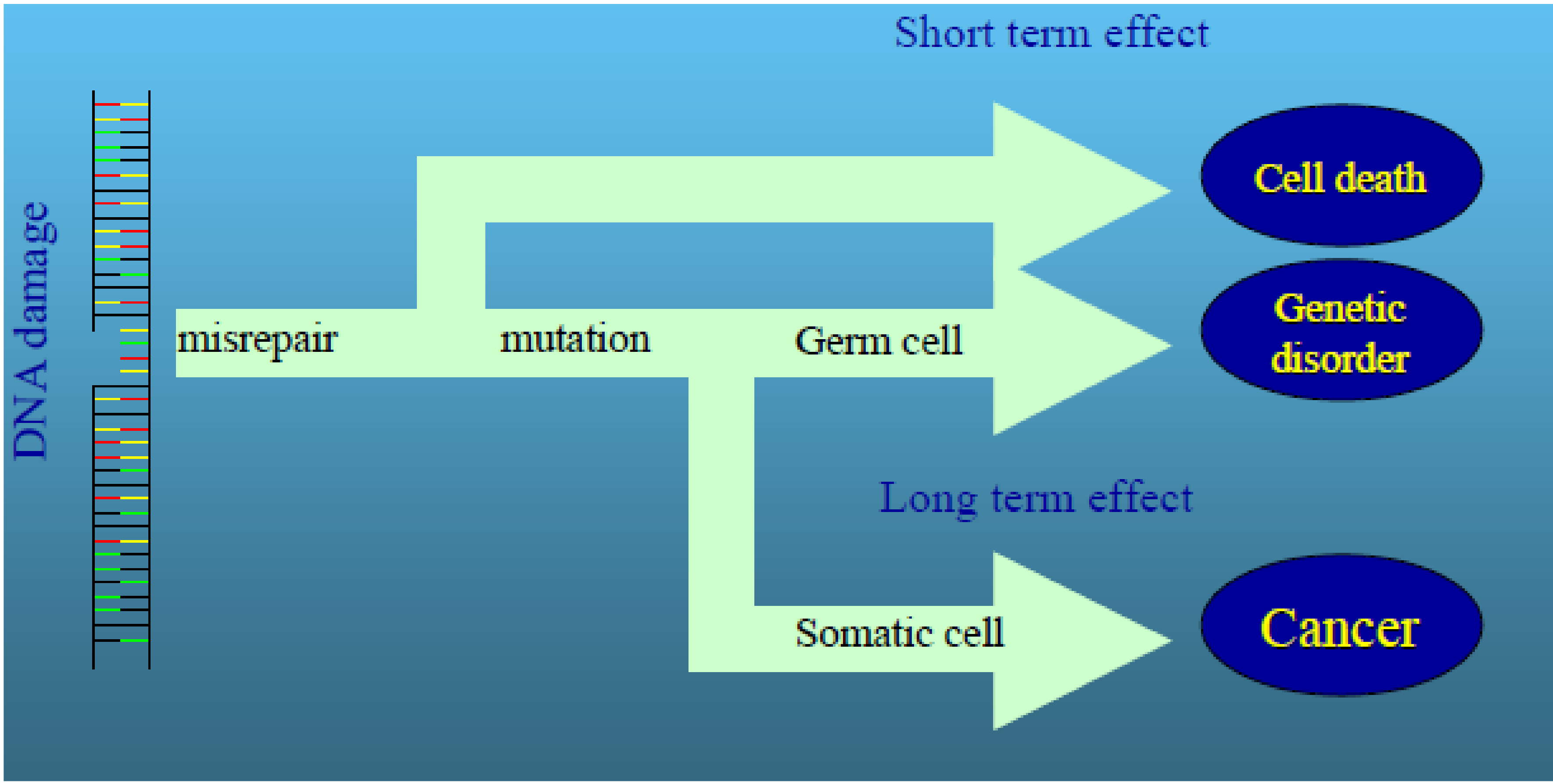
Cancers radio-induits: pourquoi et comment?



Cancers radio-induits: pourquoi et comment?



Cancers radio-induits: pourquoi et comment?



Cancers radio-induits: Pourquoi et comment?

Altered base

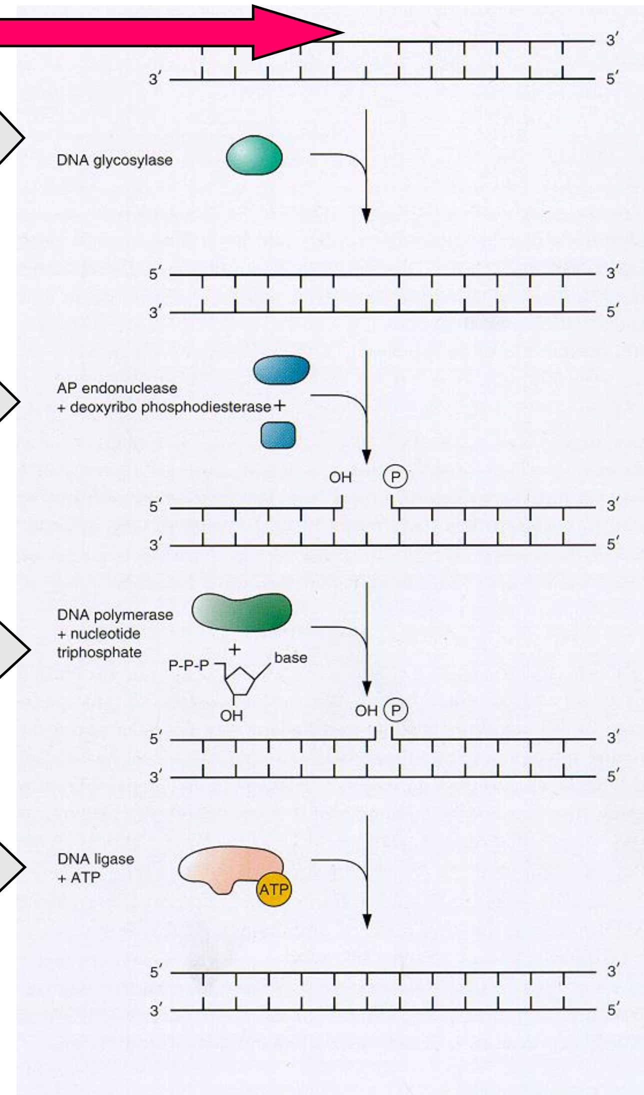
Enzyme *Glycosylases* recognizes lesion and releases damaged base

***AP-endunuclease* makes incision and releases remaining sugar**

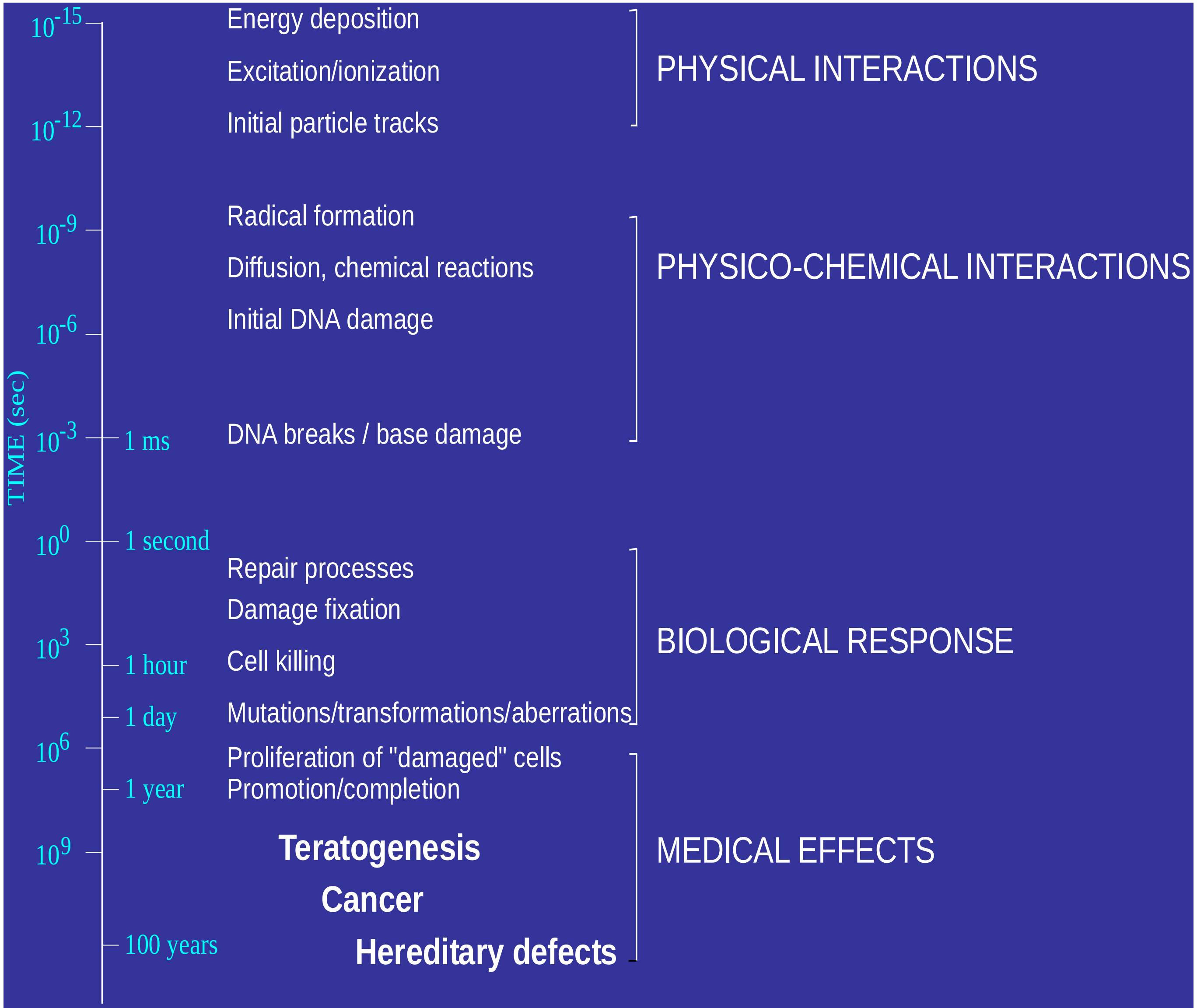
***DNA-polymerase* fills resulting gap but nick remains**

***DNA ligase* seals the nick. Repair completed.**

DNA has been repaired with no loss of genetic information



Cancers radio-induits: pourquoi et comment?

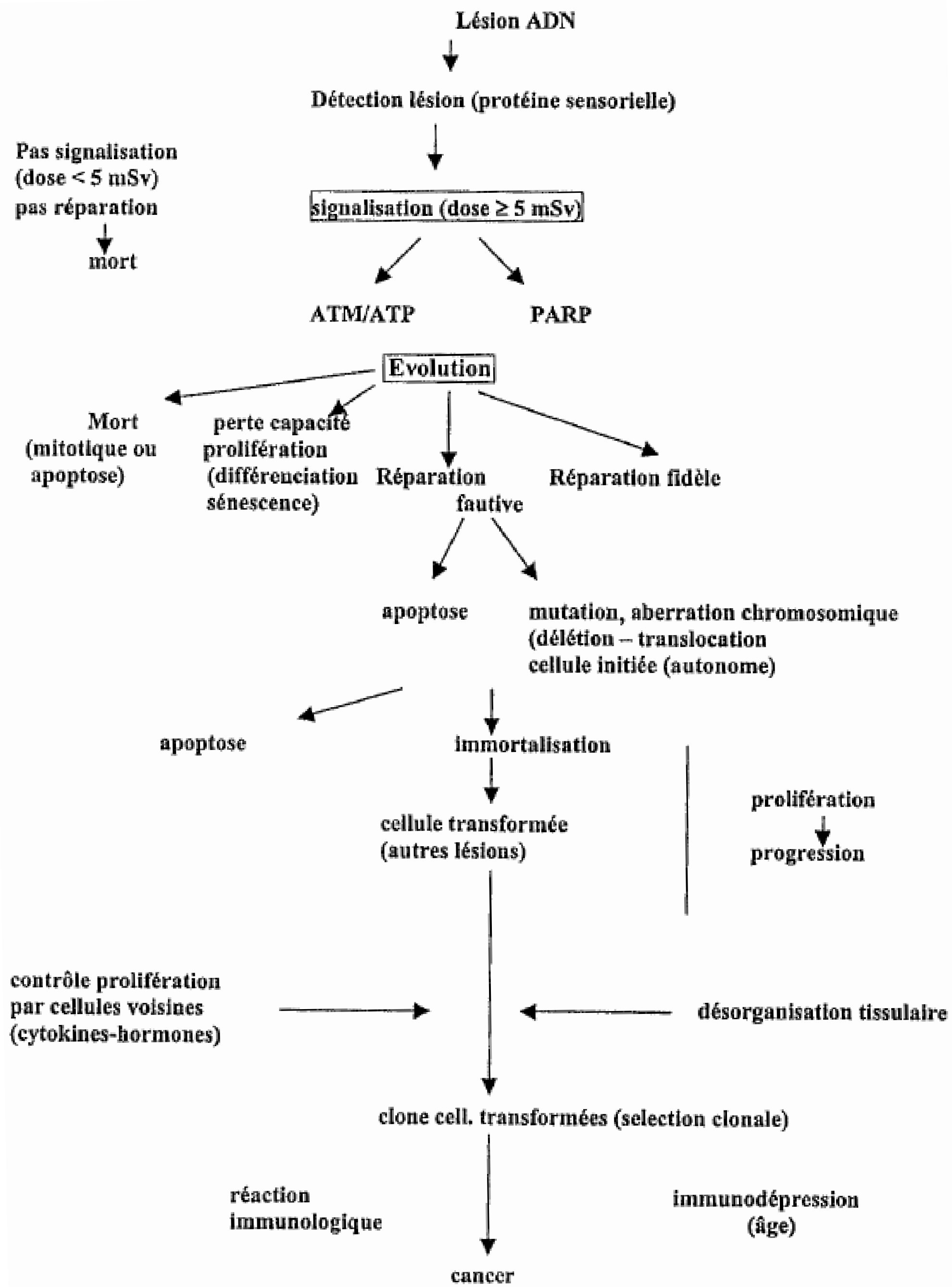


Cancers radio-induits: pourquoi et comment?

- Différentes étapes – tout n'est pas lié uniquement à **une mutation**

- 999 cellules / 1000 mutées se réparent
- 999 cellules mutées / 1000 meurent (ceci n'est pas un problème…)
- Beaucoup de cellules avec mutation(s) sont viables

- Il faut donc d'autres étapes:
  - **Initiation:** mutation d'un gène qui affecte la prolifération (proto-oncogène ou gène suppresseur)
  - **Promotion**: multiples facteurs: hormones, alcool, toxiques (dont chimio), inflammation →nouvelles mutations
  - **Progression:** prolifération non contrôlée →nouvelles mutations

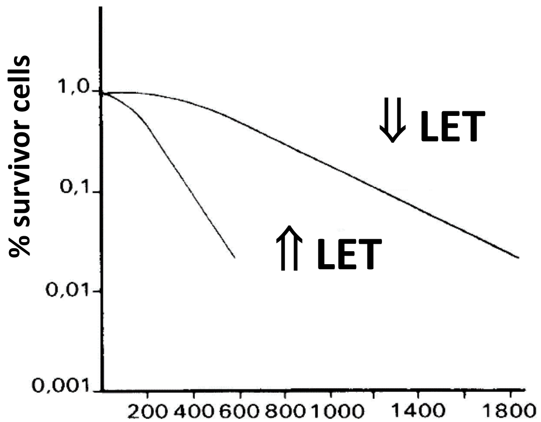

Lésion ADN
Détection lésion (protéine sensorielle)
Pas signalisation
(dose < 5 mSv)
pas réparation
mort
signalisation (dose ≥ 5 mSv)
ATM/ATP
PARP
Evolution
Mort
(mitotique ou
apoptose)
perte capacité
prolifération
(différenciation
sénescence)
Réparation
fautive
Réparation fidèle
apoptose
mutation, aberration chromosomique
(délétion – translocation
cellule initiée (autonome)
apoptose
immortalisation
cellule transformée
(autres lésions)
prolifération
progression
contrôle prolifération
par cellules voisines
(cytokines-hormones)
désorganisation tissulaire
clone cell. transformées (selection clonale)
réaction
immunologique
immunodépression
(âge)
cancer

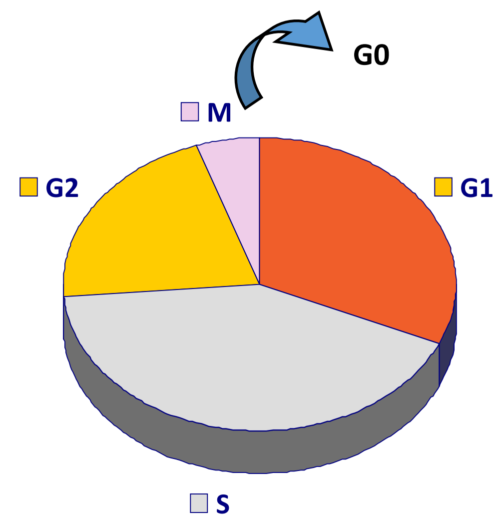
Cancers radio-induits: pourquoi et comment?

- Multiples facteurs favorisants/modulateurs
  - Age
  - Sexe
  - Toxicité combinée (ex. radon et tabac)
  - Effet du débit de dose
  - Transfert linéique d’énergie
  - Effet du fractionnement (aigu vs protracted vs chronique)
  - Type de tissu
  - Phase du cycle cellulaire
  - Index mitotique naturel: ex. leucémie

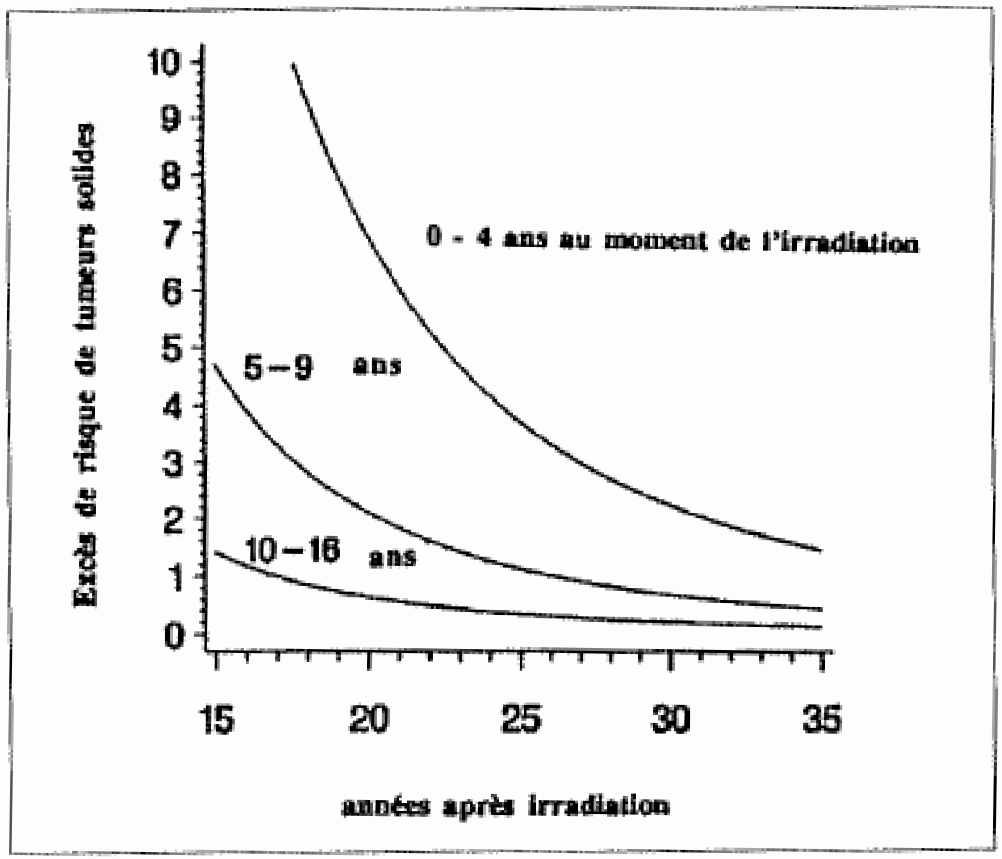
Cancers radio-induits: effets sur la radiosensibilité

- Physical
  - LET (linear energy transfer): ⇑ RS
  - Dose rate: ⇑ RS
  - Temperature ⇑ RS
- Chemical
  - Increase RS: OXYGEN, cytotoxic drugs.
  - Decrease RS: SULFURE (cys, cysteamine…)
- Biological
  - Cycle status:
    - ⇑ RS: G2, M
    - ⇓ RS: S
  - Repair of damage (sub-lethal damage may be repaired e.g. fractionated dose)

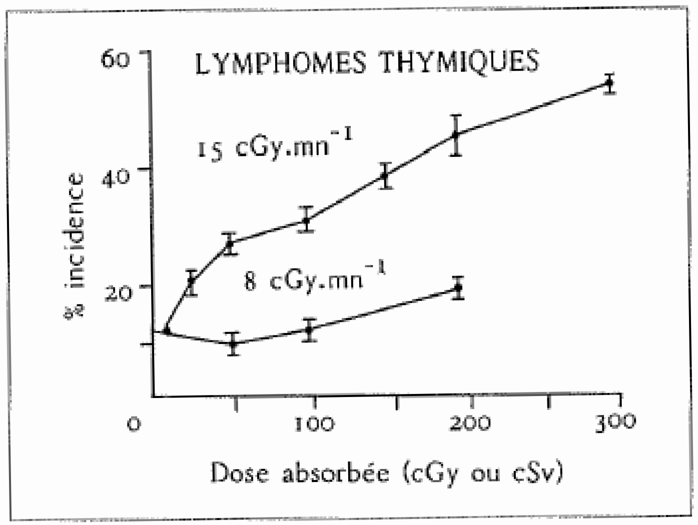


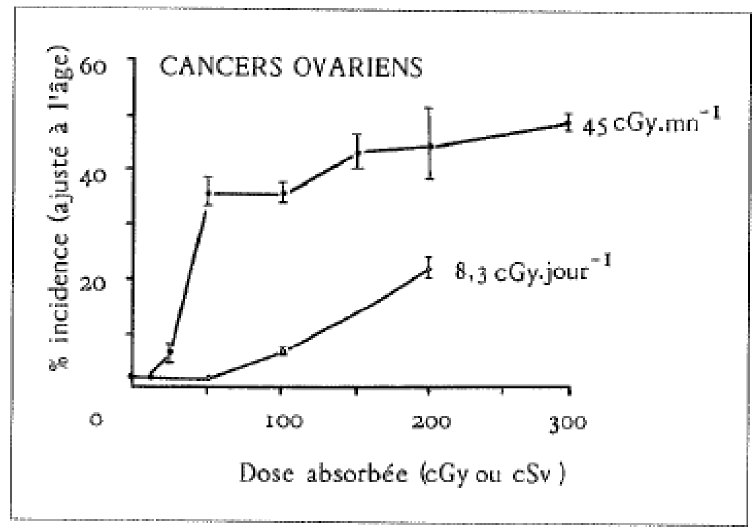


Cancers radio-induits: effet de l'âge



Cancers radio-induits: effet du débit de dose





Cancers radio-induits: différenciation cellulaire

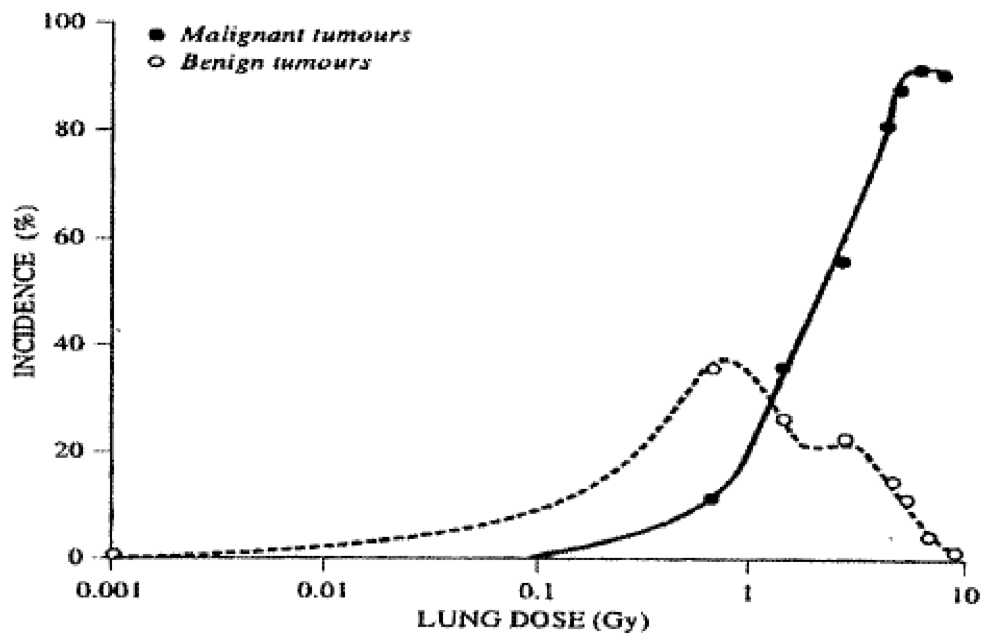


Figure 8 :
Tumeurs bénignes et malignes provoquées par inhalation d'un aérosol de $^{239}PUO_2$.
Les tumeurs bénignes sont provoquées par des doses plus faibles que les malignes, ce qui correspond vraisemblablement à un moindre nombre d'altérations de l'ADN (d'après UNSCEAR 1986).

Cancers radio-induits: effets sur la radiosensibilité

High RS	Medium RS	Low RS
Bone Marrow **Spleen** **Thymus** **Lymphatic nodes** **Gonads** **Eye lens** **Lymphocytes** (exception to the RS laws)	**Skin** **Mesoderm organs (liver, heart, lungs…)**	**Muscle** **Bones** **Nervous system**

Cancers radio-induits: marqueurs?

DNA repair foci after ^{131}I therapy
~100 mCi, 0.3 Gy to blood
Lassmann et al. JNM 2010

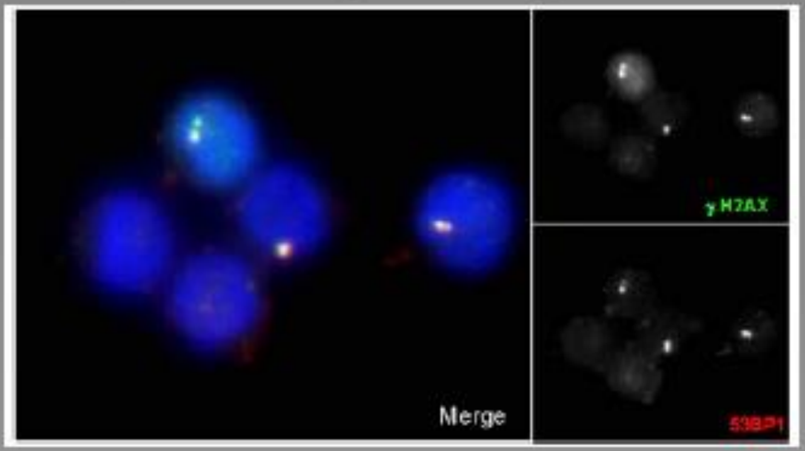


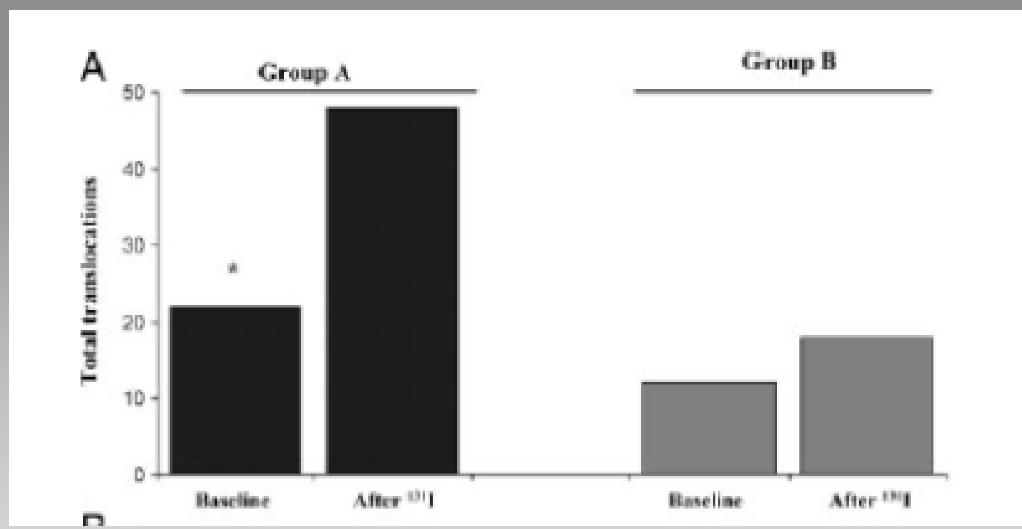
TABLE 3. γ-H2AX and 53BP1 IRIF per Absorbed Dose Rate

Variable	Time after radioiodine administration (h)					
	2	24	48	72	96	120
γ-H2AX						
Median $(mGy/h)^{-1}$	0.0168	0.0338	0.0695	0.108	0.1413	0.2764
n*	20	13	19	17	13	5
53BP1						
Median $(mGy/h)^{-1}$	0.0180	0.0234	0.0675	0.1351	0.1096	0.1752
n*	20	13	19	17	13	5

*Number of patients with evaluable samples for each time point.
See "Results" section for explanation of nonevaluable patients and samples.

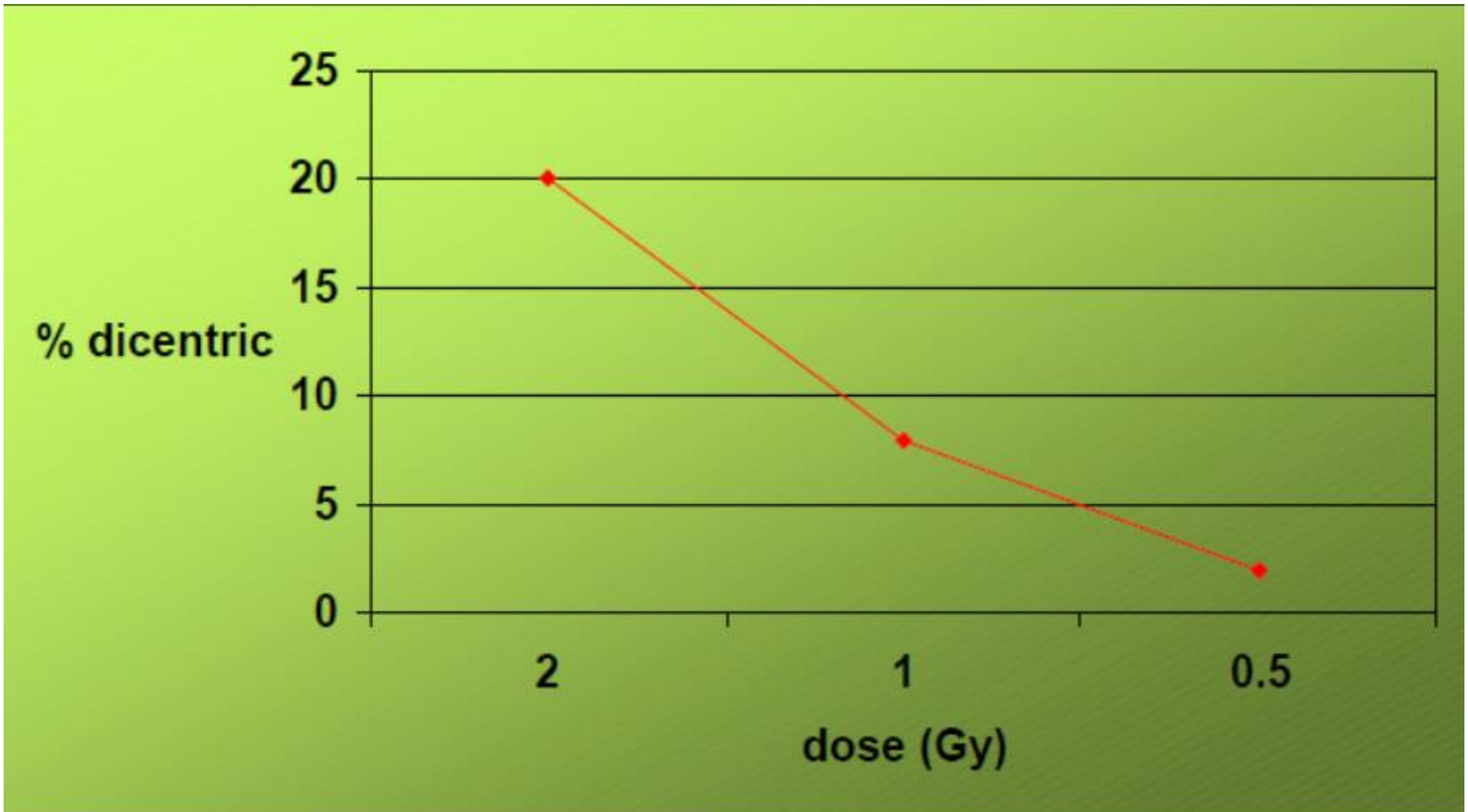
Cancers radio-induits: marqueurs?

Chromosome Translocation Frequency after Radioiodine Thyroid Remnant Ablation: A Comparison between Recombinant Human Thyrotropin Stimulation and Prolonged Levothyroxine Withdrawal

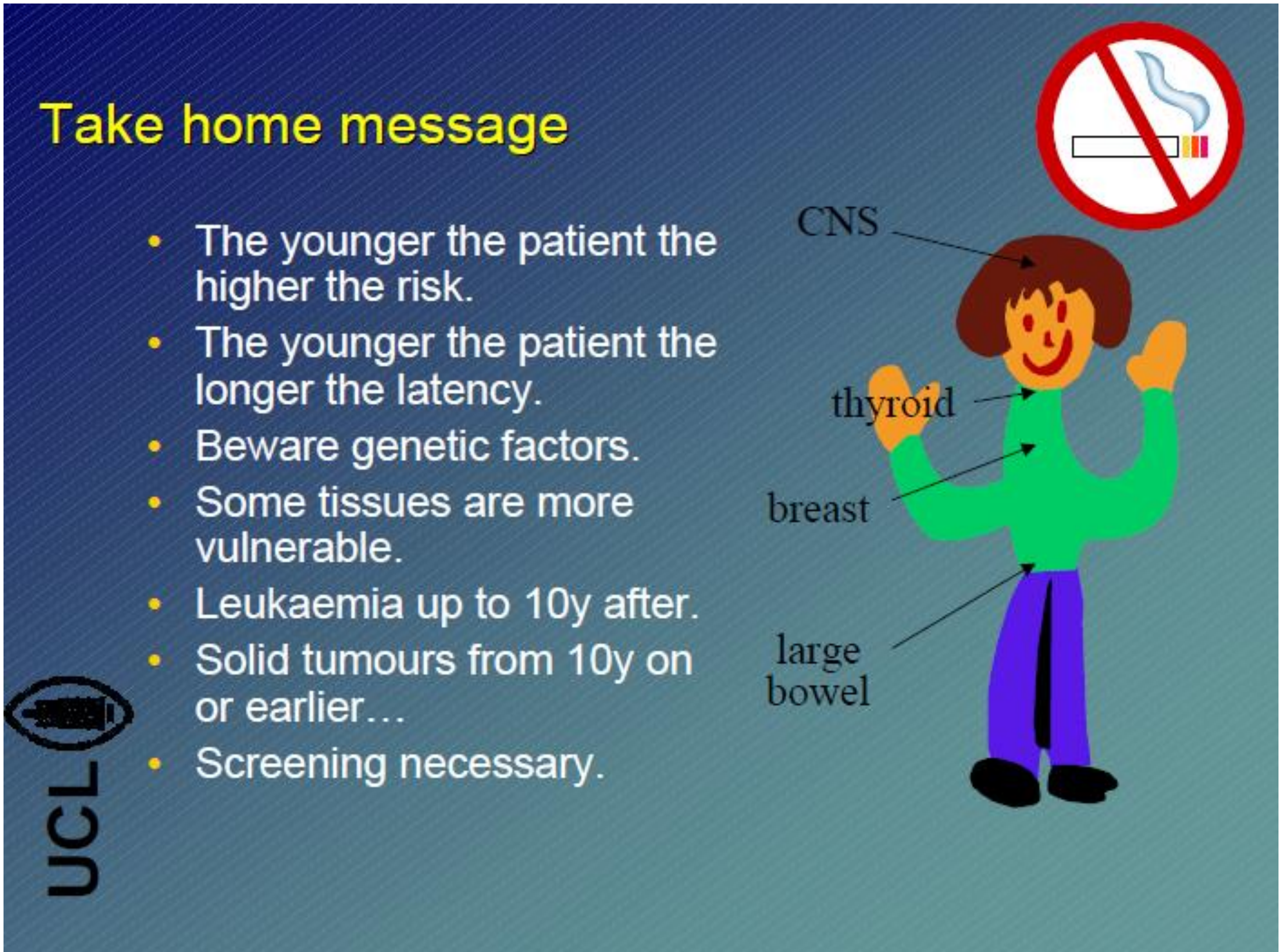


Frigo et al. JCEM 2009

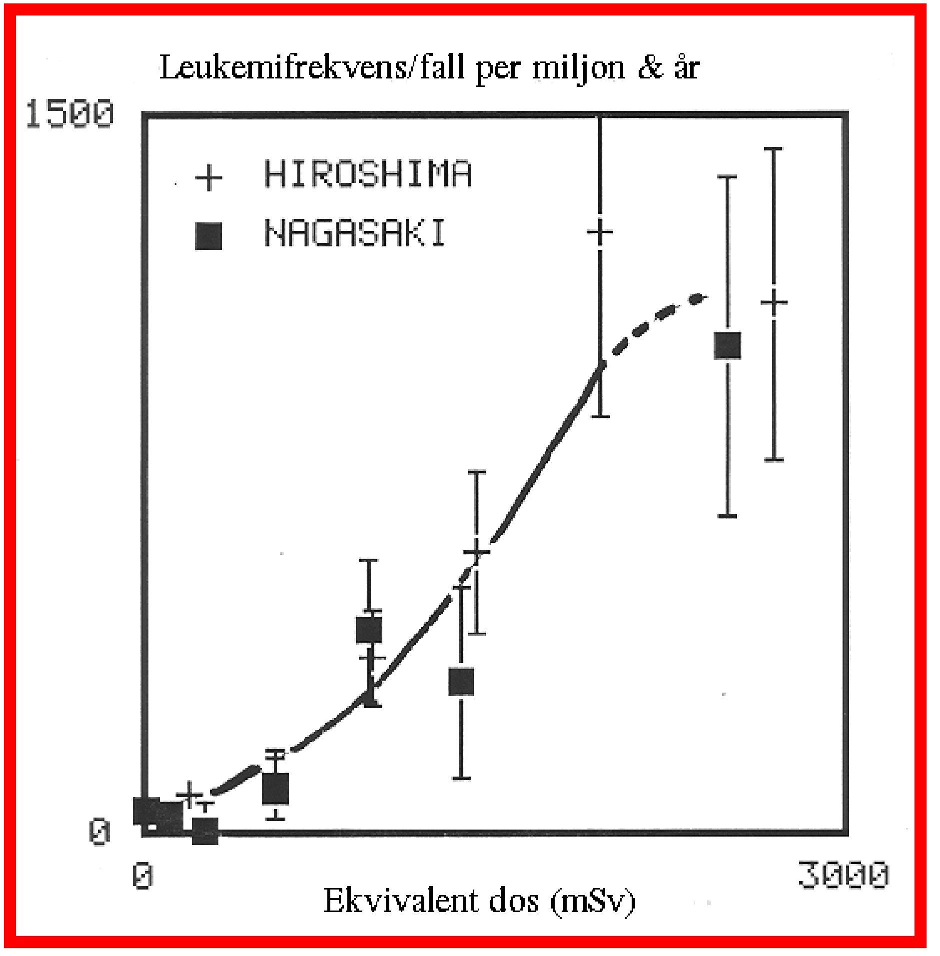
Cancers radio-induits: marqueurs?



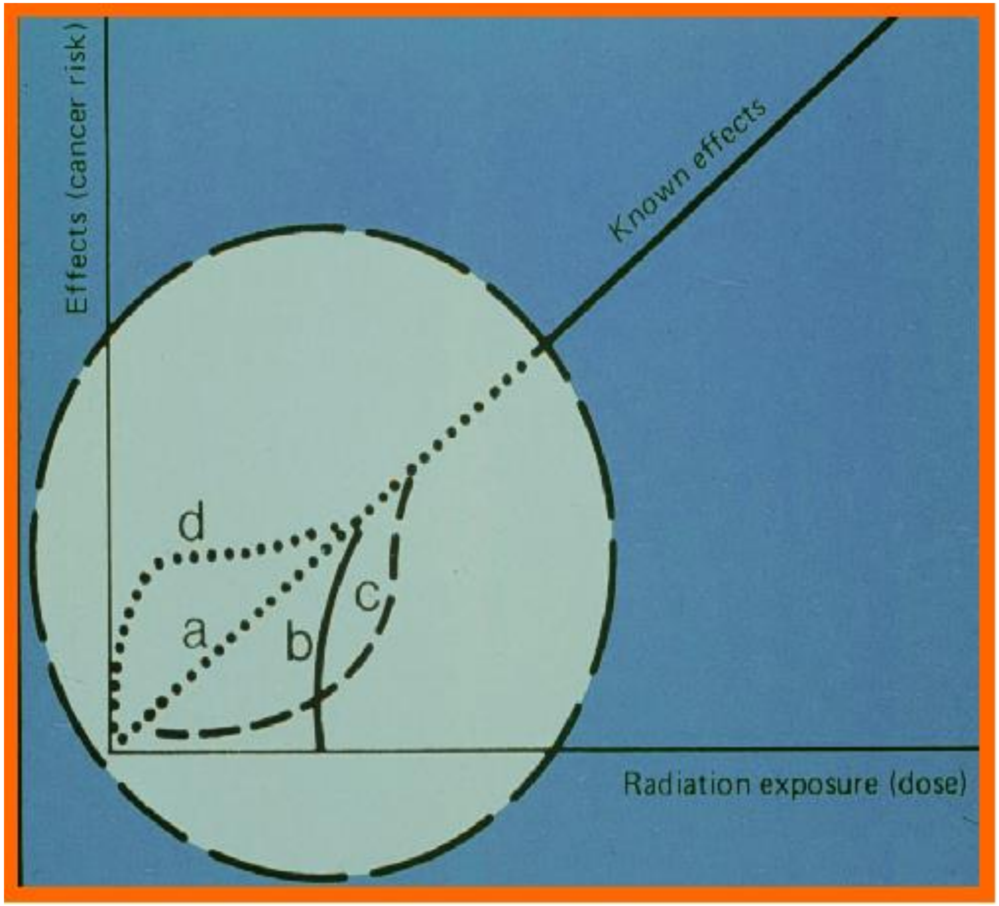
Cancers radio-induits: second cancer (ou +) après radiothérapie



Cancers radio-induits: hautes doses

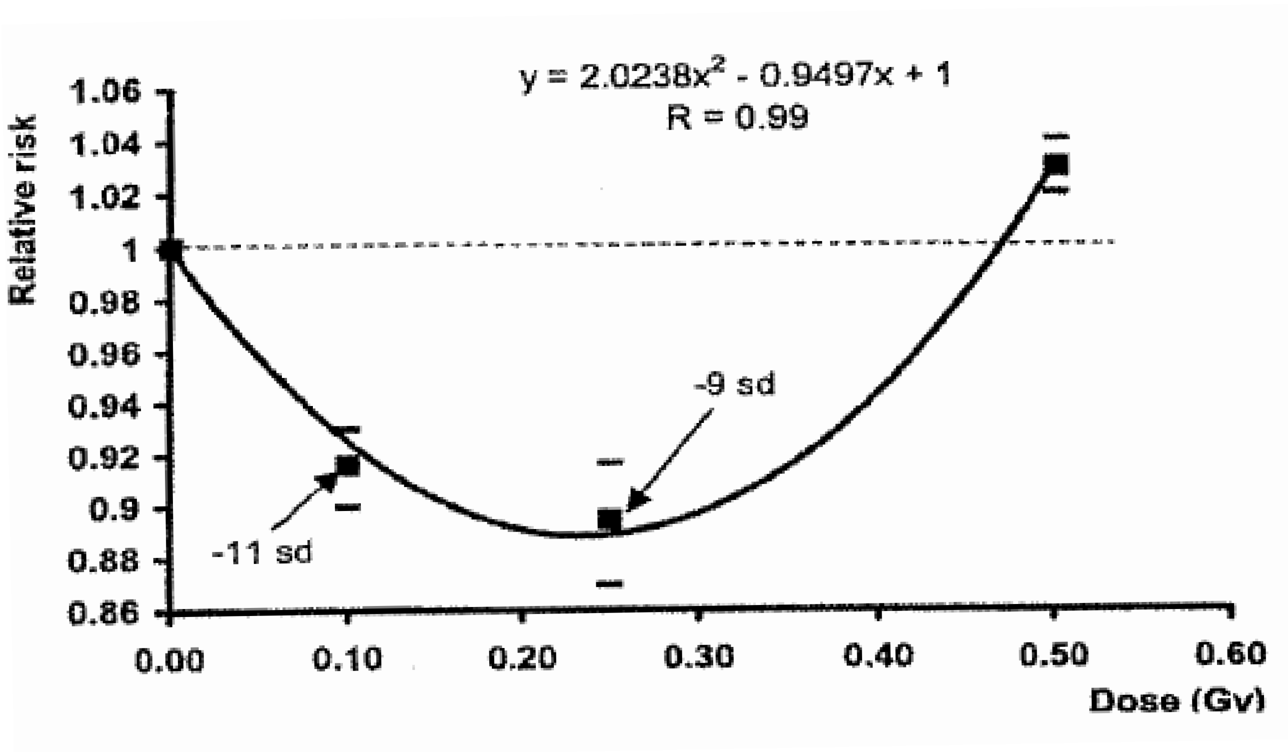


Cancers radio-induits: faibles doses?

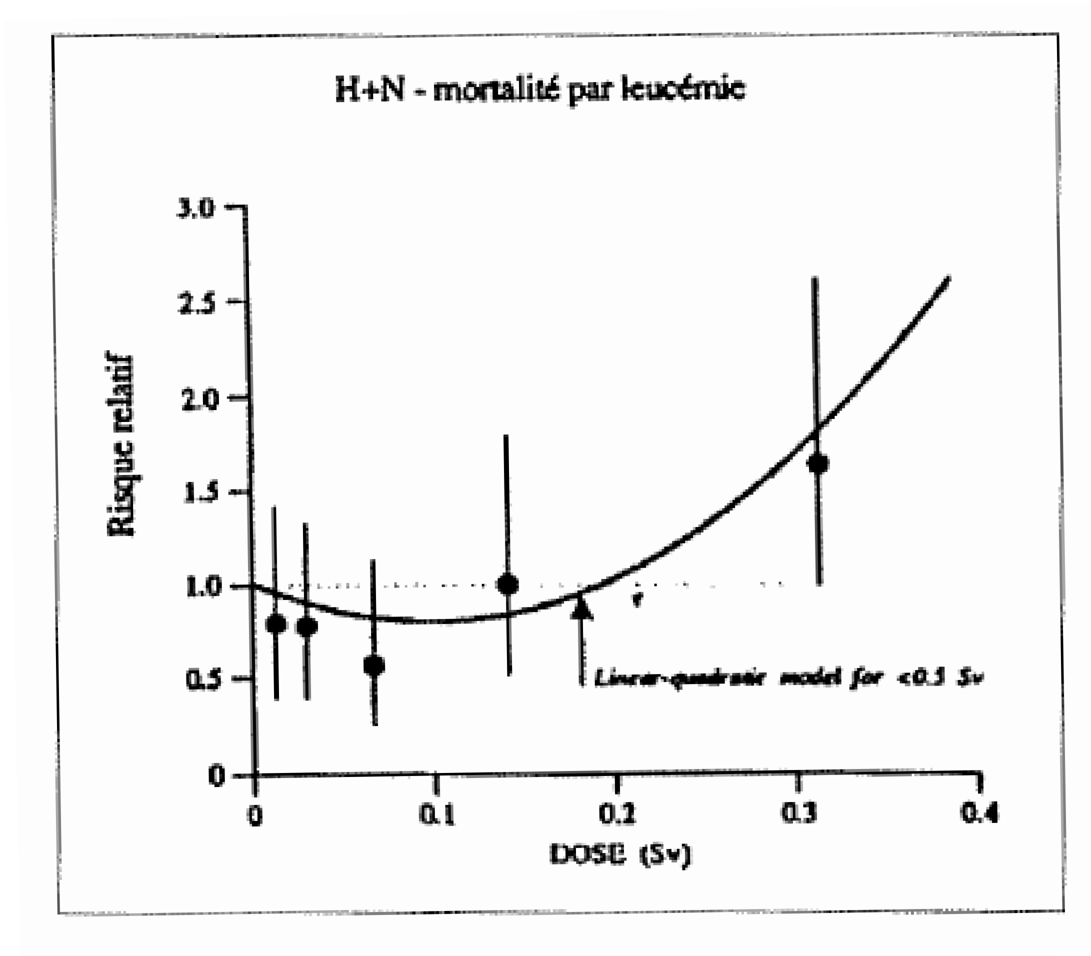


a) Linear extrapolation
b) Threshold dose
c) Lower risk per dose for low doses
d) Higher risk per dose for for low doses

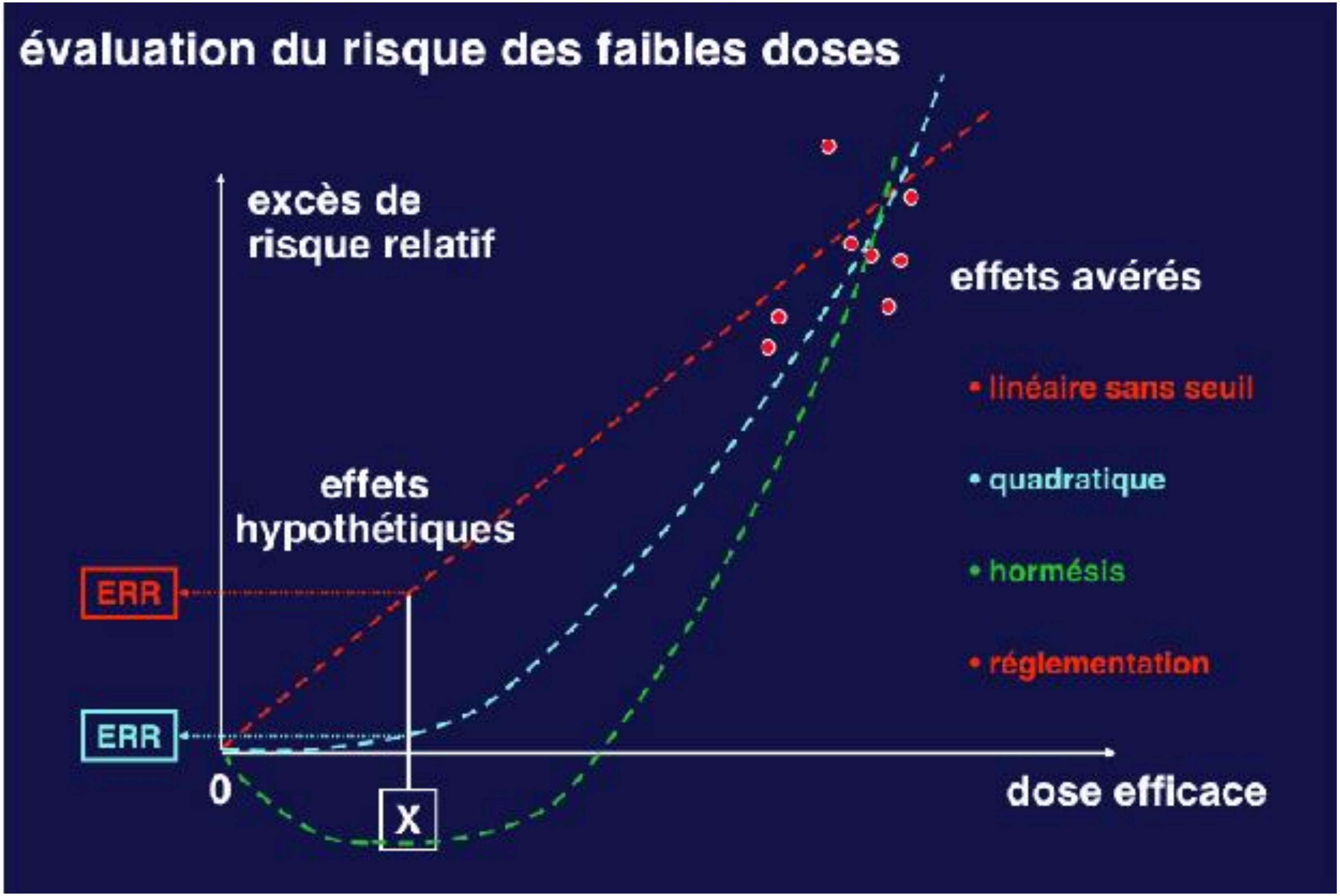
Cancers radio-induits: hormésis –souris (γ)



Cancers radio-induits: hormésis - Hiroshima

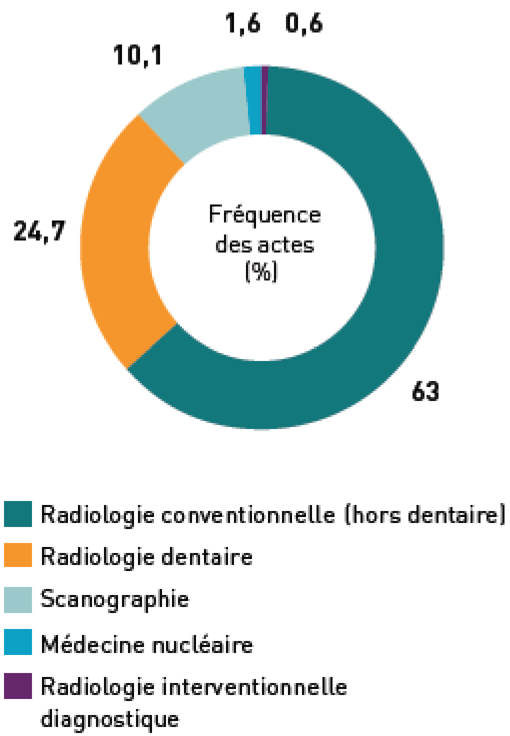


Cancers radio-induits: quel modèle choisir



Cancers radio-induits: faibles doses et imagerie

- Quelle irradiation pour quel examen?



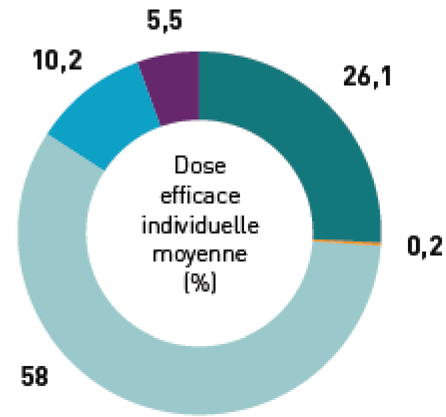
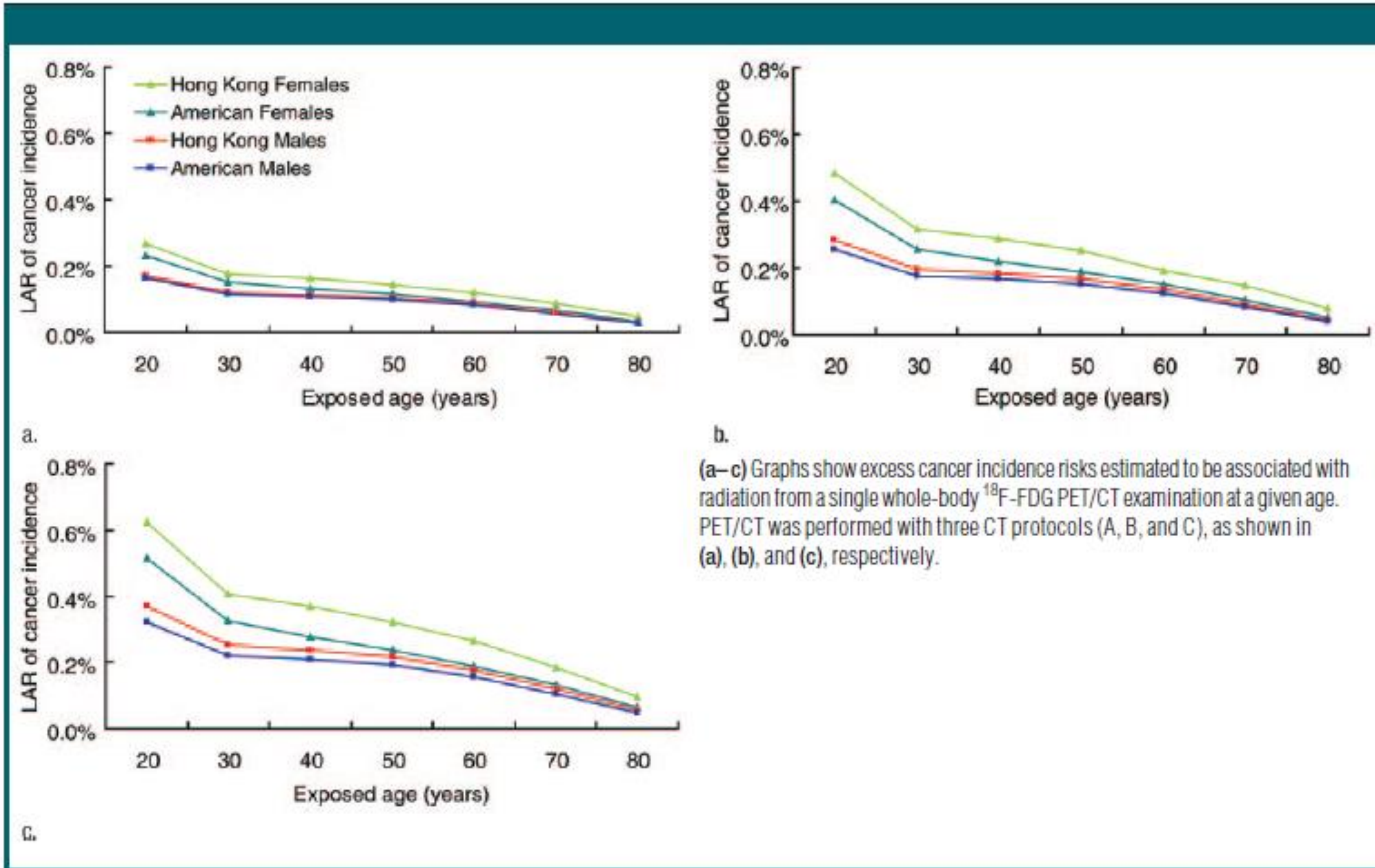


Figure 1 : Répartition des examens et de la dose efficace associée en fonction des modalités d'imagerie en 2007

Cancers radio-induits: faibles doses et imagerie



(a– c) Graphs show excess cancer incidence risks estimated to be associated with radiation from a single whole-body ^{18}F-FDG PET/CT examination at a given age. PET/CT was performed with three CT protocols (A, B, and C), as shown in **(a)**, **(b)**, and **(c)**, respectively.

Cancers radio-induits: faibles doses et imagerie

Table 5

LARs of Cancer Incidence for U.S. and Hong Kong Populations

Lifetime risk for 100 mSv

Sex and Cancer Site	Age at Exposure (y) 0		10		20		30		40		50		60		70		80	
	United States	Hong Kong	United States	Hong Kong	United States	Hong Kong	United States	Hong Kong	United States	Hong Kong	United States	Hong Kong	United States	Hong Kong	United States	Hong Kong	United States	Hong Kong
Male patients																		
Stomach	66	139	48	100	35	72	24	51	23	49	22	44	17	36	12	25	6	12
Colon	309	384	222	275	159	197	115	140	112	135	104	124	86	103	60	68	28	29
Liver	71	229	50	163	35	116	26	82	24	77	22	66	16	48	9	29	3	13
Lung	308	405	212	279	146	191	103	131	102	130	99	125	87	110	64	82	33	46
Prostate	89	39	64	28	46	20	34	14	34	14	32	14	25	12	13	8	5	4
Bladder	217	177	156	127	112	91	82	65	82	64	79	62	69	55	49	41	24	21
Other solid organ	1112	1609	498	533	309	341	196	223	170	196	139	160	97	116	56	68	23	28
Thyroid	147	125	64	54	27	23	12	9	4	8	1	7	0	4	0	3	0	0
Female patients																		
Stomach	90	203	64	146	46	104	32	74	31	69	28	59	24	46	17	25	10	8
Colon	207	165	149	117	107	83	77	59	74	54	69	48	58	38	42	22	22	8
Liver	31	243	22	173	16	122	11	87	11	76	10	60	8	41	6	19	2	6
Lung	777	831	534	567	367	389	257	267	254	258	244	244	213	220	156	167	82	95
Breast	1089	1351	662	813	399	487	235	288	131	274	65	237	29	180	11	118	4	59
Uterus	47	6	33	5	24	3	17	2	15	2	12	2	8	1	5	0	2	0
Ovary	82	57	58	40	40	28	27	20	24	16	20	12	14	8	9	5	4	2
Bladder	218	204	157	141	112	101	81	73	80	72	76	71	66	65	48	53	25	33
Other solid organ	1312	1869	513	822	317	547	203	369	177	312	145	246	107	196	67	148	29	79
Thyroid	856	736	371	319	153	133	55	54	19	44	5	33	1	22	0	12	0	2

Note.—Data are numbers of cancer cases in the lifetimes of 100 000 persons exposed to a radiation dose of 100 mSv. LARs were calculated as described in Appendix E1 (*http://radiology.rsnajnls.org/cgi/content/full/2511081300/DC1*) and by applying the Hong Kong Cancer Statistics 2005 (15) and Hong Kong Life Table 2005 (16).

Cancers radio-induits: BEIR VII

	All Solid Cancer		**Leukemia**	
Excess cases (including non-fatal cases) from exposure to 100 mSv	Males	Females	Males	Females
	800 (400–1600)	1300 (690–2500)	100 (30–300)	70 (20–250)
Number of cases in the absence of exposure	45,500	36,900	830	590
Excess deaths from exposure to 100 mSv	410 (200–830)	610 (300–1200)	70 (20–220)	50 (10–190)
Number of deaths in the absence of exposure	22,100	17,500	710	530

Table 1. The table shows the estimated number of cancer cases and deaths expected to result in 100,000 persons (with an age distribution similar to that of the entire U.S. population) exposed to 100 mSv. The estimates are accompanied by 95% subjective confidence intervals shown in parentheses that reflect the most important uncertainty sources including statistical variation, uncertainty in adjusting risk for exposure at low doses and dose rates, and uncertainty in the method of transporting data from a Japanese to a U.S. population. For comparison, the number of expected cases and deaths in the absence of exposure is listed.

2Approximately 42 cancers per 100 individuals calculated from Table 12-4 in Chapter 12 of the BEIR VII report.

3 In special cases, such as in utero exposure, some evidence suggests excess cancers can be detected as low as 10 mSv.

Cancers radio-induits: according to BEIR V

	Annual X-rays per 1000*	Males		Females		Total	
		Attributable risk (%)	Cases cancer per year	Attributable risk (%)	Cases cancer per year	Attributable risk (%)	Cases cancer per year
Country							
Australia	565	1·2	204	1·5	227	1·3	431
Canada	892	1·1	406	1·0	378	1·1	784
Croatia	903	1·5	66	2·2	103	1·8	169
Czech Republic	883	0·9	67	1·2	105	1·1	172
Finland	704	0·7	20	0·7	30	0·7	50
Germany	1254	1·3	963	1·7	1086	1·5	2049
Japan†	1477	2·9	3724	3·8	3863	3·2	7587
Kuwait	896	0·7	25	0·6	15	0·7	40
Netherlands	600	0·7	100	0·7	108	0·7	208
Norway	708	1·3	28	1·1	49	1·2	77
Poland	641	0·5	99	0·7	192	0·6	291
Sweden	568	1·1	91	0·8	71	0·9	162
Switzerland	750	1·0	93	1·0	80	1·0	173
UK	489	0·6	341	0·6	359	0·6	700
USA	962	0·9	2573	1·0	3122	0·9	5695

*Taken from worldwide survey.[1] †Estimates assume annual frequency of CT examinations in Japan was equal to that for all health-care level 1 countries. However, number of CT scanners per million population in Japan is 3·7 times that for all health-care level 1 countries. If this number is reflected in annual frequency of CT examinations, then for Japan estimated annual number of X-rays per 1000 increases to 1573 and the attributable risk increases to 4·4%, corresponding to 9905 cases of cancer per year.

Table 6: **Frequency of diagnostic X-rays per 1000 population, percentage of cumulative cancer risk to age 75 years attributable to diagnostic X-rays, and number of radiation-induced cases of cancer per year for 15 countries**

Berrington de Gonzalez, Lancet, 2004

Cancers radio-induits: according to BEIR V

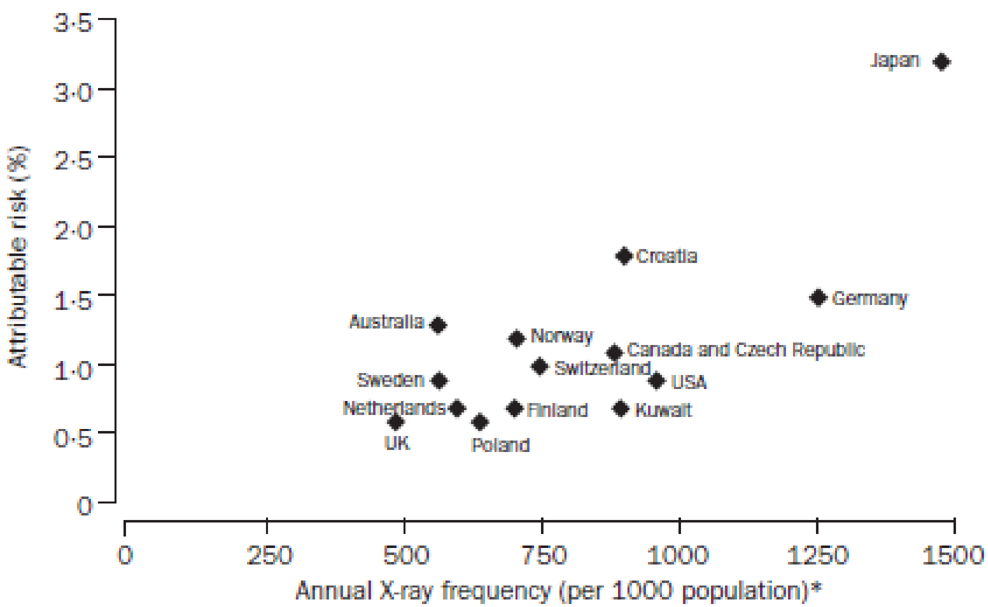


Figure 3: **Risk of cancer attributable to diagnostic X-ray exposures versus annual X-ray frequency**

*Taken from worldwide survey.[1]

	Cases of radiation-induced cancer per year*			Cases per million examinations*
	Males	Females	Total	
X-ray type				
Abdomen	16	15	31	30
Barium meal	5	6	11	40
Barium enema	27	28	55	170
Chest	1	3	4	1
Coronary angiography	13	28	41	280
CT scan	31	39	70	60
Cerebral angiography	1	1	2	180
Hip or pelvis	28	24	52	30
Lumbar spine	23	16	39	40
Screening mammography	..	8	8	8
Thoracic spine	2	4	6	20
Each other type	<10	<10	<20	..

*Includes only nine cancer sites listed in Table 2. Detailed estimation of number of radiation-induced cases for all cancers is not possible, since estimates of organ-specific doses are not available for other cancers.

Table 3: **Estimated number of radiation-induced cases of cancer per year in the UK by type of X-ray**

Berrington de Gonzalez, Lancet, 2004

Cancers radio-induits: BEIR VII

MAYO CLINIC

ORIGINAL INVESTIGATION

Projected Cancer Risks From Computed Tomographic Scans Performed in the United States in 2007

Amy Berrington de González, DPhil; Mahadevappa Mahesh, MS, PhD; Kwang-Pyo Kim, PhD; Mythreyi Bhargavan, PhD; Rebecca Lewis, MPH; Fred Mettler, MD; Charles Land, PhD

Using BEIR VII report, estimated radiation-related incident cancers

Estimated that 29,000 future cancers could be related to CT scans performed in the U.S. in 2007…..and would translate into about 14,500 cancer deaths.

Arch Intern Med. 2009;169(22):2078-2086

M.K. O’Connor, Mayo Clinic

Cancers radio-induits: BEIR VII

MAYO CLINIC

TABLE 12D-1 Lifetime Attributable Risk of Cancer Incidence[a]

Cancer Site	Age at Exposure (years) 0	5	10	15	20	30	40	[illegible]	[illegible]	[illegible]	80
Males											
Stomach	76	65	55	46	40	28	27	[illegible]	[illegible]	[illegible]	7
Colon	336	285	241	204	173	125	122	[illegible]	[illegible]	[illegible]	30
Liver	61	50	43	36	30	22	21	[illegible]	[illegible]	[illegible]	3
Lung	314	261	216	180	149	105	104	[illegible]	[illegible]	[illegible]	34
Prostate	93	80	67	57	48	35	35	[illegible]	[illegible]	[illegible]	5
Bladder	209	177	150	127	108	79	79	[illegible]	[illegible]	[illegible]	23
Other	1123	672	503	394	312	198	172	[illegible]	[illegible]	[illegible]	23
Thyroid	115	76	50	33	21	9	3	[illegible]	[illegible]	[illegible]	0.0
All solid	2326	1667	1325	1076	881	602	564	[illegible]	[illegible]	[illegible]	126
Leukemia	237	149	120	105	96	84	84	[illegible]	[illegible]	[illegible]	48
All cancers	2563	1816	1445	1182	977	686	648	591	489	343	174
Females											
Stomach	101	85	72	61	52	36	35	[illegible]	[illegible]	[illegible]	11
Colon	220	187	158	134	114	82	79	[illegible]	[illegible]	[illegible]	23
Liver	28	23	20	16	14	10	10	[illegible]	[illegible]	[illegible]	2
Lung	733	608	504	417	346	242	240	[illegible]	[illegible]	[illegible]	77
Breast	1171	914	712	553	429	253	141	[illegible]	[illegible]	[illegible]	4
Uterus	50	42	36	30	26	18	16	[illegible]	[illegible]	[illegible]	2
Ovary	104	87	73	60	50	34	31	25	18	11	5
Bladder	212	180	152	129	109	79	78	74	64	47	24
Other	1339	719	523	409	323	207	181	148	109	68	30
Thyroid	634	419	275	178	113	41	14	4	1	0.3	0.0
All solid	4592	3265	2525	1988	1575	1002	824	678	529	358	177
Leukemia	185	112	86	76	71	[illegible]	62	62	57	51	37
All cancers	4777	3377	2611	2064	1646	1065	886	740	586	409	214

NOTE: Number of cases per 100,000 persons exposed to a single dose of 0.1 Gy.

100,000 women aged 30

Single dose of 100 mGy

Over their lifetime

M.K. O'Connor, Mayo Clinic

Cancers radio-induits: BEIR VII

MAYO CLINIC

Where does the estimate of 29,000 cancers come from ?

Based on Table 12D BEIR VII, and risk estimates for 56,900,000 patients

For comparison: 9,700,000 people will die of cancer

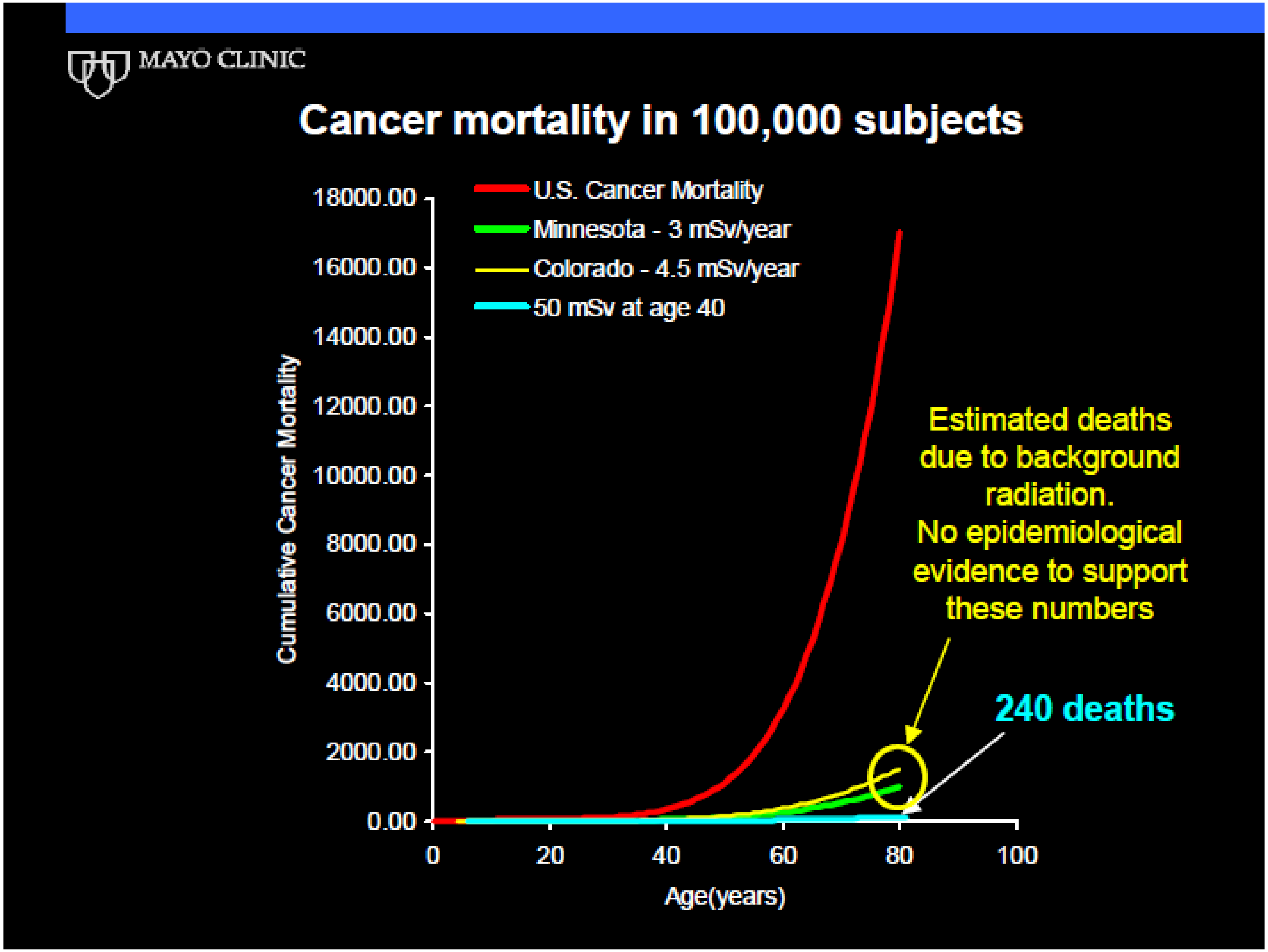
IF they all lived in Minnesota, (bkg rad = 3 mSv) we would expect 576,000 deaths from background radiation

IF they all lived in Colorado, (bkg rad = 4.5 mSv) we would expect 863,000 deaths from background radiation

Differences in residence = 287,000 cancers, or ~10 CT scans/patient

M.K. O'Connor, Mayo Clinic

Cancers radio-induits: BEIR VII



M.K. O'Connor, Mayo Clinic

Cancers radio-induits: imagerie pédiatrique

Cancers radio-induits: imagerie pédiatrique

Paediatric head CT scan and subsequent risk of malignancy and benign brain tumour: a nation-wide population-based cohort study

W-Y Huang[1,2], C-H Muo[3], C-Y Lin[4], Y-M Jen[1], M-H Yang[2,5], J-C Lin[1], F-C Sung[3,6] and C-H Kao*[,6,7]

Table 1. Incidence and adjusted hazard ratio of cancer type compared with the unexposed cohort

	Unexposed cohort $N=97668$			Exposure cohort $N=24418$				
Subtype (ICD-9-CM)	**Case**	**Person-years**	**IR**	**Case**	**Person-years**	**IR**	**HR**	**(95% CI)**
Overall (140–208, 225, 227.3 and 227.4)	122	428 381	28.48	39	106 216	36.72	1.29	(0.90–1.85)
Brain tumour								
Malignat and Benign	30	428 381	7.00	19	106 216	17.89	2.56	(1.44–4.54)**
Malignant (191, 192, 194.3 and 194.4)	11	428 381	2.57	5	106 216	4.71	1.84	(0.64–5.29)
Benign (225, 227.3 and 227.4)	19	428 381	4.44	14	106 216	13.18	2.97	(1.49–5.93)**
Leukaemia (204–208)	17	428 381	3.97	8	106 216	7.53	1.90	(0.82–4.40)
ALL (204.0)	10	428 381	2.33	6	106 216	5.65	2.43	(0.88–6.68)
AML (205.0)	7	428 381	1.63	2	106 216	1.88	1.15	(0.24–5.53)
Other cancers	75	428 381	17.51	12	106 216	11.30	0.65	(0.35–1.19)

Abbreviations: ALL = acute lymphoid leukaemia; AML = acute myeloid leukaemia; CI = confidence interval; HR = hazard ratio; IR = incidence rate per 100 000 person-years. HR adjusted for age and sex. **$P<0.01$.

British Journal of Cancer (2014) 110, 2354–2360 | doi: 10.1038/bjc.2014.103

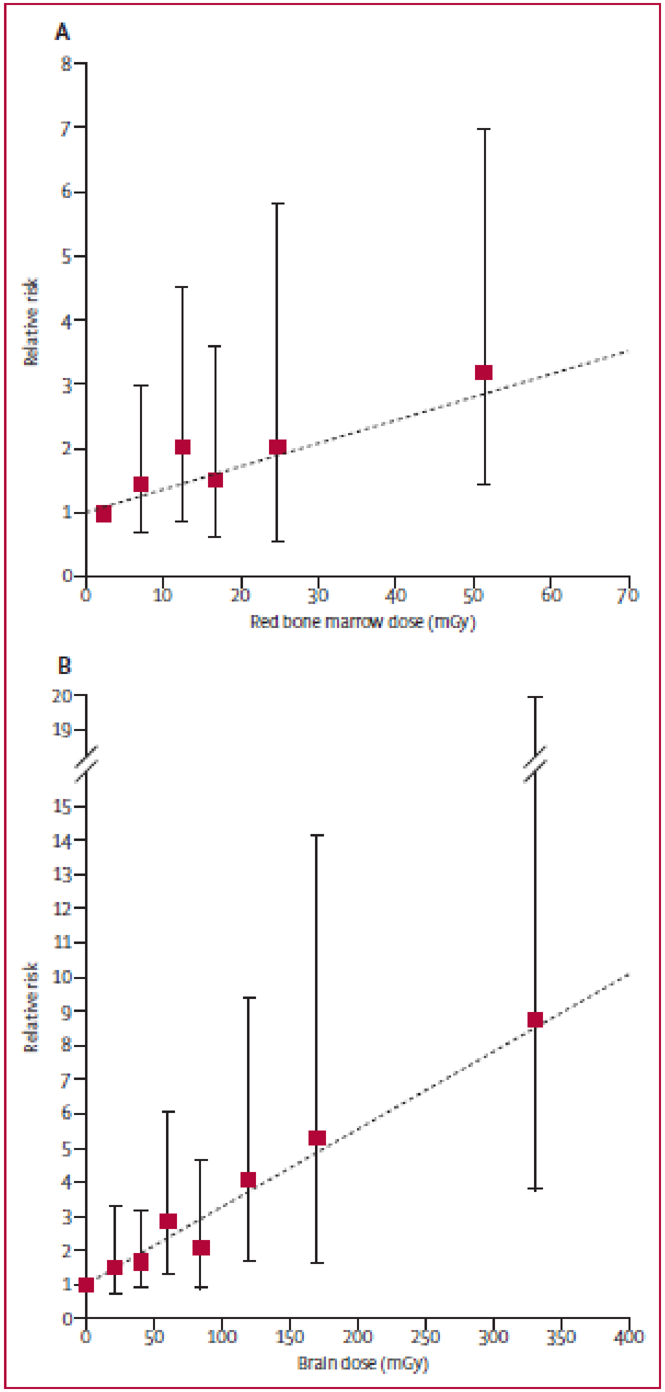
Cancers radio-induits: imagerie pédiatrique

Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study

	Cases	ERR per mGy (95% CI)	p value (test for dose-response)
Red bone marrow dose			
All leukaemia, including myelodysplastic syndromes	74	0·036 (0·005 to 0·120)	0·0097
Acute lymphoblastic leukaemia	26	1·719* (>0 to 17·73†)	0·0053
Acute myeloid leukaemia	18	0·021 (–0·042† to 0·155)	0·2653
Myelodysplastic syndromes	9	6·098* (>0 to 145·4†)	0·0032
Leukaemia excluding myelodysplastic syndromes	65	0·019 (–0·012† to 0·079)	0·1436
Brain dose			
All brain	135	0·023 (0·010 to 0·049)	<0·0001
Glioma	65	0·019 (0·003 to 0·070)	0·0033
Schwannoma and meningioma	20	0·033 (0·002 to 0·439)	0·0195

ERR=excess relative risk. *Iteratively reweighted least-squares algorithm failed to converge, so parameter estimates might be unreliable. †Calculated using Wald-based CI.

Table 3: Excess relative risk per mGy for cancer subtypes in relation to organ-specific radiation doses received from CT scans



Pearce et al., Lancet, 2012

Cancers radio-induits: en imagerie médicale (F. Jamar)

Même si le risque de cancer radio-induit ne peut être considéré comme nul, Il n'y a de limite que celle de la raison qui veut:

Que tout acte soit potentiellement plus utile que dangereux

JUSTIFICATION

Que tout acte soit effectué dans les meilleures conditions

OPTIMISATION

Le médecin doit rassurer le patient, pas lui-même

« La morphine a été inventée pour permettre aux médecins de dormir tranquille » S. Guitry

Cancers radio-induits - relativité

RISKS

Expected reduction of life

Unmarried man	3500 days
Smoking man	2250 days
Unmarried woman	1600 days
30% overweight	1300 days
Cancer	980 days
Construction work	300 days
Car accident	207 days
Accident at home	95 days
Administrative work	30 days
Radiological examination	6 days