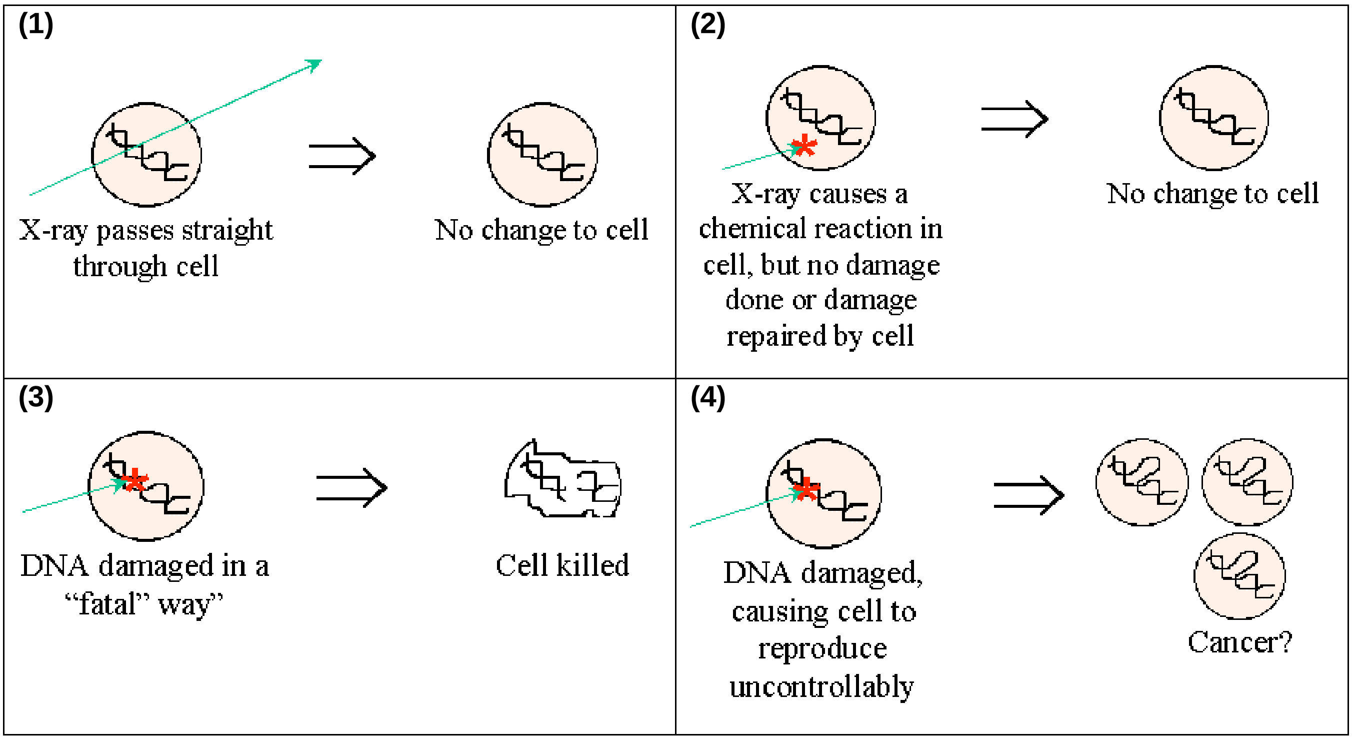
Radiation Protection for Assistant Practitioners in Mammography

by John Saunderson (RPA)

2. Radiation Hazards and Dosimetry

Biological Effects of Radiation

Human tissue is made up of millions upon millions of cells. When an X-ray photon goes through a cell, 4 things can happen



Ionising radiation can cause chemical reactions in the body's cells which may

- no harm
- kill the cell
- cause the cell to multiply out of control (cancer)
- cause the cell to malfunction in some other way (e.g. hereditary disease)

Every time an X-ray is taken, thousands of cells are killed. This cell killing ability of X-rays is used in radiotherapy to kill cancer cells.

When cells are hit by X-rays they do not become radioactive. So patient do not become radioactive when X-rayed.

In Nuclear Medicine departments, patients are injected or swallow radioactive pharmaceuticals. The patients are then slightly radioactive until the radiation decays away naturally, or is excreted. Some patients in radiotherapy have solid radioactive sources implanted in them. They usually remain as in-patients in a special room until the treatment is completed. The radioactive sources are then removed, and the patient is no longer radioactive.

Deterministic Effects ("threshold effects")

Deterministic effects are where so many cells are killed in an organ that some physical symptoms occur. Below a certain radiation dose (threshold) too few cells are damaged to cause any real harm (millions of cells die and are replaced in the body every day). Above the threshold dose, the bigger the dose, the more cells are killed, so the worse the effect.

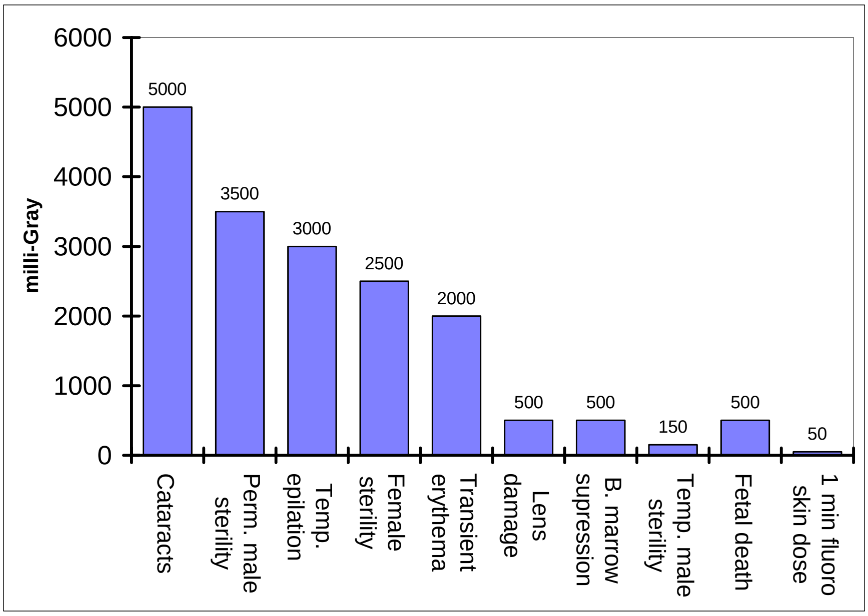
e.g. for skin doses *(see below for definition of Gy, etc.)*

Deterministic effect	**Threshold single dose**
Transient erythema ("sunburn")	2 Gy
Temporary epilation (hair loss to area irradiated)	3 Gy
Main erythema	6 Gy
Permanent epilation	7 Gy
Dermal necrosis	18 Gy
Secondary ulceration	20 Gy

If you received a skin dose of 1.5 Gy today, and another of 1.5 .Gy in a year's time this will not cause a burn, as the skin will have had time to heal in-between the two doses. If you had 1.5 Gy this morning and 1.5 Gy this afternoon it would be enough to cause a skin burn.

The skin dose for a typical mammogram is 9 mGy ($^{9}/_{1000}$ Gy)

Here are threshold for some other deterministic effects.

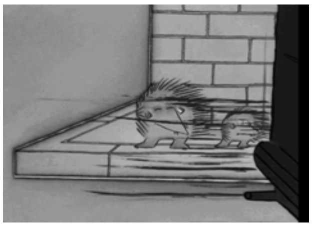


Stochastic Effects ("chance effects")

Stochastic effects occur when cells are not killed, but mutated in some way, such that they either multiply out of control, causing cancer, or they cause hereditary disease which is passed on to any children conceived thereafter.

It is assumed that any dose of radiation could potentially cause stochastic effects, as one single X-ray photon could turn one cell into a cancer cell. The bigger the dose, the more likely the effect will occur. The lower the dose, the less likely.

It is a bit like crossing the road. If you cross the road once a day you are unlikely to be run over. If you cross the road 1000 times a day, you probably still won't get run over, but you are 1000 times more likely to.



By looking at groups of people who have received large doses of radiation in the past (such as the survivors of the atomic bombs in Japan 1945) and comparing them with similar groups who have not had large doses, scientist have calculated the risks of causing cancer, etc. per Sievert of dose *(see below for "Sieverts")*.

	Detriment per mSv			
Exposed Population	Fatal cancer	Non-fatal cancer	Severed hereditary effects	Total
Adult workers	4.0×10^{-5}	0.8×10^{-5}	0.8×10^{-5}	5.6×10^{-5}
Whole population	5.0×10^{-5}	1.0×10^{-5}	1.3×10^{-5}	7.3×10^{-5}
(fetus	*3.0×10^{-5}*	*3.0×10^{-5}*		*6.0×10^{-5})*

e.g. the average chance of fatal cancer for whole population from 1 mSv is $1 \times 4.0 \times 10^{-5} = 1 \times 0.00004 = 0.00004 = {}^{4}/_{100000}$ = 1 in 20,000

The typical effective dose for a mammogram is 50 μSv which gives a risk of fatal cancer of 1 in 400,000.

If the risk from a mommogram is so small, why worry about patient doses? Because lots of people are X-rayed, so there is a risk that some will get cancer from the X-ray.

Average dose given for a mammogram = 270 μSv

Number of mammography examinations per year = 1,726,303

Collective dose = 1,726,303 x 270 μSv = 466 manSv

Statistically, it can be shown that there is a 90% chance that 466 manSv will cause at least 18 fatal cancers.

Some General Risks

Risk of being killed in a road accident in the next year : 6 in 100,000

Risk a meteorite killing ${}^{1}/_{4}$ of the world's population in the next year: 1 in 500,000

Risk of fatal cancer from a typical mammographic examinations: 1 in 400,000

Lifetime risk of cancer: 1 in 3 or 4

Risk of dying in UK at age of 40: 1 in 400

Absorbed dose, dose equivalent, effective dose and their units

Absorbed Dose (D)

- Amount of energy absorbed per kg
- Measured in Grays (Gy)
- 1 Gy = 1000 mGy   (milligray)
- 1 mGy = 1000 μGy   (microgray)
- Thresholds for deterministic effects are given in absorbed dose (e.g. 2 Gy to skin causes erythema)

Typical Values of absorbed dose

- Radiotherapy dose = 40 Gy to tumour (over several weeks)
- LD(50/30) = 4 Gy to whole body (single dose) [*LD(50/30 is Lethal Dose to kill 50% in 30 days*]
- Annual background dose = 2.5 mGy whole body
- Chest PA skin dose = 160 μGy
- Mammo skin dose = 9 mGy

Dose Equivalent (H)

- Takes into account that some types of radiation are more dangerous than others
- Measured in Sieverts (Sv)
- 1 Sv = 1000 mSv   (millisievert)
- 1 mSv = 1000 μSv   (microsievert)
- Dose equivalent = absorbed dose x Q
- Q is a "quality factor" depends on type of radiation
- For X-rays, Q = 1, so 1 Sv = 1 Gy always.
- Alpha rays are ten times as dangerous as X-rays, so Q = 10, so 10 Sv = 1 Gy

Effective Dose (E)

- Sum of equivalent doses to each tissue/organ x organ weighting factors [$E = \Sigma\ w_T.H_T$]
- Units are Sieverts (Sv)
- Risk of cancer is proportional to effective dose
- 1 Sv dose equivalent is the same risk of cancer as 1 Sv given to the whole body

The organ weighting factors are

Tissue or organ	w_T
Gonads	0.2
Red bone marrow	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05

Tissue or organ	w_T
Liver	0.05
Oesphagus	0.05
Thyroid	0.05
Skin	0.01
Bone surfaces	0.01
Remainder	0.05

In other words, the effective dose is (0.2 x dose equivalent (H) to gonads) + (0.12 x H to red bone marrow) + (0.12 x H to colon) + ... etc.,

e.g. if both breast received 2 mSv, and no other organ receives any dose then

E = 0.05 x 2mSv = 0.1 mSv.

Typical Values of effective dose

- Barium enema = 7 mSv
- CT abdomen = 10 mSv
- Conventional abdomen = 1 mSv
- Chest PA = 20 μSv
- Annual dose limit for radiation workers = 20 mSv
- Annual background dose = 2.5 mSv .

Typical Mammography doses

For a typical single mammogram

- Film needs about 7 μGy
- Patient's skin gets about 10 mGy
- Breast gets about 1.6 mGy
- Effective dose around 50 μSv
- Annual staff dose limit is 6 mSv

ICRP System of Radiological Protection

Justification

- no unnecessary exposures

Optimisation

- keep doses as low as reasonably achievable (ALARA) *(sometimes **ALARP** - as low as reasonably practicable)*

Limitation

- dose limits for workers and staff
- diagnostic reference levels (DRL) for patients
- DRL for mammo. 2 mGy glandular dose .

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13/03/03

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APPENDIX

Exponential Notation

e.g. (1) 1.23×10^4

This means 1.23 time 10 four times over = 1.23 x 10 x 10 x 10 x 10 = 12300

e.g. (2) 1.23×10^{-4}

This means 1.23 divided by 10 four times over = 1.23 ÷ 10 ÷ 10 ÷ 10 ÷ 10 = 0.000123

In computers and on calculators, 1.23×10^4 is often typed as "1.23E4", and $1.23 \times {}^{10-4}$ as "1.23E-4"

Another way of thinking about it is that 1.23 could be written 00001.230000

- 1.23×10^4 moves the decimal point 4 positions to the right 000012300.00 = 12300
- $1.23 \times {}^{10-4}$ moves the decimal point 4 positions to the left 0.0001230000 = 0.000123

Unit Prefixes

Mega = 1,000,000	e.g. 2 MV = 2 million volts
Kilo = 1,000	e.g. 28 kV = 28,000 volts
centi = $^{1}/_{100}$	e.g. 100 cm = 1 metre
milli = $^{1}/_{1,000}$	e.g. 30 mA = $^{30}/_{1000}$ amps = 0.03 A
micro = $^{1}/_{1,000,000}$	e.g. 100 μGy = $^{100}/_{1,000,000}$ Gray = 0.0001 Gy = 0.1 mGy
nano = $^{1}/_{1,000,000,000}$	e.g. 1 nm = very small indeed!!