# Radiation Dose and Risks

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## Outline

- Calculating radiation dose
- Radiation effects
- Radiation risk
- What is risk?
- Natural radiation
- Communication of risk

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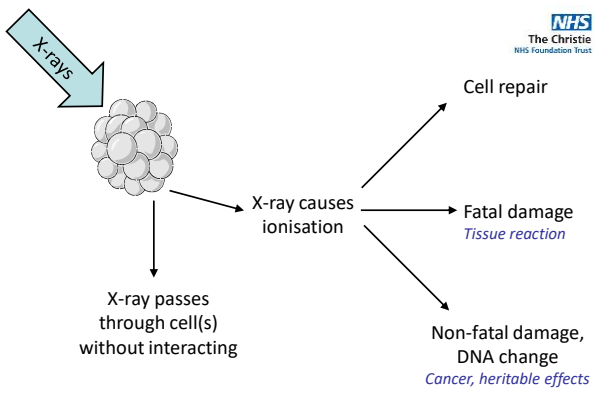


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## Absorbed Dose - dose to a substance

- Radiation is the transfer of energy
  - When it meets an object some energy is lost
- Absorbed dose is the energy deposited per kilogram
- Unit: J/kg
  - Joules (unit of energy) per kg (unit of mass)
- Special Unit: Gray (Gy)

- Typical patient organ doses:
  - Radiography: 0.1 – 10 mGy (skin)
  - Mammography: 1 – 5 mGy (breast)
  - Interventional radiology: 10 – 1000 mGy (skin)
  - Nuclear medicine (dx): 1 – 100 mGy
  - Radiotherapy: ~50 Gy (target)

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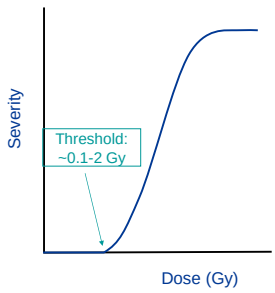
## Absorbed dose – tissue reactions




| Organ/reaction | Threshold (Gy) |
|---|---|
| Bone marrow - depression of cell production | 0.5 |
| Skin - early transient erythema | 2 |
| Skin - necrosis | 10 |
| Lens opacities | 0.5 |
| Testes - temporary sterility | 0.15 |
| Ovaries - sterility | 2.5 |

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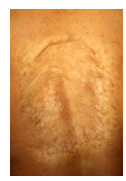
## Patient skin damage

- Patient received coronary angiography, angioplasty, further angiography and coronary artery by-pass graft
  Total dose > 20Gy

6 – 8 weeks after the procedures

16 – 21 weeks after the procedures. A small ulcerated area is present

18 – 21 months after procedures. Tissue necrosis is evident



Result after skin grafting

## Equivalent Dose – radiation damage

- Different types of radiation
  - Photons (electromagnetic) – x-rays, gamma rays
  - Particles – beta ($e^-$, e+), alpha (α), proton (p), neutron (n)
  - Heavy particles (α, p, n) interact more than photons and $e^-$
- More interactions = more damage
  - Radiation weighting factor reflects the relative damage
- Equivalent dose = absorbed dose × radiation weighting factor
- Unit: Sievert (Sv)

1 mGy absorbed dose of alpha particles in the lungs = an equivalent dose of 20 mSv to the lungs

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## Effective Dose – Risk

- Invented by ICRP to allow comparison of radiation risks
  - From all different scenarios (not just medical exposures)
  - Not intended for assessment of risk to an individual
- Tissue weighting factors take into account the total detriment
  - Some organs in the body are more likely to develop cancer after radiation exposure
  - Some cancers are more easily treated
- Effective dose = equivalent dose (organ 1) x tissue weighting (organ 1) + equivalent dose (organ 2) x tissue weighting (organ 2) + …
- Unit: Sievert (Sv)

An equivalent dose of 20 mSv to the lungs = an effective dose of 2.4 mSv (20 x 0.12)

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## Typical effective doses

| Examination | Effective dose, mSv |
|---|---|
| Chest | 0.02 |
| Lumbar spine | 0.6 |
| Ba swallow | 1.5 |
| Coronary angiogram | 4.0 |
| CT thorax/abdomen/pelvis | 10-20 |
| NM Bone scan | 1.0 |
| PET scan | 7.0 |
| Intra-oral x-ray | 0.002 |
| 2-view breast screening | 0.2 |
| *Annual staff dose (x-ray)* | *<0.3* |

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| | |
|---|---|
| **Absorbed dose** | **Unit = gray** |
| **Radiation weighting** | |
| **Equivalent dose** | **Unit = sievert** |
| **Tissue weighting** | |
| **Effective dose** | **Unit = sievert** |

## The estimated risk from radiation exposure is 5% per Sv

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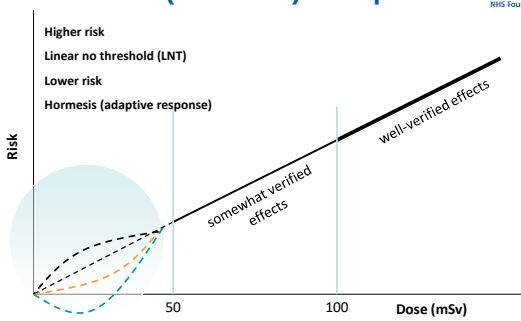
## Low dose (<100mSv) extrapolation




**Linear No Threshold (LNT) adopted by ICRP**

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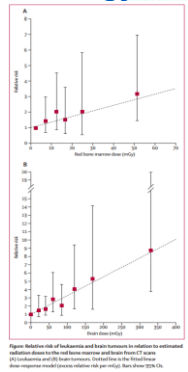
## Recent low dose epidemiology

- Pearse et al. (Lancet 7 July 2012)
- Retrospective cohort study on >150,000 UK children (~300,000 scans)
- Considered organ doses rather than effective dose
  - Bone marrow
  - Brain
- Compared risks for <5 mGy with higher doses
- Relative risks were increased for
  - Leukaemia: 3.2x for ≥30 mGy
  - Brain cancers: 2.8x for 50-74 mGy



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## Risk

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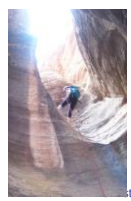
## What is Risk?

- Chance - implies uncertainty about precisely who will be affected
- Everything in life involves risk
  - We are surrounded by hazards with potential to give rise to unwanted consequences
- 'Safe' is not an absolute term

'Everyday' risks



Lifestyle choices

Engineering

## Risk statistics

| | *Average Risk of death* |
|---|---|
| Road travel | 1 in 17,000 journeys |
| Rail travel | 1 in 43,000,000 journeys |
| Commercial air travel | 1 in 125,000,000 journeys |
| Scuba diving | 1 in 200,000 dives |
| Fairground rides | 1 in 834,000,000 rides |
| Rock climbing | 1 in 320,000 climbs |
| | *Average Risk of accident* |
| Road travel | 1 in 1,432,000 km travelled |

*HSE 2001, Health and Safety Statistics from mid-1990s on http://www.hse.gov.uk/education/statistics.htm

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## Are risk figures useful?

- Individuals can make informed choices
  - Survival advantage (e.g. train vs car travel)
- Society
  - Can focus efforts and money on those areas of greatest risk
  - Provide reassurance for rare causes of death (dramatic events) are often overestimated, e.g. swine flu, tornados
  - Encourage action on the common causes that are underestimated, e.g. motor accidents, cancer

*But*

- Many risks appear to have no benefits, and vice versa
- Just telling people the numbers doesn't work
  - Risk perception depends on many other factors
  - "Good" deaths vs. "bad" deaths

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## Risk perception

- Experiences
  - 'Availability cascade'
  - Media coverage often focuses on novel and unusual events
- Feelings
  - "Do I like the activity?", "How strongly do I feel about it?"
  - Risks to vulnerable groups, e.g. children
- Control
  - Alternatives/choices
  - Risks imposed by others
- Understanding
- Messenger

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## Acceptability (tolerability) of risk

- Royal Society (UK's national academy of science)
- Annual risk of death
  - 1 in 100 → unacceptable
  - 1 in 1,000 (worker) → acceptable only if direct benefit
  - 1 in 10,000 → acceptable with benefit to society
  - 1 in 100,000 → (public) acceptable
  - 1 in 1,000,000 → ignore
- HSE framework

**unacceptable**

1 in 1,000 (work) / 10,000 (public)

**tolerable**

1 in 1,000,000 (work/public)

**broadly acceptable**

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## What about Radiation Risks?

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## Radiation risks

**Low doses**

- Cancer induction
- Random
  - But more likely for higher doses
- Risk is quoted for the whole lifetime after exposure

**High doses**

- Skin injuries, including hair loss, and cataracts
- Only occur above threshold
  - More severe at higher doses
- For skin injuries, if no reaction within 4-6 weeks of exposure, unlikely to occur later
- Cataracts may take years to develop

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## Dose and cancer risk from diagnostic examinations

| Examination | Effective dose, mSv | Lifetime Ca risk |
|---|---|---|
| Chest | 0.02 | 1 in 1 million |
| Lumbar spine | 0.6 | 1 in 33,000 |
| Ba swallow | 1.5 | 1 in 13,000 |
| Coronary angiogram | 4 | 1 in 5,000 |
| CT thorax/abdo/pelvis | 10-20 | 1 in 1,000-2,000 |
| NM Bone scan | 3 | 1 in 7,000 |
| PET scan | 8 | 1 in 2,500 |
| Intra-oral x-ray | 0.002 | 1 in 10 million |
| 2-view breast screening | 0.5 | 1 in 20,000* |
| *Annual staff dose (x-ray)* | *<0.3* | *~1 in 100,000* |

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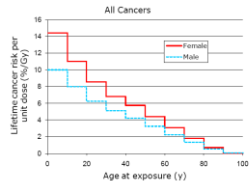
*equivalent to 10% per Sv

## Risk in older and younger people

- Older patients
  - Radiation risks are lower
  - Less time for a radiation induced cancer to develop
- Children
  - 2 to 3 times more at risk than middle aged people
  - Most of life still ahead of them
  - Cells are more active
  - Extra care required to scale doses appropriately

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## Risk for the unborn child

- No risk of organ malformation at low dose
  - Thresholds >100 mGy
- Extra risk of childhood cancer
  - 1 in 13,000 per mSv
  - Natural incidence is 1 in 500

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## Risk Communication

Be careful with comparisons!

Trivialising or comparing radiation risk with other risks can damage credibility as numerically equal risks are not perceived the same

### Where does that leave us?

- Comparisons still useful as educational tool(?)
- Staff dose
  - compare to dose limits, dose records
- Patient dose
  - justification, benefit of diagnosis or treatment
  - comparison to diagnostic reference levels
  - cautious comparison to background radiation

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Thanks for listening


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