Risk and radiations

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Learning objectives

• Briefly explain the effects of radiation on human health

• Be able to compare in the day to day life acute and chronic risks

• Understand some psychological aspects of risk perception and how ethics could help find solutions

• Understand the complexity of communicating about radiation risk
Risk and radiation

1. Effects of ionizing radiations
tissue reactions  
(deterministic effects)  
- skin burn  
- organ/tissue dysfunction  

only at high dose  
absorbed dose  
unit: gray [Gy]  

stochastic effects  
cancer  
heredity  

already at low dose  
effective dose  
unit: sievert [Sv]  

typically above 500 mGy
Dose

Effect

tissue reactions appear rapidly

threshold

Dose
How do we define the threshold of tissue reaction? (in terms of proportion of the population showing the effect)

1. 1%
2. 5%
3. 10%
4. 50%
5. 90%
Tissue reactions (*aka* deterministic effect)

- **most** radiosensitive population
- **least** radiosensitive population

Graph showing severity vs. dose (Gy) with sensitivity variation among individuals exposed to radiation.
Tissue reactions (aka deterministic effect)

Frequency (%)

Dose (Gy)

Severity

Dose (Gy)

Sensitivity variation among individuals exposed to radiation

Threshold for morbidity
lethal whole body acute (1 Gy)

lethal whole body 1-3 months (10-14 Gy)

lethal whole body 1 week (4-8 Gy)

sterility F acute (2.5-6 Gy)

sterility M acute (3.5-6 Gy)

CV (0.5 Gy)

cataract (0.5 Gy)

very young brain (>0.1 Gy)
Does the risk to develop a radiation-induced cancer have a threshold?

1. Yes, below a given dose, the risk is zero
2. No, whatever the dose, there is a risk
3. Nobody really knows for sure
A lot of information thanks to the survivors of Hiroshima et Nagasaki.
A lot of information thanks to the survivors of Hiroshima et Nagasaki

Not only Hiroshima et Nagasaki

- nuclear workers
- miners
- radon residents
- radiation therapy patients
- radiation diagnostic patients
- Chernobyl
- natural irradiation

A linear non-threshold hypothesis (LNT) suggests that effects that need time to appear (cancers, hereditary effect) increase with dose.
Probability to develop a **cancer** after a **effective dose = 100 mSv**

*(energy uniformly distributed within the body)*
Probability to develop a **cancer** after a **effective dose** = 100 mSv
Effective dose is a good approximation of possible stochastic risk.
Exercise: what is the probability to die from cancer after receiving an effective dose (E) of 20 mSv? (for a 25 year old person)
Exercise: what is the probability to **die from cancer** after receiving an effective dose \((E)\) of **20 mSv**? *(for a 25 year old person)*

**solution**

risk factor: \(r = 5\% \text{ Sv}^{-1} = 0.05 \text{ Sv}^{-1}\)

\[E = 20 \text{ mSv} = 0.02 \text{ Sv}\]

**Risk:** \(R = r \times E = 0.05 \times 0.02 = 0.001 = 10^{-3}\)
Risk and radiation

2. How do we justify limits?
An effective dose $E = 20$ mSv is the annual dose limit for professionals.
Limits are not borders between SAFE and DANGEROUS
Risk **unacceptable**

Limit **are not** borders between **SAFE** and **DANGEROUS**

Risk **tolerable**

1 mSv/year approximately natural background *(ICRP-103)*

20 mSv/year risk of $10^{-3}$ *(ICRP-103)*

http://www.denaligrizzlybear.com/
What is the probability to **die today**?

*(whole population; any cause)*

Possible probabilities:

- $10^{-8}$
- $10^{-7}$
- $10^{-6}$
- $10^{-9}$
What is the probability to die today? 
(all causes combined, in a developed country)

1. $20 \times 10^{-8}$
2. $20 \times 10^{-7}$
3. $20 \times 10^{-6}$
4. $20 \times 10^{-5}$
5. $20 \times 10^{-4}$
6. $20 \times 10^{-3}$
7. $20 \times 10^{-2}$
## Probability to die per day

*(all causes; whole population)*

<table>
<thead>
<tr>
<th>Context</th>
<th>Time period</th>
<th>N deaths</th>
<th>N population</th>
<th>$10^{-6}$</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>England and Wales</td>
<td>2012</td>
<td>499,331</td>
<td>56,567,000</td>
<td>24</td>
<td>ONS Deaths Table 5.</td>
</tr>
<tr>
<td>Canada</td>
<td>2011</td>
<td>242,074</td>
<td>33,476,688</td>
<td>20</td>
<td>Statistics Canada</td>
</tr>
<tr>
<td>US</td>
<td>2010</td>
<td>2,468,435</td>
<td>308,500,000</td>
<td>22</td>
<td>CDC Deaths Table 18.</td>
</tr>
</tbody>
</table>

about $20 \times 10^{-6}$ per day

https://en.wikipedia.org/wiki/Micromort
In Switzerland

31,257 + 33,704 = **64,961** death in 2013

\[
\frac{64961}{8 \cdot 10^6 \cdot 365} = 22.2 \cdot 10^{-6} \text{ deaths per day per inhabitant}
\]

http://www.bfs.admin.ch/bfs/portal/fr/index/themen/14/02/04/key/01.html#parsys_84305
Today statistics in Switzerland

What is the probability to die today?
(of a non-natural cause, in a developed country)

1. $1 \times 10^{-8}$
2. $1 \times 10^{-7}$
3. $1 \times 10^{-6}$
4. $1 \times 10^{-5}$
The probability to die from a non-natural cause in the general population is about $1 \times 10^{-6}$ per day.
Number of deaths in Switzerland (2013)

\[
\frac{1312 + 1285}{8 \times 10^6 \times 365} = 0.89 \times 10^{-6}
\]

deaths per day per inhabitant

\[
1312 + 1285 = 2597 \text{ people}
\]

http://www.bfs.admin.ch/bfs/portal/fr/index/themen/14/02/04/key/01.html#parsys_84305
The probability to die from an accident in the general population is about $10^{-6}$ per day.

$10^{-6}$ is 1 MicroMort

$10^{-3} \ (20 \text{ mSv/y}) = 1000 \text{ MicroMort/y}$

In radiation protection, 3 MicroMort/day is unacceptable.
Which **risk** do I **tolerate** when I climb during the winter season?
20-30 deaths per year in Switzerland
8 million inhabitants

\[
\text{risk} = \frac{30}{365 \times 8,000,000} = 0.01 \times 10^{-6}
\]

0.01 MicroMort/day
Risk of dying in an avalanche [MicroMort/day]

- Outdoor population (4.9 MicroMort)
- Men (7.0 MicroMort)
- Ski (11.0 MicroMort)

(2.0 MicroMort) (2.1 MicroMort)
**MicroMort** is useful for events with **immediate** effect.

It allows us to **evaluate now** a risk that could (or not) **materialize now**.

**not adequate** for **stochastic risk**
For **delayed risks**, we need to project ourselves into the future
(and there is **no reset button**, once the risk has been taken)
How many half-hours of life can you expect when you enter adulthood?

1. 1 000
2. 10 000
3. 100 000
4. 1 000 000
5. 10 000 000
30 minutes = 1 MicroLife

Entering adulthood
1 million half-hours to use

M. Blastland and D. Spiegelhalter, The Norm Chronicles, Stories and Numbers About Danger, Profile Books, 2013
Long-term risk can be understood **now** as changing the pace of time.

- Smoking 15-24 cigarettes uses 10 additional **MicroLives** (at the end of the day, you actually used 58 MicroLives).
- Doing a 20 min exercise gives you **2** additional **MicroLives** (at the end of the day, you actually used 46 MicroLives).

https://en.wikipedia.org/wiki/Microlife
Exercise
compute the average time loss
for an effective dose of 20 mSv

Simplistic hypotheses

Risk to die: 5% Sv$^{-1}$
Latency: L=20 years (assume that those who will die, will do it exactly at this time)
Life expectancy: 80 years
Possible expositions between e=20 and e=60 years old
Exercise (solution)
compute the average of time loss
for an effective dose of 20 mSv

Simplistic hypotheses
Risk to die: 5% Sv
Latency: L = 20 years (assume that those who will die, will do it exactly at this time)
Life expectancy: 80 years
Possible expositions between e = 20 and e = 60 years old
Risk to die: \( r = 0.02 \times 0.05 = 1/1000 \)
Life loss if exposed at 20 y.o.: \( r \times (80-40) = 40/1000 = 0.04 \) years = 14.6 days

\[
\text{Life loss} = \frac{\int_{20}^{60} r (80 - e - L) \, de}{\int_{20}^{60} de} = \frac{0.8}{40} = 0.02 \, \text{y} = 7.3 \, \text{d}
\]
<table>
<thead>
<tr>
<th>Exposure</th>
<th>E [mSv]</th>
<th>Average loss in life expectancy</th>
<th>MicroLives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual occupational limit</td>
<td>20</td>
<td>7 days</td>
<td>400</td>
</tr>
<tr>
<td>Whole body CT scan</td>
<td>10</td>
<td>3 days</td>
<td>150</td>
</tr>
<tr>
<td>Fukushima prefecture</td>
<td>1 – 10</td>
<td>10h – 3d</td>
<td>20 - 150</td>
</tr>
<tr>
<td>Fukushima Town Hall in the two weeks following accident</td>
<td>0.1</td>
<td>1 h</td>
<td>2</td>
</tr>
<tr>
<td>Flight from London to New-York</td>
<td>0.07</td>
<td>37 min</td>
<td>1</td>
</tr>
<tr>
<td>Chest X-ray</td>
<td>0.02</td>
<td>11 min</td>
<td>0.5</td>
</tr>
</tbody>
</table>

M. Blastland and D. Spiegelhalter, The Norm Chronicles, Stories and Numbers About Danger, Profile Books, 2013
Risk and radiation

3.
How ethics can help to decide what is acceptable
The role of **genetic differences** in determining **individual sensitivity** has the potential to significantly influence radiological protection...

...so do **life style** characteristics *(e.g. smoking)*
Should we **exclude** a worker in a nuclear power plant if he smokes *tobacco*?

*(risk is potentially 25 times higher than the non-smoking population)*

1. Yes, exclude
2. No, he can work
Should we exclude a worker in a nuclear power plant if he has a high risk gene for developing leukemia? (risk is potentially 25 times higher than the "normal" population)

1. Yes, exclude
2. No, he can work
What kind of worker should we **exclude** from exposure situations?

- **YES**
- **NO**
- don't know

Excluding tobacco smoker (risk 25 times higher)

- **12**
- **33**

Live questionnaire during the annual meeting for the radiological protection experts day (Lausanne, 04.12.2013)
What kind of worker should we exclude from exposure situations?

Exclude if leukemia risk is 25 times higher
Exclude if tobacco smoker (risk 25 times higher)

Exclude if leukemia risk is 25 times higher
Ethics in radiation protection has been introduced to help us to make choices.
Beneficence
(and non-maleficence)
Prudence

the ability to make informed and carefully considered choices without the full knowledge of the scope and consequences of actions

cowardice

cautiousness

over

recklessness

certainty
Depending on the **prevailing circumstances**, both may (or may not) act **with prudence**.
Justice
Every **human being** deserves **unconditional respect**, whatever their age, gender, mental or physical health, religion, social condition or ethnic origin.
Example 1

Should we forbid a **female surgeon** to work with **fluoroscopy** as soon as she's **pregnant**?

1. Yes, exclude
2. No, she can choose
3. No, she should work
4. Don't know
Should we forbid a female surgeon to work with fluoroscopy as soon as she's pregnant?

**beneficence/non-maleficence**
more good than harm for the radiologist or for the fetus?

**justice**
comparable with other risks? *(bus driver, cleaner)*

**prudence**
doses to the fetus almost guaranteed to be < 1mSv

**dignity**
no more autonomy for the radiologist

if anything happens at birth, even with the most unlikely link with radiation, there will be a doubt
Example 1

Should we forbid a female surgeon to work with fluoroscopy as soon as she's pregnant?

1. Yes, exclude
2. No, she can choose
3. No, she should work
4. Don't know
Example 2

Should we set up a **lung cancer screening** program for **smokers**?
*(after 55 years old, 1 low-dose CT yearly, could save 3 people out of 1000)*

1. Yes
2. No
3. Don't know
Should we set up a lung cancer screening program for smokers?

beneficence/non-maleficence
more good than harm

justice
dignity
prudence
Reduced Lung-Cancer Mortality with Low-Dose Computed Tomographic Screening

The National Lung Screening Trial Research Team

BACKGROUND

The average and increasing prevalence of lung cancer has threatened efforts to reduce mortality from this cancer through the use of screening. The advent of low-dose computed tomography (CT) allowed the advancement of lung cancer screening, with evidence suggesting that low-dose CT scans may be an early stage to diagnose whether screening with low-dose CT may result in mortality from lung cancer.

METHODS

From August 2001 through November 2004, 53,454 persons at high risk for lung cancer were randomly assigned to undergo either low-dose CT (LDCT) or standard radiography (XR) every 2 years. The primary outcome was lung-cancer death. The trial was stopped after 5.722 participants of 53,454 participants had died of lung cancer or lung cancer was diagnosed, with 253 in the LDCT group and 280 in the XR group. The relative reduction in mortality from lung cancer with low-dose CT screening was calculated in the LDCT group.

RESULTS

The rate of death from lung cancer was 2.4% in the LDCT group, and 1.7% in the XR group, with a relative reduction of 28%. This difference in lung cancer death rates was statistically significant (P = 0.012).

CONCLUSIONS

Screening with the use of low-dose CT reduces mortality from lung cancer. (Funded by the National Cancer Institute National Lung Screening Trial; ClinicalTrials.gov number NCT00047045.)
Should we set up a lung cancer screening program for smokers?

National Lung Screening trial NLST-study

53,454 current or former heavy smokers
(30+ packs/year; half current/half former) ages 55 to 74
(highly motivated and primarily urban group)

randomized trial

- low-dose chest CT
  
  \( (E=1.5 \text{ mSv}) \)
  
  once a year
  
  (over 3 years)

- chest radiograph
  
  \( (E=0.03 \text{ mSv}) \)
  
  once a year
  
  (over 3 years)
chest x-ray

69 +

low-dose CT

242 +

chest x-ray

4 TP
(5.5%)

low-dose CT

9 TP
(3.6%)

TP: true positive
<table>
<thead>
<tr>
<th>Total positive tests</th>
<th>Total chest x-ray</th>
<th>Total CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung cancer confirmed</td>
<td>5043 (100.0)</td>
<td>18,146 (100.0)</td>
</tr>
<tr>
<td>Lung cancer not confirmed†</td>
<td>279 (5.5)</td>
<td>649 (3.6)</td>
</tr>
<tr>
<td>Positive screening results with complete diagnostic follow-up information</td>
<td>4764 (94.5)</td>
<td>17,497 (96.4)</td>
</tr>
<tr>
<td>Any diagnostic follow-up</td>
<td>4953 (100.0)</td>
<td>17,702 (100.0)</td>
</tr>
<tr>
<td>Clinical procedure</td>
<td>4211 (85.0)</td>
<td>12,757 (72.1)</td>
</tr>
<tr>
<td>Imaging examination</td>
<td>2795 (56.4)</td>
<td>10,430 (58.9)</td>
</tr>
<tr>
<td>Chest radiography</td>
<td>3884 (78.4)</td>
<td>10,246 (57.9)</td>
</tr>
<tr>
<td>Chest CT</td>
<td>1613 (32.6)</td>
<td>2,547 (14.4)</td>
</tr>
<tr>
<td>FDG PET or FDG PET–CT</td>
<td>3003 (60.6)</td>
<td>8,807 (49.8)</td>
</tr>
<tr>
<td>Percutaneous cytologic examination or biopsy</td>
<td>397 (8.0)</td>
<td>1,471 (8.3)</td>
</tr>
<tr>
<td>Transthoracic</td>
<td>172 (3.5)</td>
<td>322 (1.8)</td>
</tr>
<tr>
<td>Extrathoracic</td>
<td>141 (2.8)</td>
<td>254 (1.4)</td>
</tr>
<tr>
<td>Bronchoscopy</td>
<td>39 (0.8)</td>
<td>80 (0.5)</td>
</tr>
<tr>
<td>With neither biopsy nor cytologic testing</td>
<td>225 (4.5)</td>
<td>671 (3.8)</td>
</tr>
<tr>
<td>With biopsy or cytologic testing</td>
<td>96 (1.9)</td>
<td>320 (1.8)</td>
</tr>
<tr>
<td>Surgical procedure</td>
<td>150 (3.0)</td>
<td>391 (2.2)</td>
</tr>
<tr>
<td>Mediastinoscopy or mediastinotomy</td>
<td>239 (4.8)</td>
<td>713 (4.0)</td>
</tr>
<tr>
<td>Thoracoscopy</td>
<td>55 (1.1)</td>
<td>117 (0.7)</td>
</tr>
<tr>
<td>Thoracotomy</td>
<td>53 (1.1)</td>
<td>234 (1.3)</td>
</tr>
<tr>
<td>Other procedures</td>
<td>184 (3.7)</td>
<td>509 (2.9)</td>
</tr>
<tr>
<td></td>
<td>122 (2.5)</td>
<td>327 (1.8)</td>
</tr>
</tbody>
</table>

**many medical procedures performed on all positive cases**
number of deaths with chest x-ray not significantly different than no-screening (community care)

3 deaths avoided with CT (15 to 20 percent lower risk of dying from lung cancer)
3 deaths avoided with CT (15 to 20 percent lower risk of dying from lung cancer)

Exercise

According to LNT, what would be the number of additional deaths induced by the low dose CT on a population of 1000 people?
Exercise: According to LNT, what would be the number of additional deaths induced by the low dose CT on a population of 1000 people? 

\[(3 \times 1.5 \text{ mSv})\]

1. I'm finished
**beneficence/non-maleficence**
more good than harm

**radiation protection** perspective
3 x 1.5 mSv (*collective dose 4.5 Sv*)
risk according to LNT ($\approx 2\%$/Sv): **0.1 additional** (potential) **death**

**medical** perspective
NLST performed
  on **favorable cohort**
  with **top quality** medical **staff**
  *(especially for surgical resection)*
> **95% false positive** *(follow-up procedure costly and invasive)*
Not all lung cancers found with screening will be early stage
**Performance may increase** with more than three rounds
**Screening** programs may **discourage smoker to quit**
political perspective
program costly
(CT-screening; additional tests;
loss of productivity of the patients; ...)

Switzerland may learn from nearby countries
(prevention is cheaper)
Example 2

Should we set up a lung cancer screening program for smokers?  
(after 55 years old, 1 low-dose CT yearly, could save 3 people out of 1000)

1. Yes
2. No
3. Don't know
Risk and radiation

4.
Perception is reality!
Risk is highly subject to bias of perspective

(perspective of D. Kahneman & T. Tversky)
(inspired by YouTube channel ScienceEtonnante, Risque, décision et incertitude)
What do you prefer?
*(imagine that you won a contest)*

1. Win 3000 $ *(certain)*
2. Win 4000 $ *(probability 80%)*
What do you prefer
*(imagine that you have to pay a fine)*

1. Pay 3000 $ *(certain)*
2. Pay 4000 $ *(probability 80%)*
Faced with a gain we tend to prefer certainty

Faced with a loss we tend to prefer risk
Faced with a **gain** we tend to **prefer certainty**

---

**Utility**

**Pleasure**

**Satisfaction**

---

![](chart.png)
Faced with a gain, we tend to prefer certainty.
Faced with a **loss** we tend **to prefer risk**.
Faced with a **loss**, we tend **to prefer risk**.

We tend to **prefer certainty**.

We tend to **prefer risk**.
Pandemic in a country. 600 people concerned

1. Treatment A
   - 200 saved

2. Treatment B
   - All saved probability 1/3
   - Nobody saved probability 2/3
Pandemic in a country. 600 people concerned

1. Treatment C
   - 400 die

2. Treatment D
   - Nobody dies 1/3
   - All die 2/3
Pandemic in a country. 600 people concerned

A
200 saved

B
all saved probability 1/3
nobody saved probability 2/3

C
400 die

D
Nobody dies 1/3
All die 2/3

Tversky & Kahneman, The framing of decisions and the psychology of choice, Env Impact Tech Ass, and Risk Ana (1985)
Pandemic in a country. 600 people concerned

Tversky & Kahneman, The framing of decisions and the psychology of choice, Env Impact Tech Ass, and Risk Ana (1985)

Preferred

Certainty

C
400 die

expressed in terms of gain

risk

Preferred

D
Nobody dies 1/3
All die 2/3
Pandemic in a country. 600 people concerned

Tversky & Kahneman, The framing of decisions and the psychology of choice, Env Impact Tech Ass, and Risk Ana (1985)
Perception

- Confidence
- Nature of the effect
- Affectivity

Rationality/cognition
- Probability of the effect
- Magnitude of the effect
- Lack of numeracy
- Convincing justification

Familiarity

Ethics
The probability of dying of "normal gun violence" is higher than of dying of a terror attack (in the USA; years 2014-2013)

1. wrong, 1000 times smaller
2. wrong, 100 times smaller
3. wrong, 10 times smaller
4. wrong, it is the same
5. true, 10 times higher
6. true, 100 times higher
7. true, 1000 times higher
NUMBER OF AMERICANS DEATHS CAUSED BY TERRORISM VS. GUN VIOLENCE

For every American killed by terrorism in the U.S. and around the world, more than 1,000 were killed by firearms inside the U.S. during the most recent decade for which comparative data is available.

Source: Centers for Disease Control and Prevention, U.S. State Department
When **you** make a decision about risk, what is usually the decisive parameter?

1. Facts
2. Emotional and cultural predispositions
3. I don't know
A common belief among scientists is that people who seem to them to hold views inconsistent with the evidence simply need enlightening with the facts.

Kahan and colleagues (Yale University) questioned 1,800 Americans about nanotechnology. Their original views generally only hardened the more they learned.

This suggests that our visceral and emotional response determines how risky we think about risk.

M. Blastland and D. Spiegelhalter, The Norm Chronicles, Stories and Numbers About Danger, Profile Books, 2013
Scientists and other educated people are not immune!

We tend to assimilate new knowledge in a manner that confirms our emotional and culture predispositions. In other words, we filter the facts to suit our beliefs and instincts.

M. Blastland and D. Spiegelhalter, The Norm Chronicles, Stories and Numbers About Danger, Profile Books, 2013
During the Fukushima accident, the discussion was more about (possible) impact than probabilities.
For a given cost, which action do you choose?

1. Transform the Gotthard tunnel in order to avoid a large accident
2. Mark all Swiss roads with fluorescent painting in order to reduce many small accidents
Acceptation of "objective risk"

We give much more weight to large impacts events; even if they are not frequent

31 deaths in the London underground fire on 18.11.1987

- The government invested 300 M£ to reduce the risk of another fire in the underground
- The same amount could have paid smoke detectors in all British homes
  - Each year, 500 people are killed by fires in Britain
  - A large part could be saved by installing smoke detectors
<table>
<thead>
<tr>
<th>Intervention</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flu shots</td>
<td>$500</td>
</tr>
<tr>
<td>Water chlorination</td>
<td>$4,000</td>
</tr>
<tr>
<td>Pneumonia vaccinations</td>
<td>$12,000</td>
</tr>
<tr>
<td>Breast cancer screening</td>
<td>$17,000</td>
</tr>
<tr>
<td>All medical interventions</td>
<td>$19,000</td>
</tr>
<tr>
<td>Construction safety rules</td>
<td>$38,000</td>
</tr>
<tr>
<td>All transportation interventions</td>
<td>$56,000</td>
</tr>
<tr>
<td>Highway improvement</td>
<td>$60,000</td>
</tr>
<tr>
<td>Home radon control</td>
<td>$141,000</td>
</tr>
<tr>
<td>Asbestos controls</td>
<td>$1.9 million</td>
</tr>
<tr>
<td>All toxin controls</td>
<td>$2.8 million</td>
</tr>
<tr>
<td>Arsenic emission controls</td>
<td>$6.0 million</td>
</tr>
<tr>
<td>Radiation controls</td>
<td>$10.0 million</td>
</tr>
</tbody>
</table>

Perception

Confidence

Nature of the effect
- reversible or not
- controllable or not
- immediate or delayed

Affectivity

Rationality/cognition

Familiarity

Ethics
Risk and radiation

5.
Communication of risk in medicine
Communicating the **numerical** rational **risk**

<table>
<thead>
<tr>
<th><strong>Ratio</strong> (e.g. $10^{-5}$)</th>
<th>nobody has any cue <em>(what is riskier $10^{-4}$ or $10^{-5}$?)</em></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MicroMort</strong></td>
<td>$10^{-6}$ linked to one &quot;normal day&quot; scale intuitive and easy to grasp</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Natural background</strong></th>
<th>most people don't even know about natural radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MicroLife</strong></td>
<td>put radiation risk into &quot;normal life&quot; scale intuitive and easy to grasp</td>
</tr>
</tbody>
</table>
MicroMort

- negligible
- low
- very low
- extremely low
- moderate

diagnostic radiology

- CT exams
- interventional radiology

- chest radiograph
- knee radiograph
MicroMort

- Negligible
- Extremely low
- Very low
- Low
- Moderate

- Plane crash (7'200 km)
- Car crash (3'500 km)
- Natural irradiation
Alternative way to explain the medical risk to a patient

$$D = D_y + 10D_n$$

- $D < 5$ mGy
- $5$ mGy $< D < 0.1$ Gy
- $0.1$ Gy $< D < 0.5$ Gy
- $0.5$ Gy $< D < 1.0$ Gy
- $D > 1$ Gy
- Unknown dose

Figure: Linda Walsh, KSR 23.03.2017
Alternative way to explain the medical risk to a patient???

Definitely a bad idea!

Figure 1. The chart shows the approximate radiation exposure (in Sieverts) in relation to a person’s distance from the bombsite and provides a comparison with other radiation exposures.
How is it done in practice?
**Emergency CT exam**  
(weak to moderate abdominopelvic pain)

<table>
<thead>
<tr>
<th>info risk/benefit</th>
<th>Patients</th>
<th>Emergency doctors</th>
<th>Radiologists</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7% (5/76)</td>
<td>22% (10/45)</td>
<td>47% (18/38)</td>
</tr>
<tr>
<td>increased risk of cancer</td>
<td>3% (3/76)</td>
<td>9% (4/45)</td>
<td></td>
</tr>
</tbody>
</table>

nobody was able to estimate the CT dose compared to a chest radiography

And you?
What is the **effective dose** ratio between an abdominal CT (1 pass) and a chest radiograph?

1. 20
2. 200
3. 2'000
4. 20'000
5. 200'000
Abdominal CT

\[ E \approx 6 \text{ mSv} \]

\[ E \approx 30 \mu \text{Sv} \]

Chest radiography

\[ \text{ratio} = \frac{6000}{30} = 200 \]
Which test do you prefer?
*(several possible answers)*

1. If you have this test every 2 years, it will **reduce your chance of dying** from this cancer **by around one third** over the next 10 years

2. If you have this test every 2 years, it will reduce your chance of dying from this cancer from around **3 in 1000** to around **2 to 1000** over the next 10 years

3. If around 1000 people have this test every 2 years, **1 person will be saved** from dying from this cancer every 10 years
Learning objectives

• Briefly explain the **effects of radiation** on **human health**

• Be able to **compare** in the day to day life **acute** and **chronic risks**

• Understand some **psychological aspects** of **risk perception** and how **ethics** could help find solutions

• Understand the complexity of **communicating about** radiation **risk**