Sensitivity Analysis of detriment calculation

Introducing Publication 152

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ICRP

Detriment Calculation in Pub 103

$D = R\ (k + q\ (1-k))\ l$

Where: R is the lifetime risk

k is the lethality fraction

q is the adjusted lethality

$q = q_{min} + k(1 - q_{min})$

l is the relative life lost

Risk of exposure induced cancer incidence (REIC)

Risk of expose-induced cancer incidence: lifetime risk of cancer ‘*c*’ that has been caused by exposure ‘*D*’ at age ‘*e*’.

$$REID_C(e,D) = \int_{a=e+L}^{\infty} \left[\mu_C(a\,|\,e,D) - \mu_C(a)\right] S(a\,|\,e,D)\,da$$

$$= \sum_{a=e+L}^{\infty} \left[\mu_C(a\,|\,e,D) - \mu_C(a)\right] S(a\,|\,e,D)$$

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Variables involved in the lifetime risk calculation

- $\mu_c(a)$: cancer incidence rate
  at age ‘*a*’

- $\mu_c(a|e,D)$: cancer incidence rate which is conditional on exposure to dose ‘*D*’ at age ‘*e*’

.

- S(a|e, D) : the survival function – gives the probability of surviving to age ‘*a*’, *given a dose ‘D’ at age ‘e’.*

Detriment calculation for whole population in ICRP Publication 103

For each combination of geographical region (Asian and Euro-American), Sex (male and female)

- Lifetime risk was calculated at a single exposure of 0.1 Gy, then multiplied by 10.
- 5 years of latency were assumed as latency period for all cancers.
- For each age-at-exposure 0-89, lifetime risk was cumulated up to attained age of 94, then averaged over age-at-exposure.
- The averaged lifetime risk was averaged across models, with ERR:EAR of 0:100% for breast, 100:0% for thyroid, 30:70% for lung, and 50:50% for all other cancer sites.
- Lifetime risk was adjusted downward by a DDREF of 2, except for leukaemia.
- Adjustment for lethality, quality of life, relative life lost.

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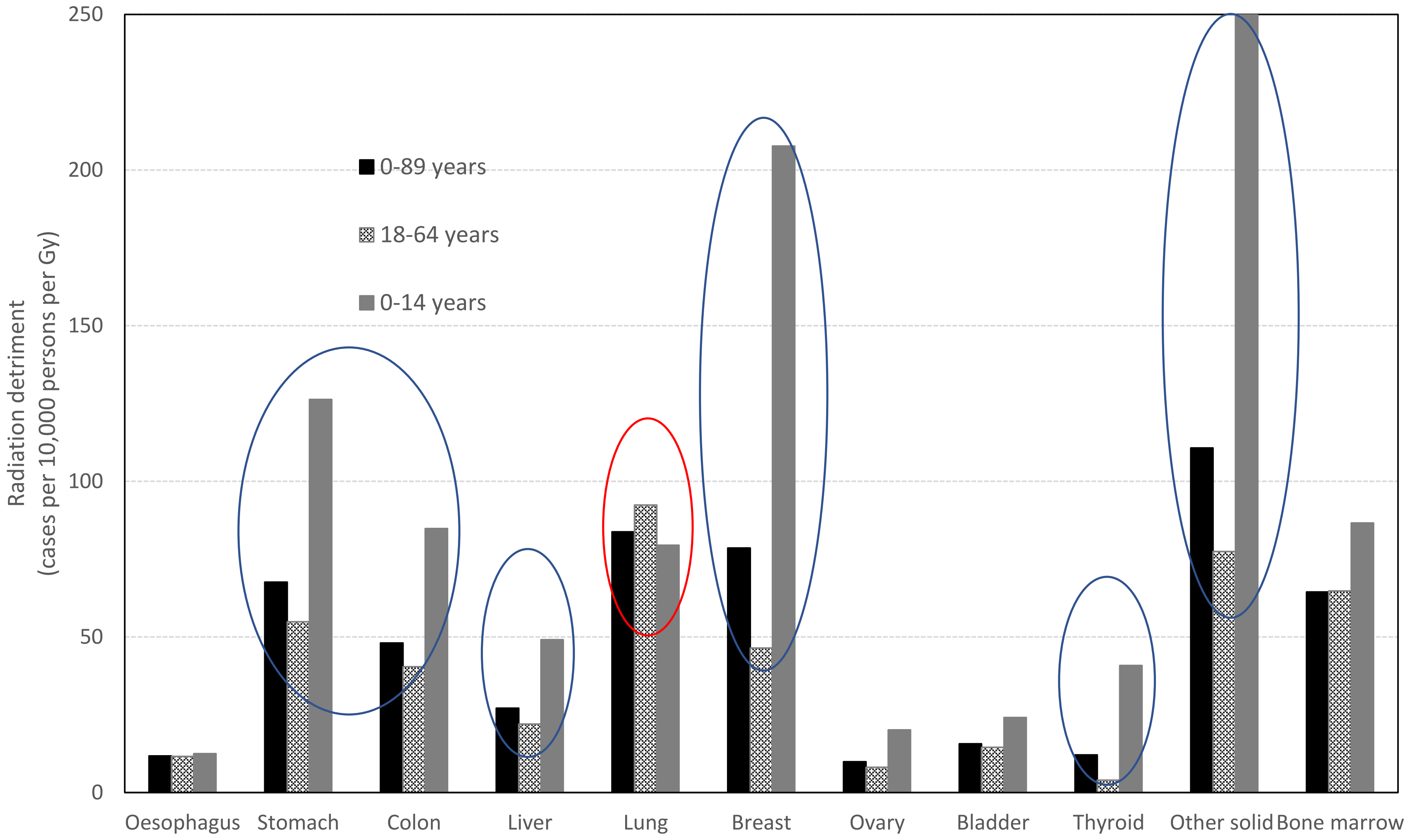
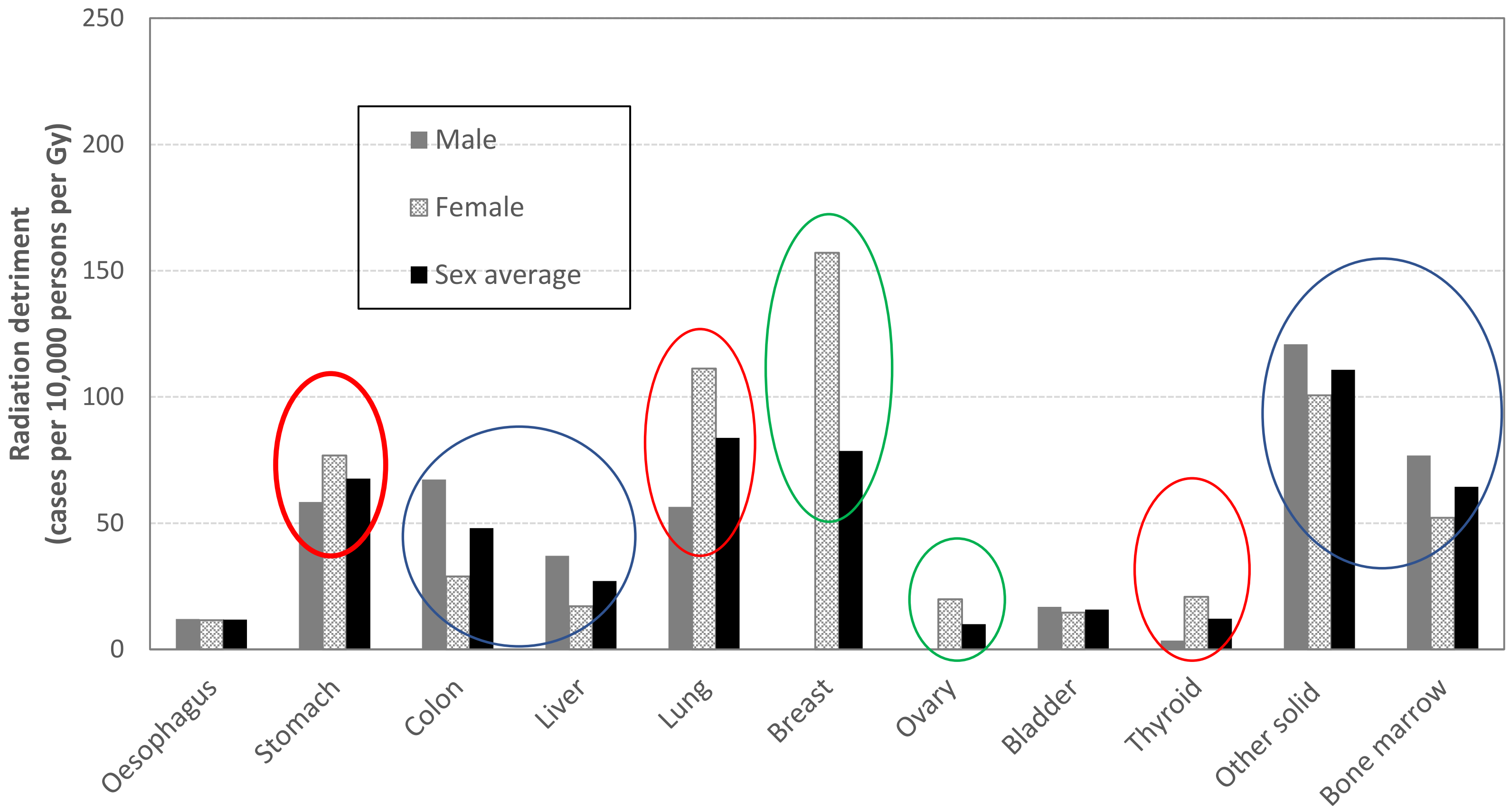
How much does detriment vary if the Calculation parameters change?

1. Average over different age-at-exposure group (0-14, 18-64, 0-89yrs)
2. Male and female separately.
3. Euro-America, Asia population separately
4. 100%ERR and 100%EAR model separately
5. Different attained age (94 or 99 years)
6. Different latency period (5 or 10 years for solid cancer, 2 or 5 years for leukaemia.
7. Different DDREF
8. REIC versus LAR
9. Different exposure level (0.1 Gy versus 1 Gy)
10. Different lethality
11. Different minimum quality of life value
12. Different relative cancer-free life lost

Effect of age-at-exposure group

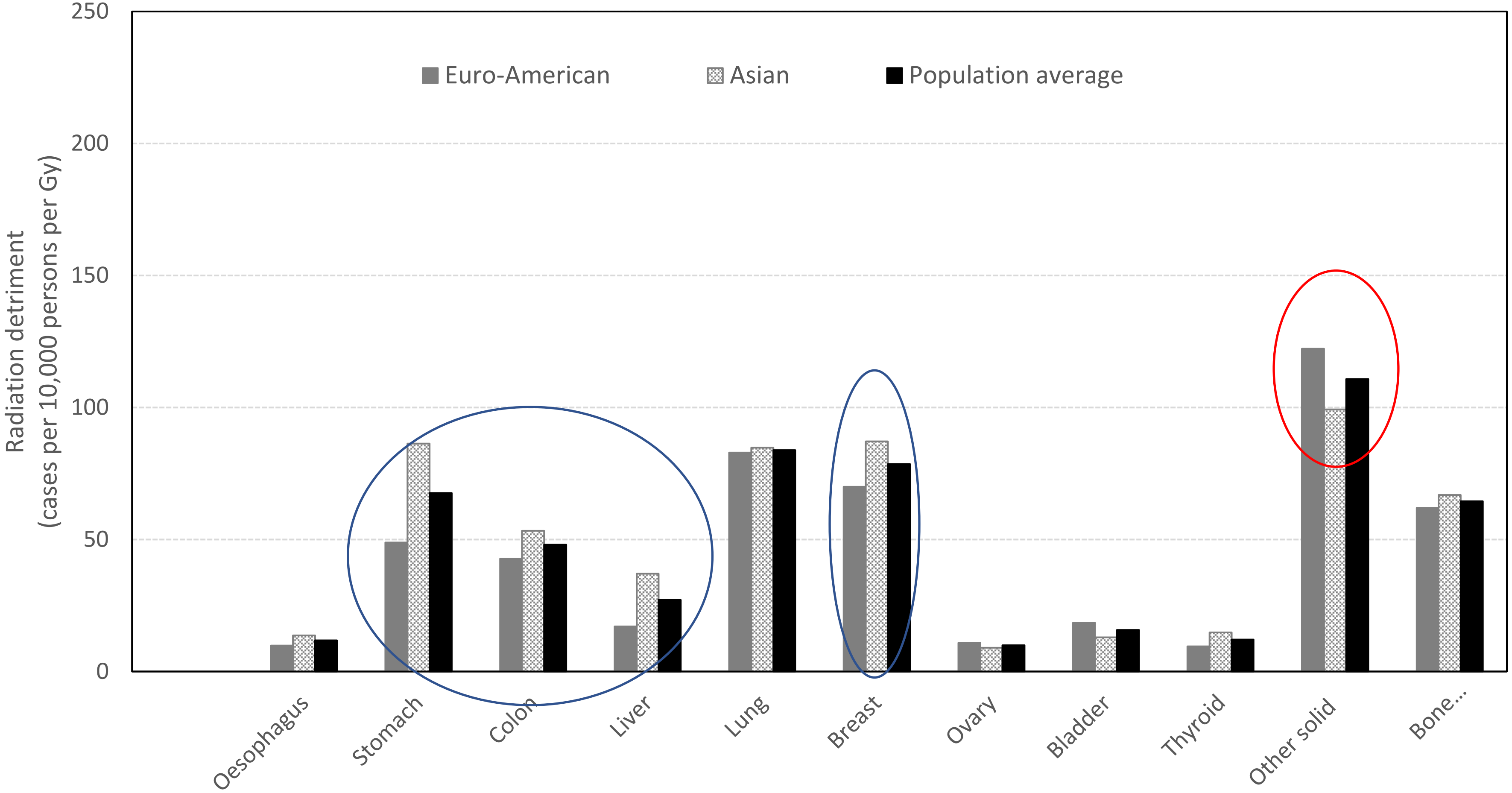


Sex effect

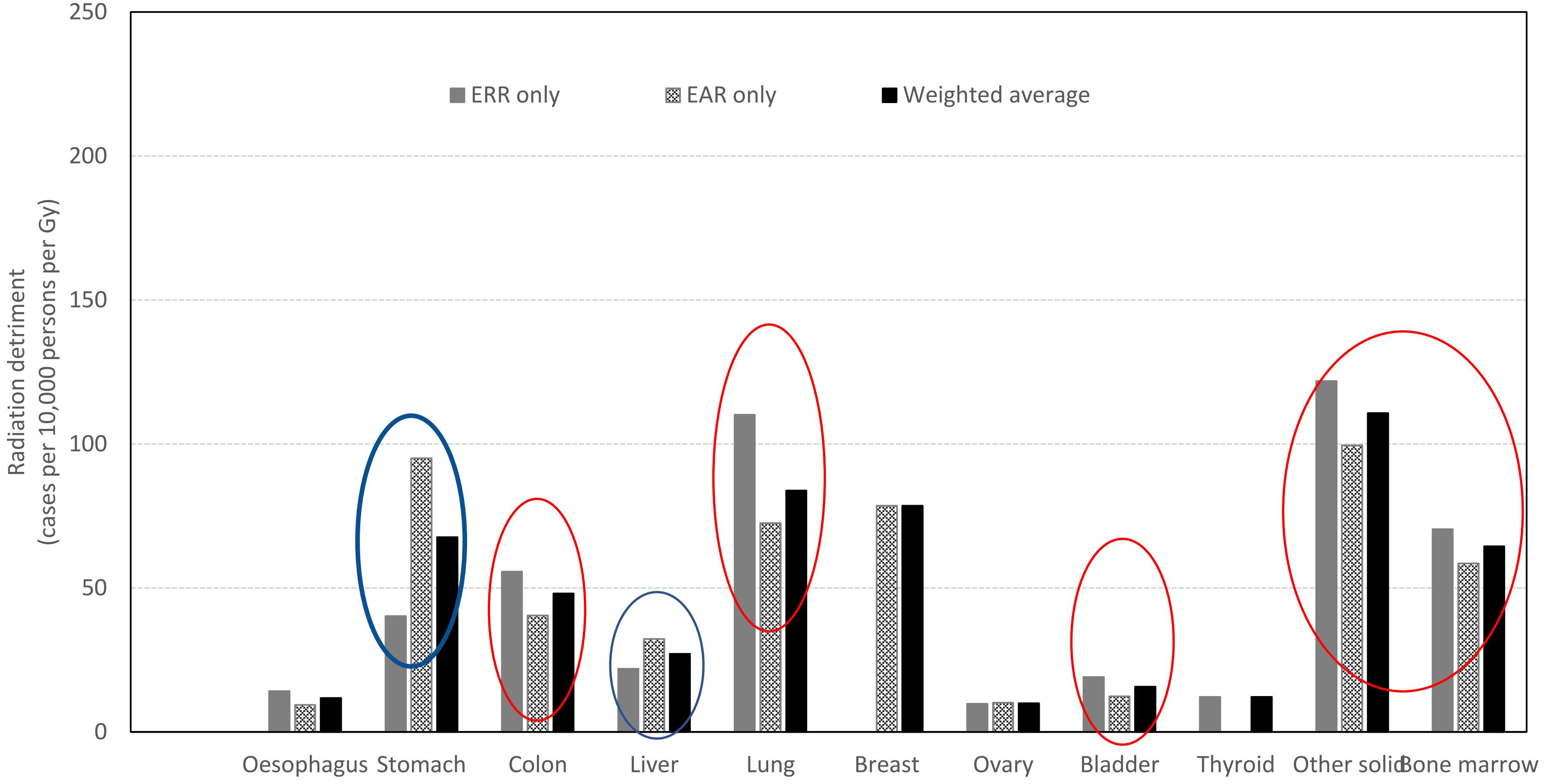


Radiation detriment (cases per 10,000 persons per Gy)
250
200
150
100
50
0
Male
Female
Sex average
Oesophagus
Stomach
Colon
Liver
Lung
Breast
Ovary
Bladder
Thyroid
Other solid
Bone marrow

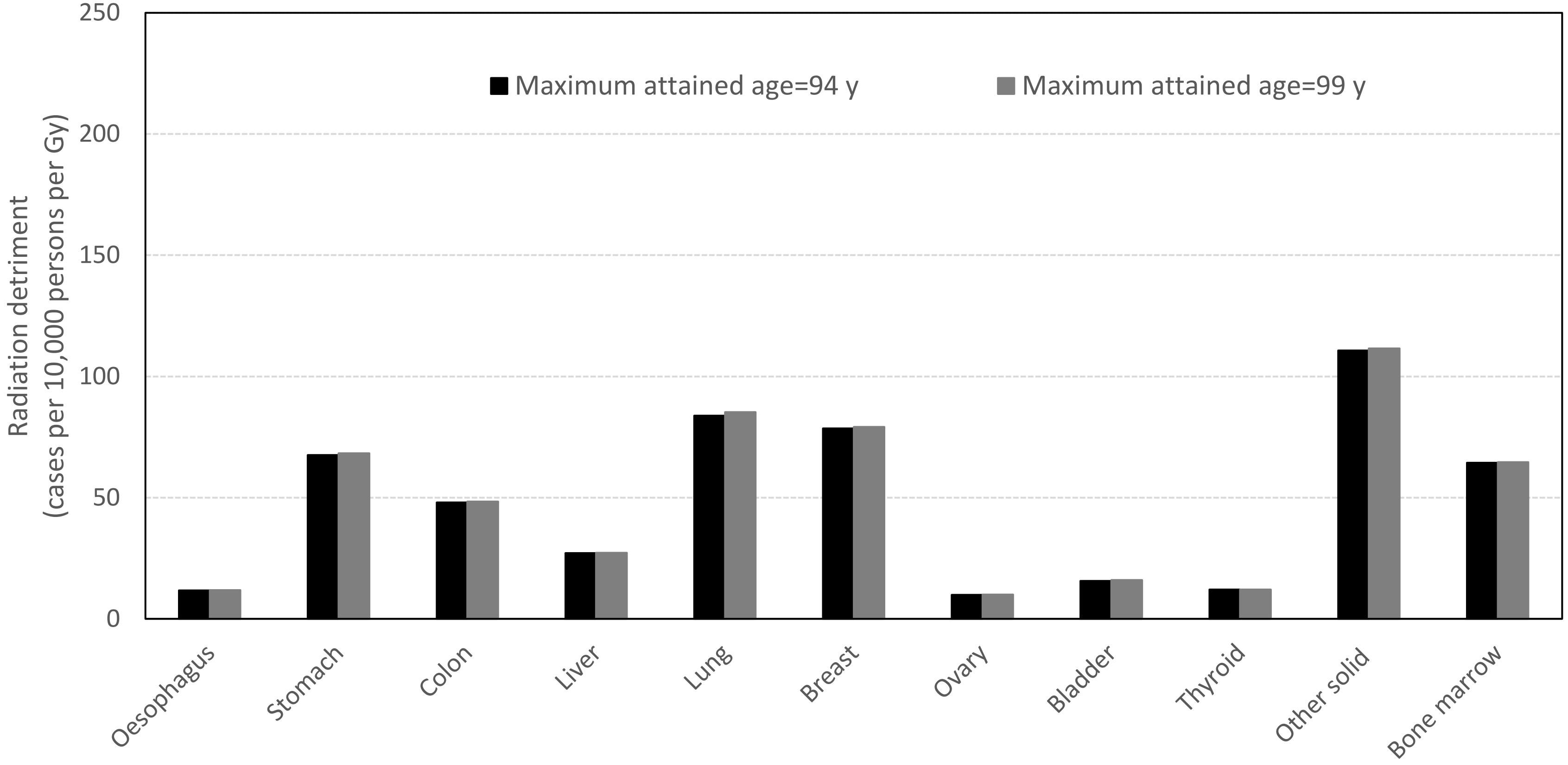
Population effect



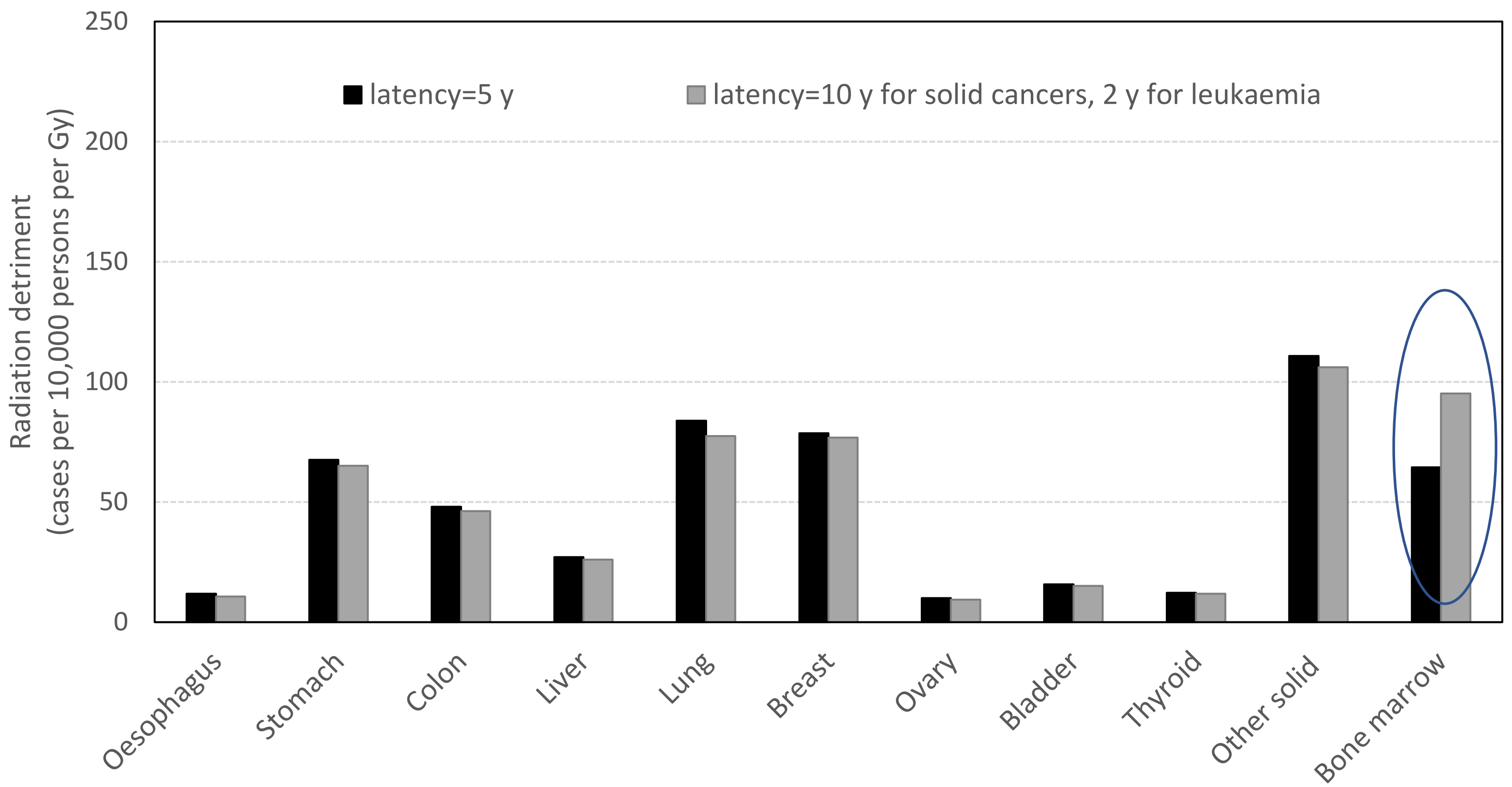
Modelling effect



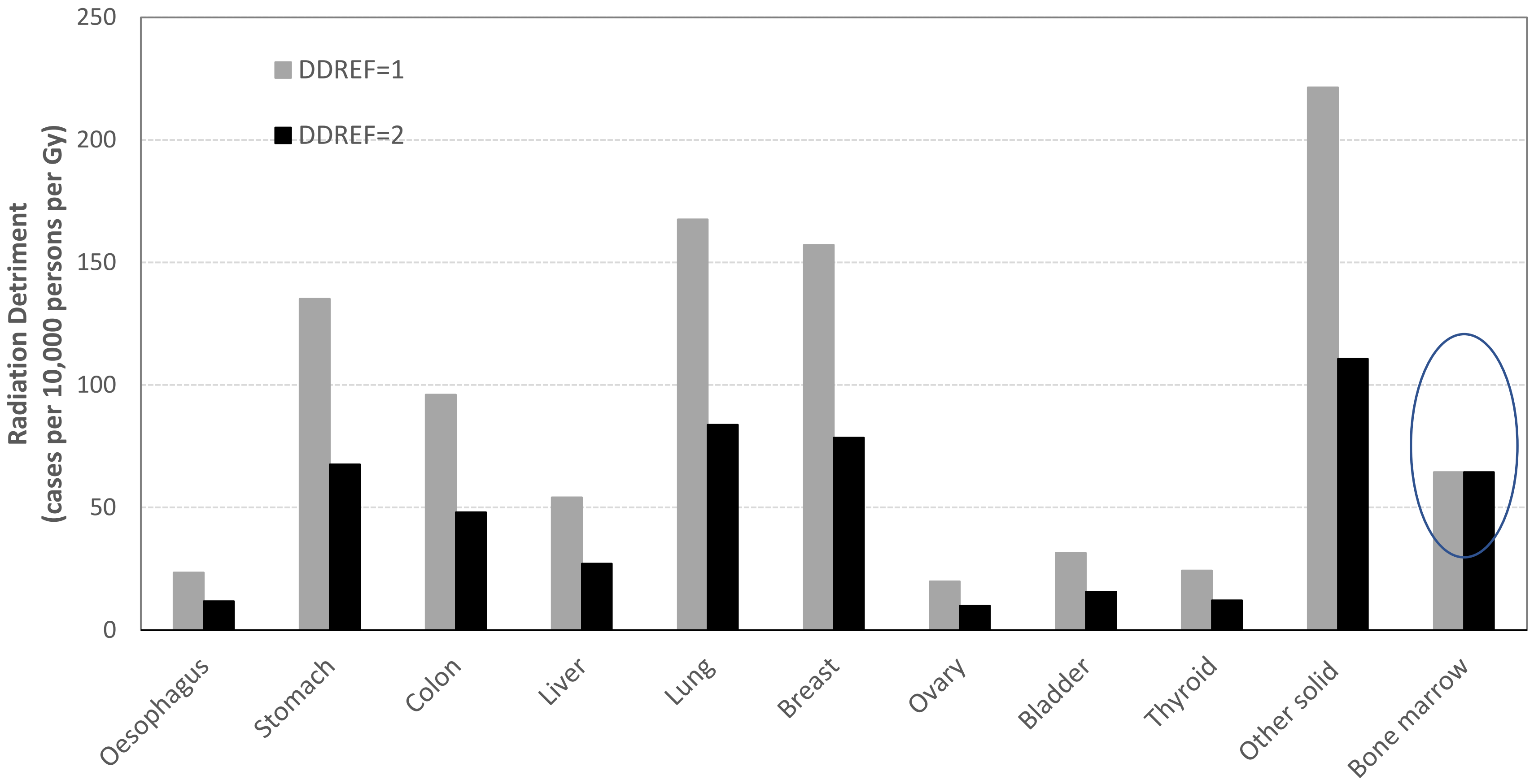
Effect of attained age



Latency effect



Effect of DDREF



Sensitivity analysis

- Detriment increased by a factor of 2, with a DDREF of 1.
- For breast and ovary cancers, detriment increased by 2 if calculated for female only.
- For lung cancer, detriment for females appears to be higher than that for male, but the inverse is observed for liver, colon, and other solid cancers.
- For most cancer types, the detriment for the young age-at-exposure population (0-14) is higher than that of a whole population (0-89). For breast cancer, thyroid cancer and other solid cancer, the detriment for age-at-exposure 0-14 years is about 2-3 times higher compared with that of 0-89 years.

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REIC and LAR

$$REIC_c(e, D) = \int_{a=e+L}^{\infty} [\mu_c(a|e, D) - \mu_c(a)]\ S(a|e, D)da$$

$$LAR_c(e, D) = \int_{a=e+L}^{\infty} [\mu_c(a|e, D) - \mu_c(a)]\ S(a)da$$

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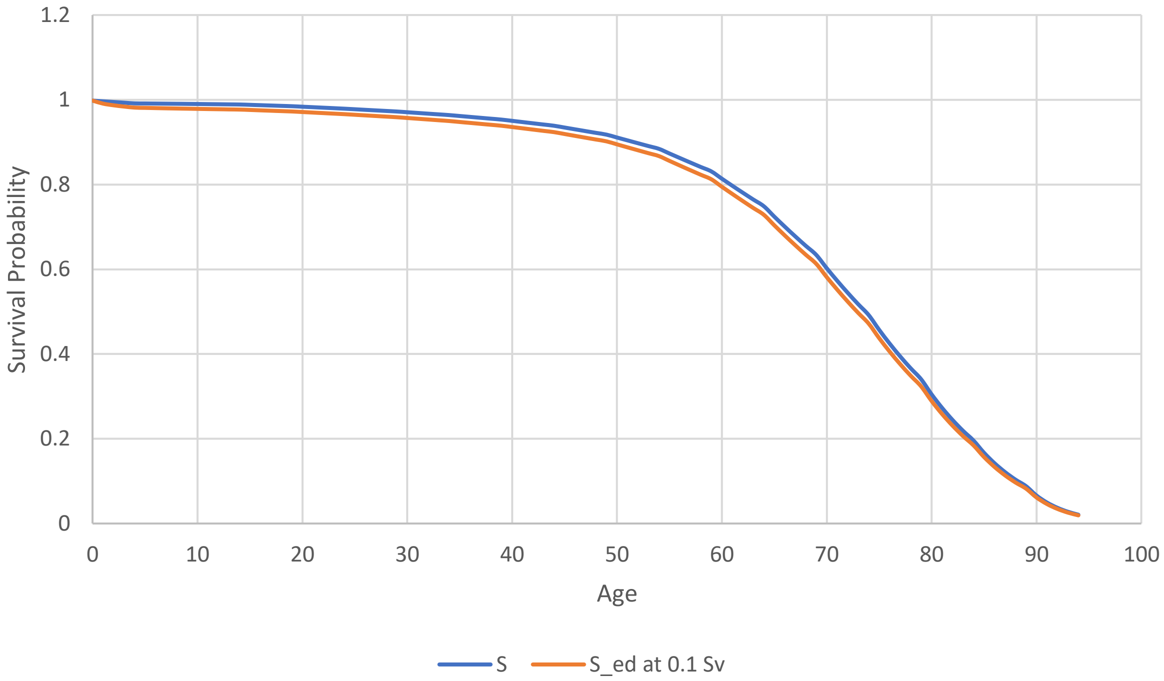
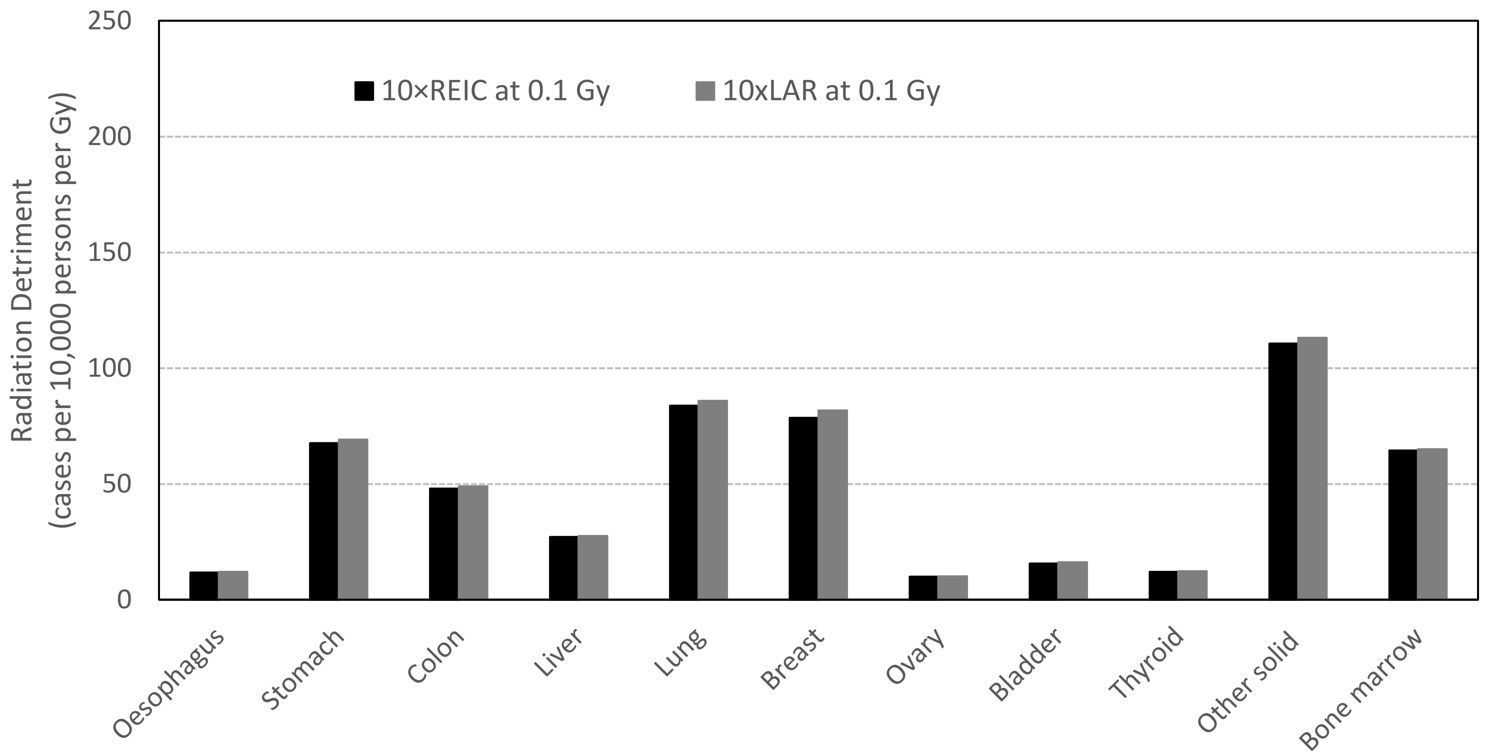
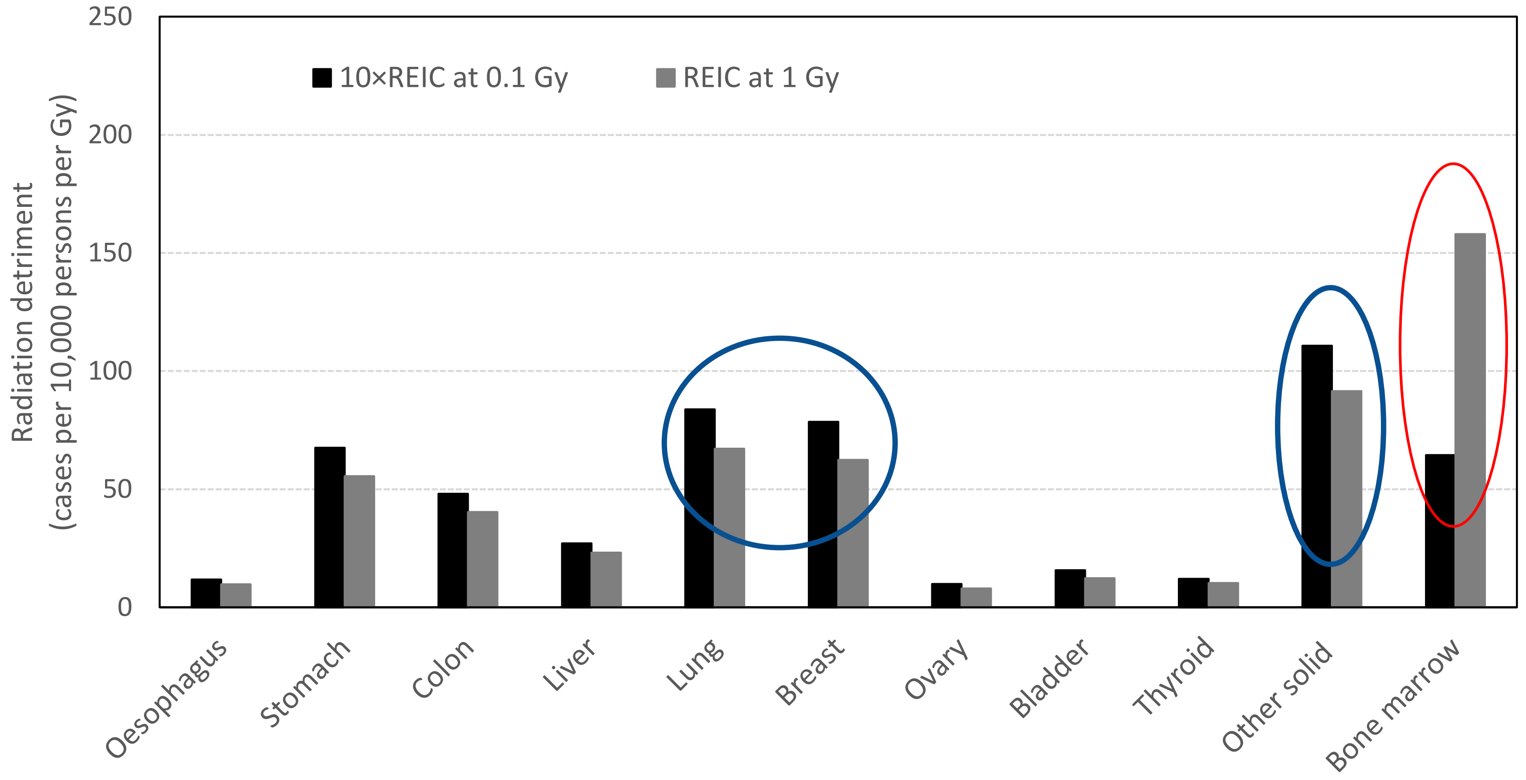
S(a) versus S(a|e,D) at 0.1 Gy



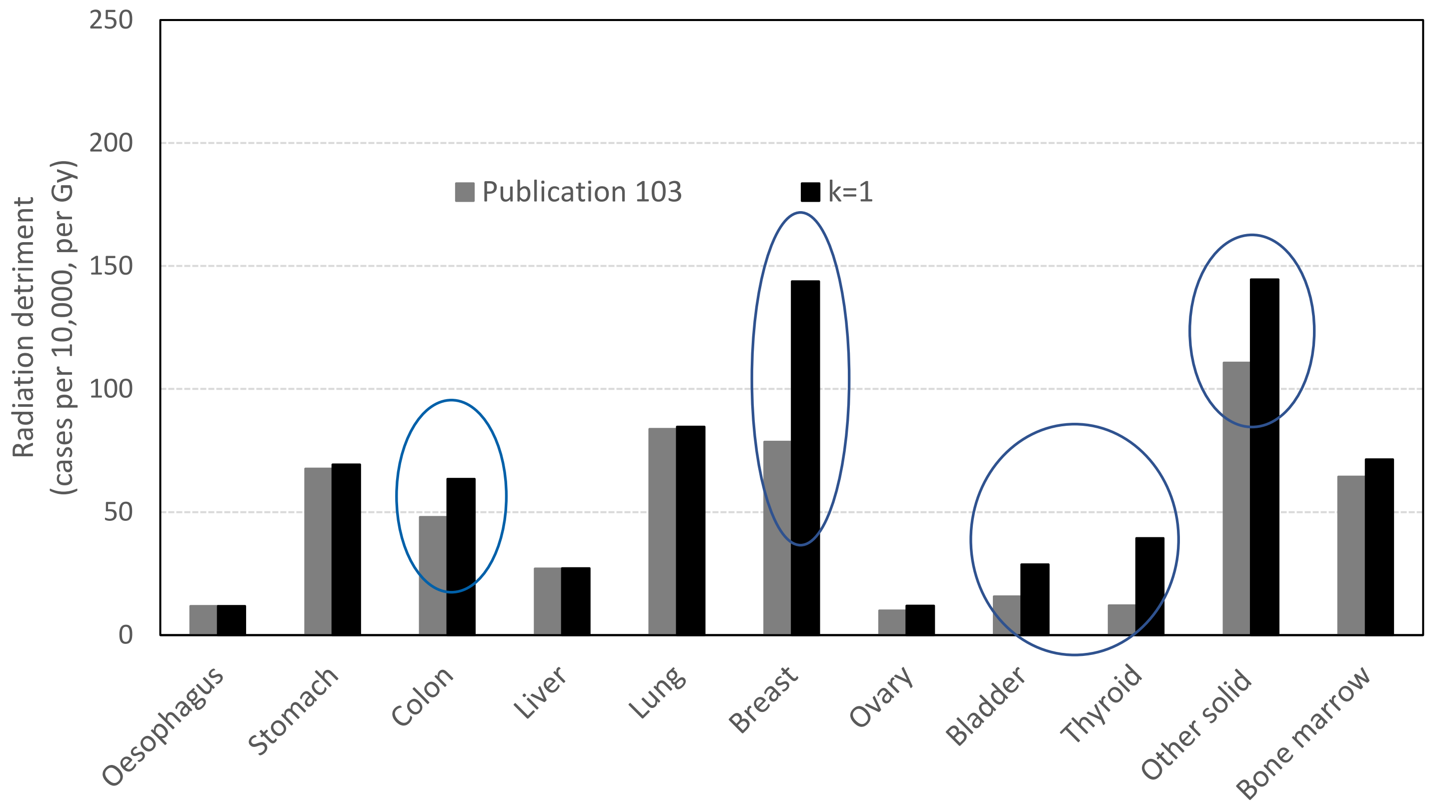
Difference between REIC and LAR



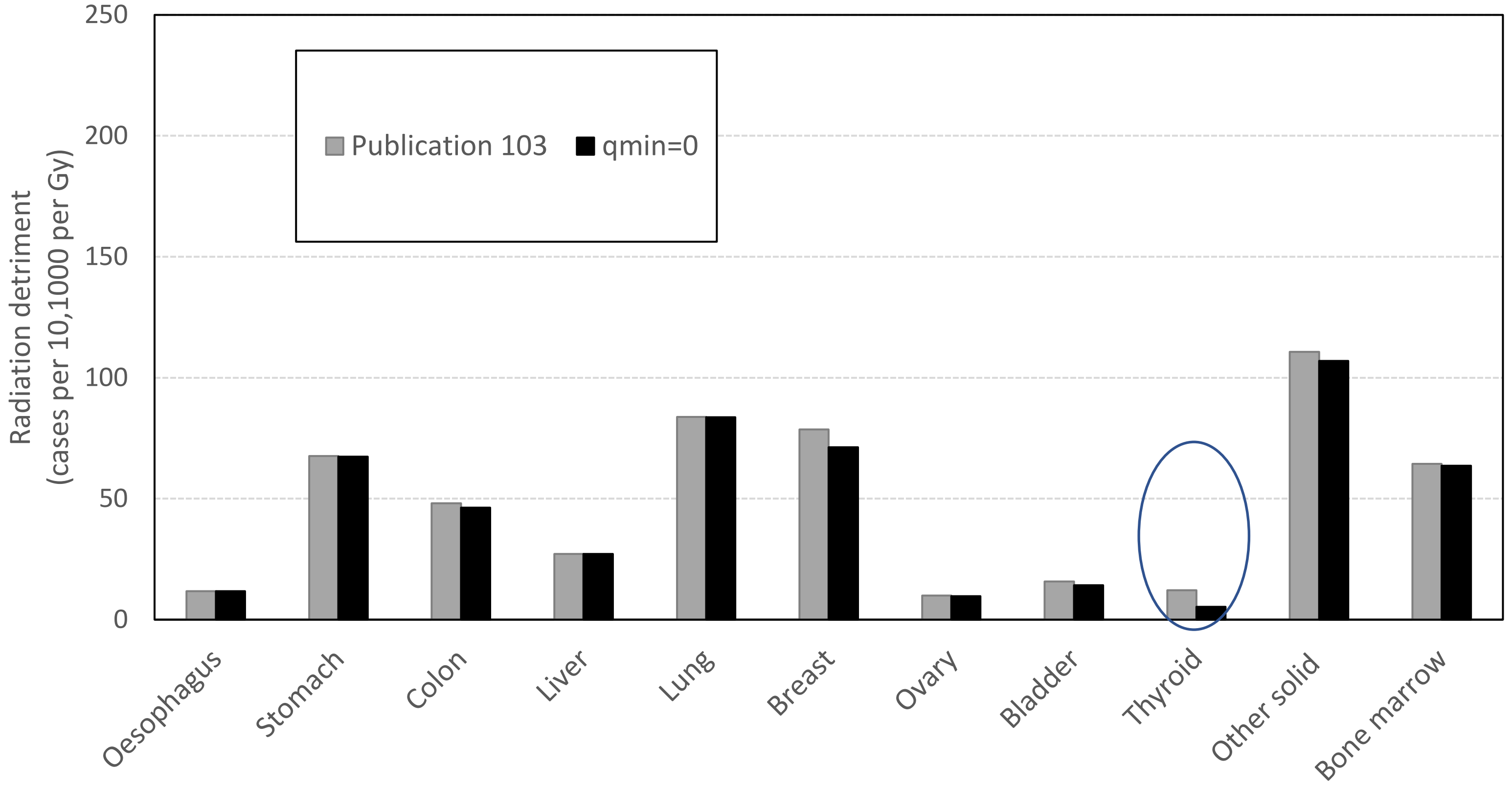
Calculations at different exposure levels



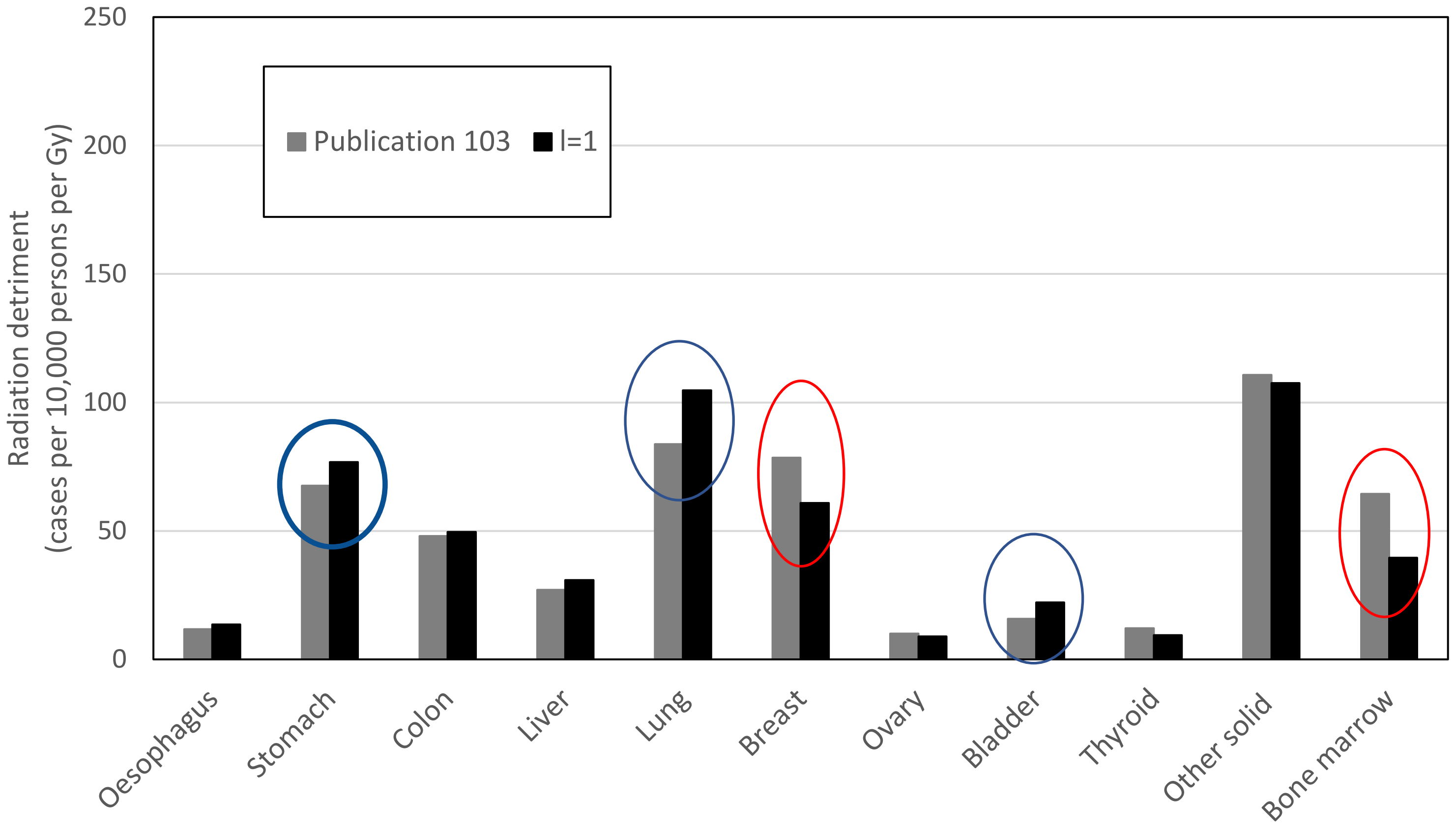
Lethality effect



Effect of minimum quality of life



Effect of relative cancer-free life lost



Sensitivity analysis

- There is very little difference between REIC and LAR if calculations are done at 0.1 Gy, and linearly extrapolate to risk at 1 Gy.
- In comparison to above mentioned method, REIC calculated at 1 Gy decreases for solid cancers, but increases for leukaemia by a factor of > 2, due to the effect of linear-quadratic dose response.
- For breast cancer and other solid cancers, detriment increases as lethality k increases.
- For lung and stomach cancers, the detriment increases as relative life lost increases.

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Severity of impact

- Minimal impact (*):

  a factor of change of < 1.5

- Moderate impact (**):

  a factor change of ≥ 1.5, and < 2

- Substantial impact (***):

  a factor change of ≥ 2

Impact of parameters

	Impact severity
Reference population	
sex	***
population	**
age-at-exposure	***
Parameter for risk calculation	
lifetime risk metric:	*
Dose (0.1 Gy Vs. 1 Gy):	***
latency:	*
Maximum attained age:	*
Model transfer:	**
DDREF:	***
Severity adjustment	
Lethality fraction:	***
Min. QOL factor:	*
Relative cancer-free life lost:	**

Summary of sensitivity analysis

- Slight variation of detriment to latency, attained age, lifetime risk calculation method (calculated at low dose) or min. quality of life
- Noticeable variation of detriment with population, transfer model (100%ERR or 100%EAR Model) and relative life lost.
- Sex has a major impact for certain cancer types. Need to think about whether lifetime risk for breast cancer and ovary cancer should be averaged over sex.
- The age-at-exposure has a major impact on detriment, with much smaller detriment for 0-89 years group than 0-14 years group for some cancer types.
- DDREF and lethality also have major impact on cancer detriment.

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