Effects of radiation exposure on offspring and next generations

Effects consequent to intrauterine exposure to ionising radiation

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Intrauterine Exposure

- Considers exposure
  - From the point of conception
  - To the time of birth
  - So, for humans, about 40 weeks

- Encompasses effects
  - On the conceptus, embryo and through to
  - The late fetus
Effects of Exposure *in utero*

- For antenatal exposure
  - The risks of *cancer* and *hereditary effects* must be considered, as for postnatal exposure
  - But the magnitude of these risks may well vary with gestational age

- But also
  - *Teratogenic* (developmental) effects must be considered, such as congenital malformations
  - The risk of teratogenic effects will vary with gestational age
Teratogenic Effects

- Effects of exposure *in utero* include
  - Lethality (spontaneous abortion, miscarriage, stillbirth), congenital malformations and growth retardation
  - Level of effect varies with gestational age
- Mental retardation (Japanese atomic bomb survivors - epidemiology)

Variation of severe mental retardation and IQ score with respect to uterine dose received during the bombings and weeks since conception at the time of exposure

ICRP Publication 90, 2003
NCRP Report No. 174, 2013
Cancer and Hereditary Disease

• Stochastic health effects
  • Radiation exposure in utero is assumed to increase the risks of cancer and hereditary disease
  • Degree of risk is likely to vary with gestational age

• Cancer risk
  • Human epidemiological findings available
    • Case-control studies of childhood cancer and antenatal X-rays
    • Cohort study of Japanese atomic bomb survivors exposed in utero
  • Oxford Survey of Childhood Cancers (OSCC) gives, for all childhood cancers combined (Doll & Wakeford, Br J Radiol 1997; 70: 130-9)
    • ERR = 0.5 (95% CI: 0.3, 0.8) at 10 mGy (X-rays)
    • Little variation of ERR between the typical childhood cancer types
Comparison of relative risks (RR = ERR + 1) of antenatal exposure to X-rays: Oxford Survey of Childhood Cancers and all other case-control studies appropriately combined in a meta-analysis

Bomb Survivors Exposed *in utero*

- Cohort study of survivors irradiated *in utero* (average dose, 0.25 Gy)
  - Solid cancer mortality to end-2012 (66-67 years of age)
    - **Females:** \( \text{ERR/Gy} = 2.10 \ (95\% \ CI: 0.26, 5.61) \) (21 deaths)
    - **Males:** \( \text{ERR/Gy} = -0.08 \ (95\% \ CI: <-0.82, 1.36) \) (24 deaths)
  - Sugiyama *et al.*, *Eur J Epidemiol* 2021; 36: 415-28

  - 2 cases of childhood cancer against 0.42 expected
  - 0 case of childhood leukaemia (but only 0.18 case expected)
  - Absence of childhood leukaemia surprising given the excess among those irradiated as young children
Chromosome Translocation Frequencies

Atomic bomb survivors
exposed in utero (●),
and some of their mothers (□)

Ohtaki et al.,
Hamasaki & Nakamura,
Cologne et al.,
*Radiat Environ Biophys* 2022; 61: 59-72