A New Look At Radiation Carcinogenesis

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Protracted Exposures To Ionizing Radiation
Evans et al. (1972)

PERCENT TUMOR CUMULATIVE INCIDENCE

CUMULATIVE SKELETAL DOSE (cGy)
DISTRIBUTION OF DEATHS FOR DAVIS BEAGLES EXPOSED TO $^{226}\text{Ra}$

**CONTROLS**

**MEDIAN LIFE SPAN FOR 435-DAY OLD BEAGLES**

$t_L = 4984$ DAYS

**MEDIAN BONE CANCER RISK**

$\bar{d} = 582.6 \; \bar{d}^{-1/3}$

($\sigma_g = 1.22$)

**MEDIAN RADIATION INJURY RISK**

$\bar{d} = 7.5 \; \bar{d}^{-3}$

($\sigma_g = 1.80$)

- **BONE CANCER DEATHS**
- **RADIATION INJURY DEATHS**
- **OTHER DEATHS**
BONE CANCERS FROM $^{226}$Ra IN DAVIS BEAGLES

TIME TO DEATH, $t$ (d)

MEDIAN LIFE SPAN
$t_L = 4938$ DAYS POST EXPOSURE

MEDIAN BONE CANCER RISK
$t = 582.6 \bar{d}^{-1/3}$
$(\sigma_g = 1.22)$

RISK = 0.95

RISK = 0.05

AVERAGE DOSE RATE TO SKELETON, $\bar{d}$ (Gy d$^{-1}$)

O. RAABE
DISTRIBUTION OF DEATHS FOR PNL BEAGLES
AFTER INHALATION DEPOSITION IN LUNG OF $^{239}$PuO$_2$

**CONTROLS**

**MEDIAN LIFE SPAN FOR 540-DAY OLD BEAGLES**

$t_L = 4796$ DAYS

**MEDIAN LUNG CANCER RISK**

$t_m = 496.8 \bar{d}^{-1/3}$

($\sigma_g = 1.21$)

**STUDY 1**

- LUNG CANCER
- LUNG INJURY

**STUDY 2**

**MEDIAN LUNG INJURY RISK**

$t_m = 47.7 \bar{d}^{-1}$

($\sigma_g = 1.48$)

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BONE CANCERS FROM $^{226}$Ra AND $^{90}$Sr IN BEAGLES AT DAVIS

MEDIAN LIFE SPAN FOR $^{90}$Sr BEAGLES
$t_L = 5419$ DAYS POST EXPOSURE

MEDIAN LIFE SPAN FOR $^{226}$Ra BEAGLES
$t_L = 4984$ DAYS POST EXPOSURE

MEDIAN BONE CANCER RISK
FOR $^{90}$Sr BEAGLES
$t_{Sr} = 324.7 (\bar{d}_{Sr})^{-2/3}$

MEDIAN BONE CANCER RISK
FOR $^{226}$Ra BEAGLES
$t_{Ra} = 582.6 (\bar{d}_{Ra})^{-1/3}$

- BONE CANCER FROM $^{226}$Ra
- BONE CANCER FROM $^{90}$Sr

$t$: TIME TO DEATH AFTER BEGINNING EXPOSURE (d)
$\bar{d}$: LIFE-TIME AVERAGE DOSE RATE TO SKELETON (Gy d$^{-1}$)
DISTRIBUTION OF DEATHS FOR ITRI BEAGLES EXPOSED TO $^{91}$Y–FAP

**CONTROLS**

**MEDIAN LIFE SPAN FOR 400-DAY OLD BEAGLES**

$t_L = 4713$ DAYS

**MEDIAN LUNG CANCER RISK**

$t_m = 408.1 \, \bar{d}^{-2/3}$

($\sigma_g = 1.12$)

**MEDIAN LUNG INJURY RISK**

$t_m = 324.6 \, \bar{d}^{-1}$

($\sigma_g = 1.41$)
MEDIAN BONE AND LUNG CANCER RISKS FOR BEAGLES

TIME TO DEATH FOR BEAGLES, $t$ (d)

MEDIAN SURVIVAL FOR UNEXPOSED

THRESHOLD REGION

MODELS: $t_m = K_m \overline{d}^{-s}$

$\alpha$: $s = 1/3$  $\beta$: $s = 2/3$

AVERAGE DOSE RATE TO SKELETON OR LUNG, $\overline{d}$ (Gy d$^{-1}$)
INCIDENCE OF FATAL CANCER IN BEAGLES FED $^{90}$Sr

CORRECTED OBSERVED / EXPECTED RATES

- BONE SARCOMA
- PERIODONTAL CARCINOMA
- ORAL/NASAL CARCINOMA
- LEUKEMIA

DOSAGE LEVEL AND MEAN DOSE (Gy)

CONTROLS (0) D05 (0.4) D10 (1.2) D20 (6.7) D30 (22.5) D40 (50.4) D50 (80.2) D60 (107.0)
RADIATION INDUCED CANCER

• Cancer Induction depends of lifetime average dose rate to the target organ.

• Cancer induction risk is not proportional to cumulative dose.

• Low dose rates yield a life span virtual threshold (cumulative doses <10 Sv).
Acute Exposures To Ionizing Radiation
Atomic Bomb Survivor Studies

- Radiation Effects Research Foundation, RERF
- 79,972 survivors with calculated rad doses
- 44,636 survivors with doses > 0.005 Sv

RERF Solid Cancer Dose Response

Excess Relative Risk

Weighted Colon Dose (Gy)
EXCESS CANCER INCIDENCE FOR 1 Sv EXPOSURES AT AGES 10, 30 & 50 YEARS

EXCESS RATE PER 10,000 PERSON-YEARS

AGE (years)
• A-Bomb Survivor Risk for 1 Gy Exposure
• Age 5: 13%/80 y;  Age 25: 9.5%/60 y;
• Age 45: 6.5%/40 y.  ALL = 0.16% per year
CANCER INDUCTION IS NOT PROPORTIONAL TO DOSE

• A-Bomb cancer promotion data for a very high dose-rate instantaneous exposure cannot be used to estimate cancer induction risk from protracted exposures to ionizing radiation.

• Liner models to currently used by the International Commission on Radiological Protection and the U.S. Environmental Protection Agency are not valid.
References


THE END