Epidemiologic Studies on Low-Dose Radiation and Late Effects in Medically Exposed Populations

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Radiation from diagnostic imaging

Divergent focus and goals of epidemiology versus clinical practice

Focus/goals	Epidemiology	Clinical practice
Primary	Quantify radiation - disease risks	Address immediate problem
Exams of interest	Ionizing radiation (IR), all exams	Appropriate (justified) exams
Exposure emphasis	Cumulative IR (organ doses)	Optimize exposure (ALARA) from justified exam(s)
Latency	Late effects of IR: cancers, cataracts, circulatory diseases	Early & late effects: early identification & treatment

Radiation from diagnostic imaging

Overlap in populations of concern

Epidemiology **Clinical Practice**

Children, pregnant women,
patients with radio-sensitive genetic disorders,
patients with selected diseases

Epidemiologic methods beyond dose tracking

- Medical radiation source and type (x-rays, radionuclides)
- Surrogate measures to estimate doses
- Anatomic site & measurement: partial vs whole body
- Primary dose measure: cumulative
- Dose-response pattern (linear, quadratic, etc) and statistical models

Epidemiological studies on low-dose radiation in medically exposed populations: Overview

- Patients:
  - Adults: diagnostic exams not consistently associated with cancer
    - Exception: older contrast agent Thorotrast (α-particle, angiographic procedures, 1928-54) $\rightarrow$ increased MDS/AML
  - Children/adolescents: repeated exams $\rightarrow$ growing evidence of increased cancer risks

- Medical radiation workers (badge dose measurements):
  - Study rationale: informs patient guidelines & protection standards
  - Early workers (before 1960) $\rightarrow$ increased cancer risks

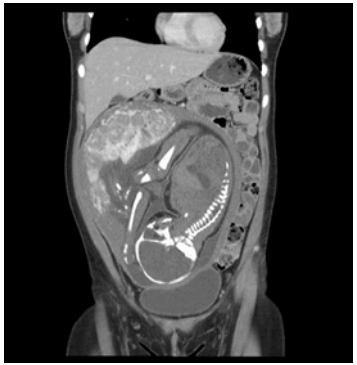
Prenatal diagnostic exams and childhood cancer risks

- Small leukemia excess (↑ 32%) in offspring
  [RR=1.32; 95% CI = 1.19-1.46]
  32 studies: 1956-1996

- Dosimetry lacking

- Inconsistency in risks of other childhood cancers

NOTE: Survey U.S. and Canada 1996-2016:
5.3% pregnant women had diagnostic imaging
(0.8% CT scans); mostly serious medical problems



Pelvimetry

Childhood/adolescent diagnostic x-rays and cancer risks

- Individual studies
  - Pediatric CT scans: dose-related elevated brain tumors and leukemia (4 studies, 2011-19); large pooled study underway

  - Childhood/adolescence repeated x-rays to monitor scoliosis: dose-related elevated breast cancer risk (1 study)

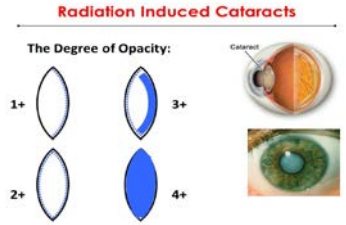
- Pooled historical study
  - Childhood exposures cumulative dose ≤ 100 mSv dose-related excess acute myeloid leukemia/MDS and elevated acute lymphocytic leukemia (4 studies):

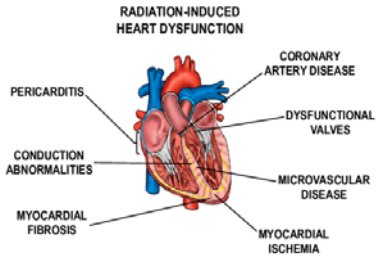
Preconception radiation and cancer risks in offspring

Populations	Findings
Medical radiation workers	No increase in offspring (2 studies)
Nuclear workers	No increase in offspring (3 studies)

Cancer risks in medical radiation workers

- 10 epidemiological studies without and 2 with estimated doses
- Early workers (started before 1960) had excesses of leukemia, breast, and skin cancer
- No cancer excess in more recent workers
- Excess cataracts at low doses (1 study)
- Data lacking at low doses, but excess circulatory diseases low-to-moderate-doses





Cancer risks in medical radiation workers:
Perform higher-dose procedures

- Small excesses of selected cancers, circulatory diseases and cataracts in workers performing fluoroscopically-guided (FG) or nuclear medicine (NM) procedures

- FG and NM procedures have highest medical worker occupational doses (potentially increasing over time)

Tracking diagnostic imaging radiation exposures:

An epidemiologist's perspective

- High-value tracking
  - Children/adolescents/young adults undergoing repeated:
    - FG procedures for congenital cardiac disease, other conditions
    - CT scans for selected morbidities, contact sports injuries, other

- Lower- /limited-value tracking
  - Middle-aged/elderly adults undergoing repeated FG, NM, or CT exams