National Cancer Institute

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

National Institutes of Health

Cancer Risks from Occupational Radiation Exposures

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Overview

1. Cohort studies of medical radiation workers
2. Nuclear worker studies
3. Risk projection using NCI-RISK

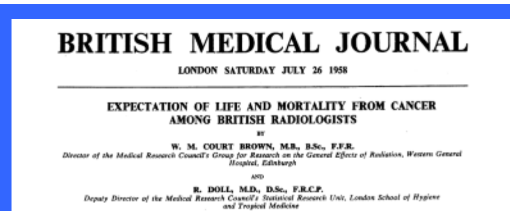
Why Study Medical Radiation Workers?

- Assess adequacy of radiation protection measures
- Assess risks from protracted low-dose exposure
  - among earliest radiation-exposed populations
  - substantial exposures before 1950
  - exposures decreased time

History: Medical radiation workers and cancer

- 1902 observation of skin cancers in radiologists
- 1931 Case-report of leukaemia in 5 radiologists
- 1944 US epidemiological study of radiologists
  - confirms link between radiation & leukaemia
- 1956 British radiologists study set-up
- 1958-present 8 epidemiological studies

Study	Subjects	Years 1st worked	Follow-up
UK radiologists	2,700	1897-1979	1897-1997
US radiologists	6,500	1920-1969	1920-1969
US technologists	146,000	1926-1982	1926-2003
US army technologists	6,600	1940s	1946-1974
Chinese X-ray workers	27,000	<1950-1980	1950-1995
Danish radiation therapy workers	4,200	1954-1982	1968-1985
Japanese technologists	12,200	1918-1971	1969-1993
Canadian radiation workers	73,100	<1950-1983	1951-1987
Total	278,300		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EXPECTATION OF LIFE AND MORTALITY FROM CANCER AMONG BRITISH RADIOLOGISTS

BY

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- 1338 radiologists registered with British radiological societies
  - Membership registers 1897 – 1955
  - Followed-up until 1956 for cause of death
- Cohort expanded to 1897-1977 registrations (n=2698)
  - Followed-up until 1997 for cause of death

Expanded UK cohort: 1897-1997

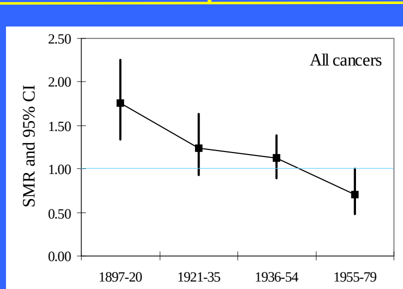
	Total	
Status on 1.1.1997	n	(%)
Alive and living in U.K.	963	(36)
Dead	1158	(43)
Emigrated	550	(20)
Lost to follow-up	27	(1)
Total	2698	(100)
Person years at risk	69,615	

[Berrington et al, Br J Radiology 2001]

Standardized mortality ratio (SMR)

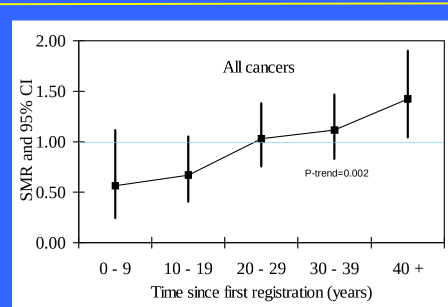
- 'External' comparison with death rates in general population = unexposed group
- UK medical practitioners
  - reported occupation on death certificate
- Healthy-worker effect
- Confounding – eg smoking

Results - Mortality from all cancers compared to medical practitioners



Year of first registration with a radiological society

Mortality from all cancers compared to medical practitioners (1920+)



Site-specific cancer deaths

- 1st registered <1920
  - Skin SMR=4.4 (n=2)
  - Pancreatic cancer SMR=3.9 (n=5) p<0.05
  - Leukemia (n=1), Bladder (n=3), Lung (n=7) SMR=2.5
- 1st registered 1920+
  - NHL SMR=3.1 (n=9) p<0.01
  - Leukaemia SMR=2.4 (n=8) p<0.05
  - Prostate SMR=1.6 (n=22) p<0.05

US radiologists: study design

RSNA: radiologists (n=6,500)	ACP, AAOO: non-exposed (n≈23,500)

- 'Internal' comparison group of 'unexposed' physicians
- Relative risk (instead of SMR)
- Both groups subject to healthy-worker effect
- Confounding still possible

US radiologists results

- Cancer mortality by year 1st registration
  - 1920-9 RR=1.5
  - 1930-9 RR=1.6
  - 1940-9 RR=1.3
- Cancer sites ($p<0.05$)
  - 1920-39
    - Skin RR=3.4, Leukemia RR=2.0, Lymphoma RR=2.7
  - 1940-49
    - Lung RR=1.2

US Radiologic Technologists cohort

- 146,022 US Technologists certified at least two years between 1926 and 1982
- Two postal surveys (mid-1980's and mid-1990's)
  - 110,000 answered one or both surveys
- Third survey 2003-2005
  - 73,000 surveys completed

Demographics:
Female: 73%
Average age: 58 years
Race: 95% White
Distribution: Entire US

Site-specific risks

- Breast cancer – increased risk <1940 (SMR=1.5)
- Leukemia – increased risk <1940 (SMR=1.3)
- Lung cancer – no increase

[Doody et al, 2006; Linet et al, 2005; Rajaraman et al, 2005]

Occupational Radiation Dosimetry

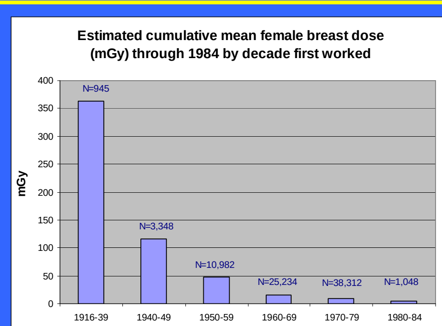
- Dose reconstruction
  - Pre-1960
    - literature review
  - 1960-1976
    - 2,800 badge readings taken on outside of apron
  - 1977 to 2005
    - 350,000 annual computerized badge dose readings available for cohort members

Dose reconstruction cont.

- Surveys queried
  - Procedure type by time period
  - Intensity of work (procedures per week by job)
  - Apron and shield use by job
  - Jobs by time period worked
  - Other: Holding patients by job
- Dosimetry is nearly “finished”

[Simon et al, 2006]

USRT Breast Organ Doses



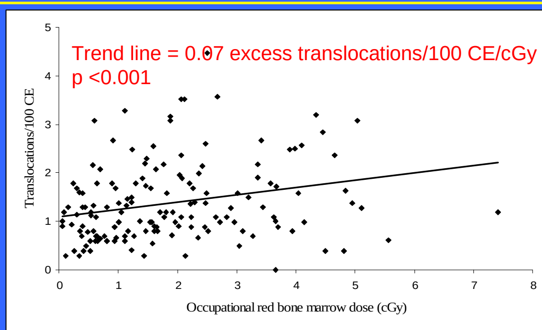
Personal Diagnostic Exposures

- Self-reported numbers and calendar time periods of procedures based on survey reports
- Weighted by nominal estimates of organ doses
- Cumulative Organ Dose “Score” with units approximating cGy

Radiation Dose Corroboration

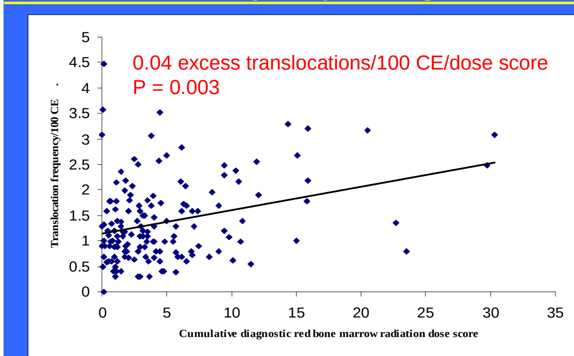
- How “good” are the occupational and personal diagnostic dose estimates?
- Biodosimetry for 152 technologists
  - Radiation estimates for red bone marrow
  - FISH whole chromosome painting for translocations
    - Expressed per 100 cell equivalents (CE) as if the entire genome had been scored

Translocation frequency vs occupational dose



[Bhattia et al, 2007]

Translocation frequency vs diagnostic dose



Ongoing and Future work in USRT

- Dose-response assessment for site-specific cancers using dosimetry
  - Breast
  - Leukemia
  - Skin
- Gene-radiation interaction studies
- Cancer risks associated with diagnostic exposures

Physicians Performing Fluoroscopically-Guided (FG) Procedures

- Cardiologists
- Interventional radiologists
- Interventional neuroradiologists
- Orthopedic surgeons
- Urologists
- Pain management physicians
- Others

Background: Health Concerns

- Clinical reports: radiation dermatitis on hands, hair loss, cataracts, cancers (brain tumors and leukemia)
- Apparent epidemic of musculoskeletal problems: attributed to heavy lead aprons
- Reduction of apron thickness: ↓ musculo-skeletal symptoms BUT ↑ cancer risks?

✶ ✶To date, no epidemiological study of ✶ ✶ practitioners performing FG procedures

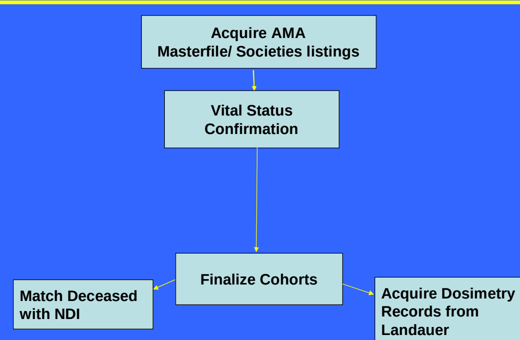
New cohort: US radiologists and Physicians who perform FG procedures

- INFOH
  - 50,000 physicians from specialist societies
    - SCAI, SIR, ACC, SNIS, HRS
  - 100,000 family practitioners and psychiatrists from AMA
  - 50,000 US radiologists from AMA
  - Mortality follow-up 1979-2006

Objectives

- 1. Compare mortality from 1979-2006 in US radiologists and physicians who perform fluoroscopically guided procedures with US physicians who have a low probability of occupational exposure to ionizing radiation
- 2. Survey of annual badge doses in these specialties for the period 1979-2006

Methods: Follow-up & Matching



Dose survey

- Landauer linkage
  - Annual dose by specialty over time
  - Complete dosimetry difficult (USRT experience)
  - Non-compliance

- 'Indirect' dose estimation
  - Dose per procedure
  - Annual workload (HMO database)

Estimated Effective Doses in *μSv* for Common FG Procedures

Procedure	No. studies	Median	Mean
Coronary angiography	37	2.5	5.3
Percutaneous coronary intervention	16	3.2	4.7
Cardiac ablation	6	2.5	3.5
Pacemaker implant	5	1.5	5.7
Vascular interventional angiography	10	2.2	3.7
Vascular embolization	3	2.0	1.7
Endovascular therapeutic head/neck	6	2.2	3.4

[Kim KP et al, 2008]

Comparison with nuclear worker studies

- Exposures generally lower
- Individual dosimetry available

- 15 country study [Cardis et al, 2007]
  - 400,000 (mostly) nuclear workers
  - Mean dose = 19mSv
  - 10% > 50mSv
  - All solid cancers mortality
  - ERR=0.87 (0.03-1.88) per Sv
  - LSS ERR=0.32 (0.01-0.50) per Sv

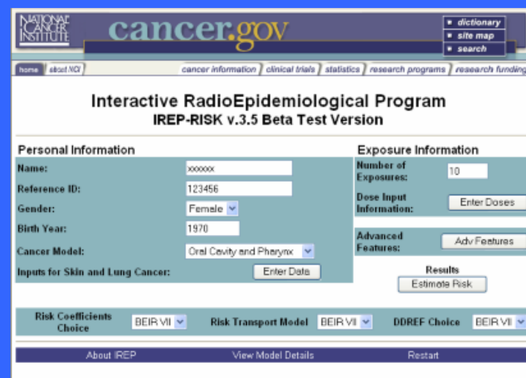
3. Risk projection – 'indirect' assessment

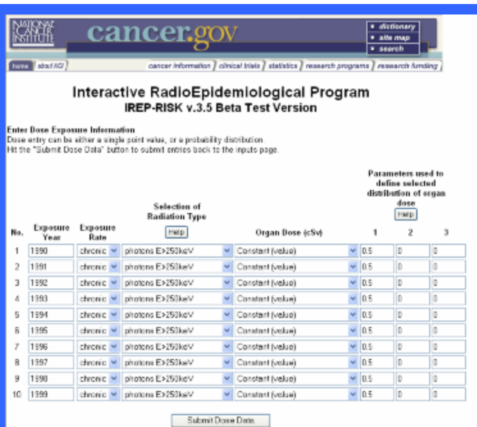
- Life Span Study
  - Range of doses
  - Range of ages at exposure
  - Long term follow-up
  - Large cohort (100,000+)

  - Single-acute exposure
  - Japanese cancer rates differ from US

3. Risk projection - methods

- LSS risk models
- Exposure history
- LNT assumption
- ‘Underlying’ cancer incidence rate
- Sum risk over expected lifetime





Results – Excess lifetime cancer risk

	Mean	95% Uncertainty Interval
Breast	2 per 1000	1 to 4 per 1000
Lung	3 per 1000	1 to 7 per 1000
Leukemia	1 per 1000	0.5 to 1.5 per 1000
Colon	1 per 1000	0.3 to 1.5 per 1000
Other	3 per 1000	1 to 6 per 1000
Total	10 per 1000	4 to 15 per 1000

NCI-RISK

- Modified BEIR VII risk models
  - 17 cancer sites
  - Additional sites esophagus, kidney, brain, pancreas, oral, rectum, gallbladder
  - Models cover 80% US cancer incidence
  - Monte Carlo uncertainty intervals
  - **http://dceg.cancer.gov/reb available end 2009**

[Berrington de Gonzalez, Gilbert, Land, in preparation]

Summary

- Protracted/low dose exposures most common in general population
- Elevated cancer risks in earliest medical workers
  - Leukemia, skin, lymphoma?
- Cancer risks decreased over time
  - Improved radiation protection
- Current levels of exposure very low
  - FG procedures physicians?
  - Risk projection to estimate risks
- New findings
  - INFOH, USRT dosimetry

Medical Worker study strengths/limitations

- Protracted low-dose
- Range of doses
- Healthy population
- Long-term follow-up
- Rare cancers in LSS

- Lack of dosimetry
- Healthy worker effect
- Confounding
- Sample size

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