National Cancer Institute

Radiation Organ Doses Received by U.S. Radiologic Technologists: Estimation Methods and Findings

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• Link to Abstract
• Link to Menu

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OVERVIEW

- This presentation summarizes methods and strategies for historical reconstruction of occupational radiation absorbed doses to organs and tissues to a large cohort of U.S. radiologic technologists who worked throughout the 20th century.
- The unique cohort is 73% female and received low-level chronic exposure throughout their working career.
- The dose reconstruction supports an epidemiological study of cancer risk underway at the National Cancer Institute to elucidate cancer risk from chronic low-level exposure.
- Estimates of organ doses for each individual and uncertainty on each dose is the overall goal of the dose reconstruction component.

OVERVIEW (con't.)

- We have derived annual and cumulative occupational badge readings to about 110,000 technologists for each year worked during the period 1916 to 2006.
- Badge estimates are based on more than 1.2 million archival personnel monitoring measurements from the largest commercial personnel dosimetry provider in the U.S. - supplemented with data from large hospitals that conducted their own monitoring, and from U.S. Army, Navy, and Air Force.
- Badge measurements when absent are simulated from PDFs derived from data on the working population of technologists and supplemented by data from a thorough review of literature conducted through the NLM.

OVERVIEW (con't.)

- Simulated badge measurements rely on extensive individual work history data from individually adminsitered questionnaires and take into account numerous sources of shared and unshared uncertainties.
- Each individual technologist's annual badge reading is estimated as a PDF.
- Each technologist's badge PDF is used to produce multiple realizations of that subject's annual and lifetime organ doses.
- Absorbed doses are presently estimated to twelve organs and tissues (red bone-marrow, ovary, colon, brain, lung, heart, female breast, skin of trunk, skin of head and neck and arms, testes, thyroid, and lens of the eye).

Methods of Organ Dose Estimation

1.Individual badge measurements are used when available, and simulated when not. In simulation, temporal correlation of 0.5, 0.4, and 0.3 are assumed for 1-yr, 2-yr, and 3-yr lags, respectively.

2.Badge estimates are converted to air kerma and then to organ dose using DCCs derived for 3 sets of typical x-ray technical parameters (peak kV and filtration) in each of 4 time-periods (<1949, 1949-1954, 1955-1968, >1968).

3.Organ DCCs for all 12 kV and filtration combinations were estimated by air-kerma weighting of organ specific mono-energetic DCCs from ICRP Report 74 with photon fluences from published x-ray spectra (IPEM 1997).

Methods of Organ Dose Estimation (con't.)

4. Energy-dependent transmission factors for protective aprons of 2 different thicknesses are applied – each specific to one of12 sets of x-ray technical parameters.

5. Individual subject responses from 3 questionnaires administered over a 20 year period are used to estimate the individual use of protective aprons.

6. RBM dose estimates tailored to each cohort member by correcting the RBM DCC applied using the individual's body mass index (BMI) derived from questionnaires.

Basic organ dose calculation without lead apron.

$$D_T = H_p(d) \left[\left(\frac{D_T}{K_a} \right) / \left(\frac{H_p(d)}{K_a} \right) \right]$$

where,

D_T = tissue or organ dose (Gy or rad)
$H_p(d)$ = personal dose equivalent (Sv or rem)
K_a = air kerma free-in-air (Gy or rad)

Organs protected by lead apron (except for RBM).

$$D_T = \left[H_p(d)\right]_{OA} TF \left[\left(\frac{D_T}{K_a} \right)_{UA} / \left(\frac{H_p(d)}{K_a} \right)_{OA} \right]$$

where,

TF = apron transmission factor (Gy per Gy) and UA means “under apron.”

Derived DCCs (D_T/K_a) factors for RBM (AP) by time period and apron usage

kV (peak)	<1949	1949-1954	1955-1968	>1968
No apron (for BMI ≈ 23.5 kg/m^2)				
70	0.062	0.11	0.14	0.16
80	0.073	0.12	0.16	0.19
90	0.085	0.14	0.18	0.21
0.5 mm Pb apron (for BMI ≈ 23.5 kg/m^2)				
70	0.50	0.50	0.51	0.53
80	0.55	0.55	0.56	0.57
90	0.58	0.59	0.60	0.61

Dose calculation to RBM must consider fraction of BM unprotected and fraction protected by apron.

$$D_T = [H_p(d)] \left[\left(\frac{D_T}{K_a} \right) / \left(\frac{H_p(d)}{K_a} \right) \right] F_{RBM-U}$$

where,

TF = apron transmission factor (Gy per Gy)
UA means “under apron.”
F_{RBM-U} = fraction of RBM unprotected by lead apron

Dose calculation to RBM must consider fraction of BM unprotected and fraction protected by apron.

$$D_T = [H_p(d)] \left[\left(\frac{D_T}{K_a} \right) / \left(\frac{H_p(d)}{K_a} \right) \right] F_{RBM-U} +$$

$$(1 - F_{RBM-U}) [H_p(d)]_{OA} \, TF \left[\left(\frac{D_T}{K_a} \right)_{UA} / \left(\frac{H_p(d)}{K_a} \right)_{OA} \right]$$

where,

TF = apron transmission factor (Gy per Gy)
UA means “under apron.”
F_{RBM-U} = fraction of RBM unprotected by lead apron

Lead aprons and F_{RBM-U} has changed over time

(i) Before about 1960, aprons were held on shoulders by thin straps – exposing most of clavicle, humeral heads, and 4 of the 12 thoracic vertebrae.

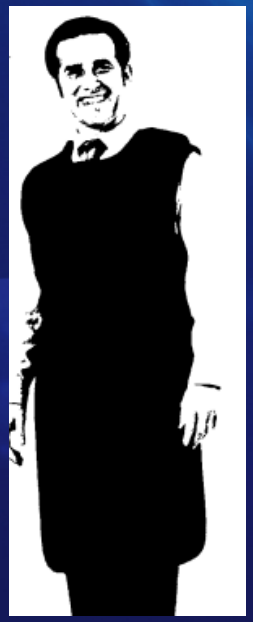
Pre-1960

Lead aprons and F_{RBM-U} has changed over time

(i) Before about 1960, aprons were held on shoulders by thin straps – exposing most of clavicle, humeral heads, and up to 4 of the 12 thoracic vertebrae

(ii) After about 1960, aprons were designed with wide shoulder straps - covering more of the clavicle, the humeral heads, and all but 3 thoracic vertebrae.

Pre-1960

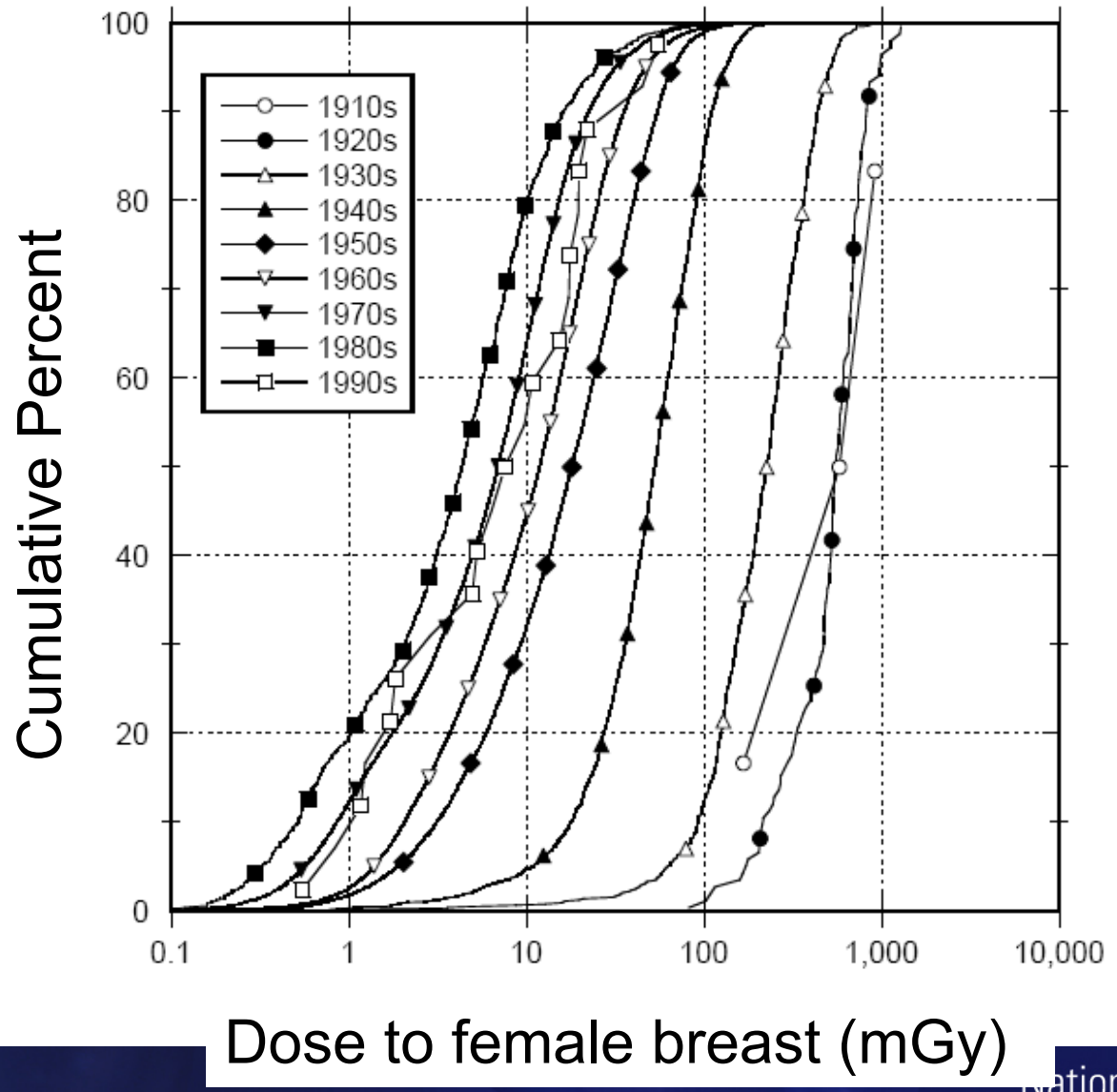


Post-1960

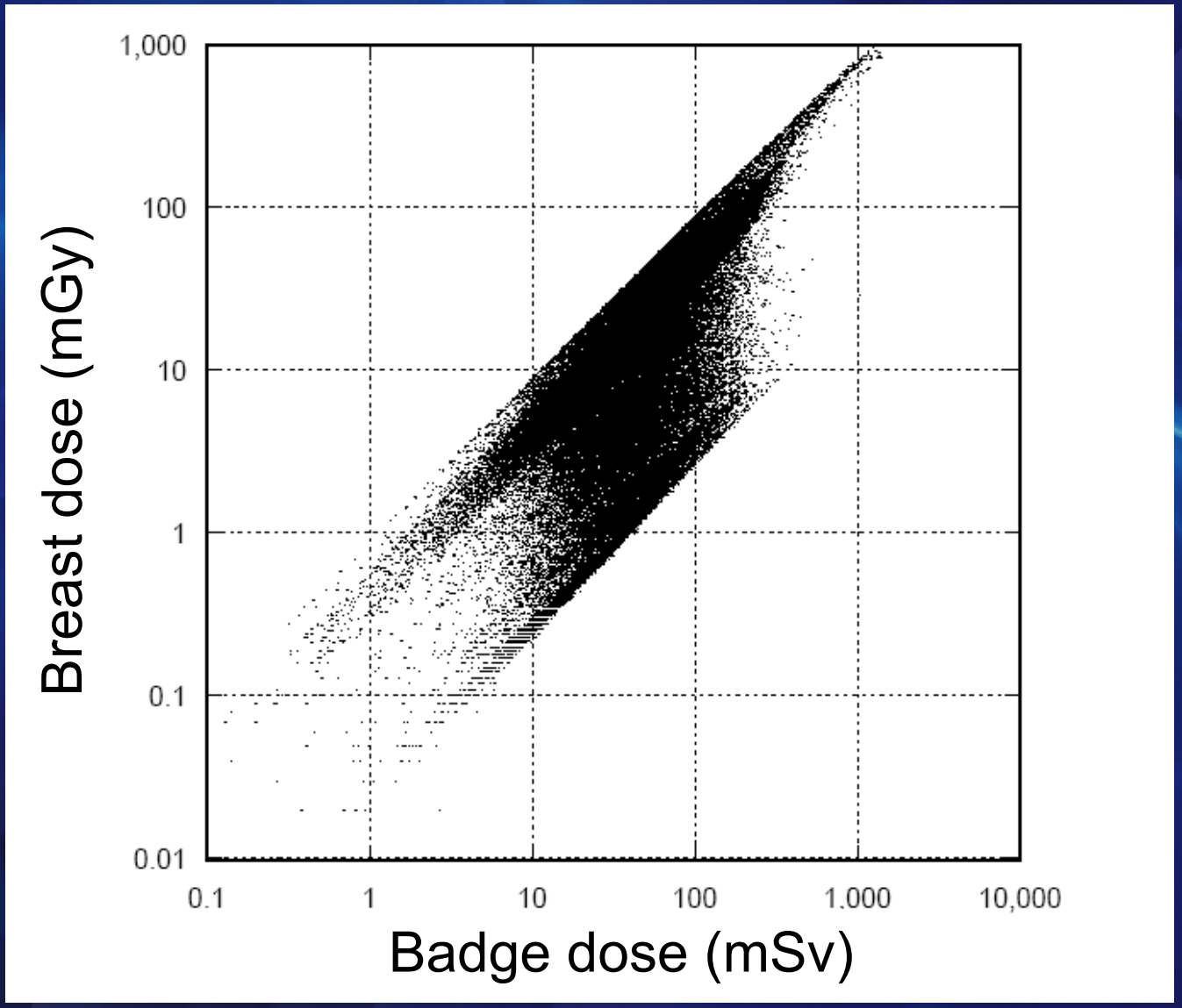
Portion of skeleton left unprotected by lead aprons	% RBM exposed pre-1960	% RBM exposed post-1960
Cranium	7.7	7.7
Mandible	0.8	0.8
Cervical vertebrae	3.7	3.7
Clavicles	0.4	0
Thoracic vertebrae	5.1	3.8
Humeri, upper half	2	0
Sum = F_{RBM-U}	**~20%**	**~16%**

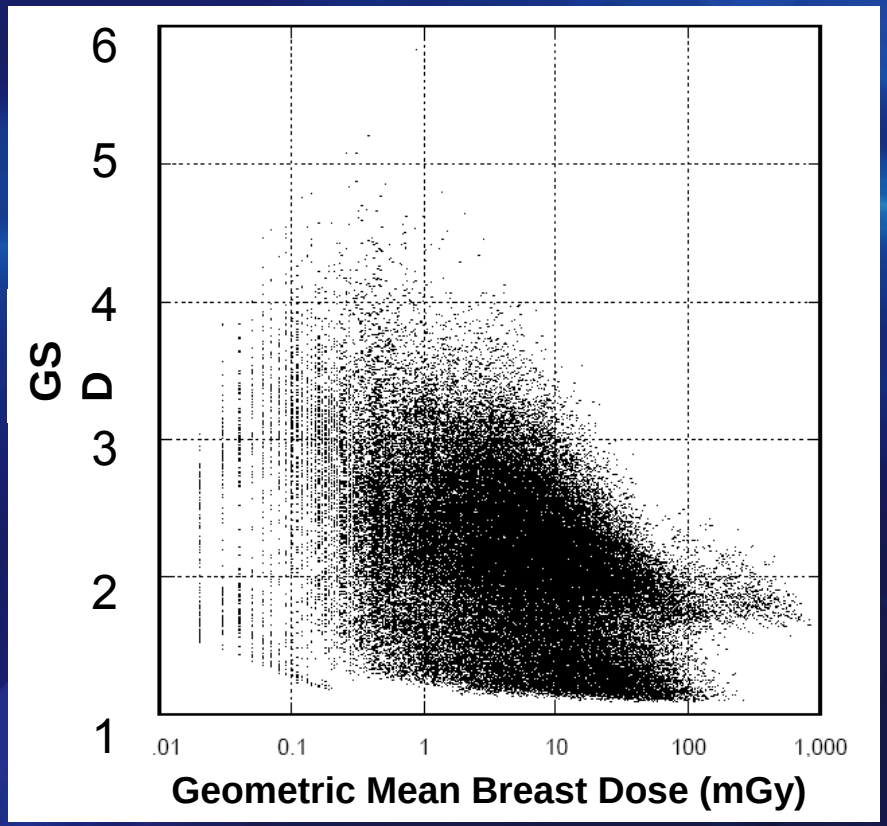
FINDINGS (brief)

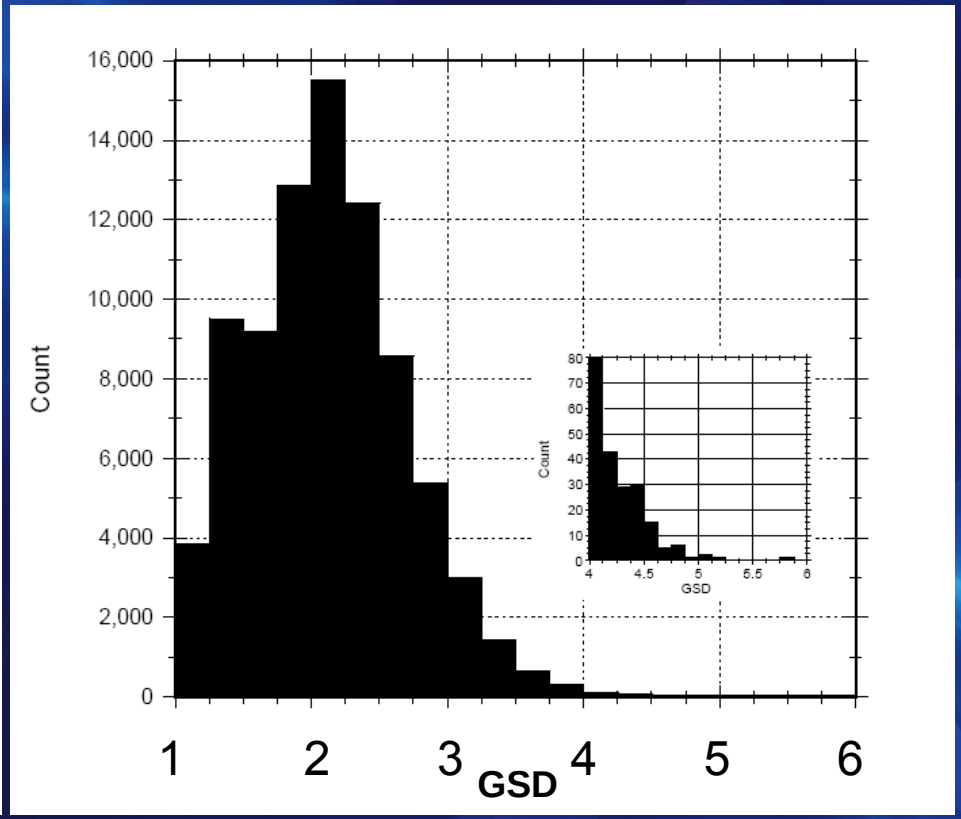
Cumulative distribution functions of female breast dose (mGy) by decade first worked



Breast dose (mGy) as a function of badge dose (mSv)







GSDs range from ~1.5 to 4

Elements we consider to be important in this dose reconstruction:

- Use of subject-specific empirical measurement data when available,
- Simulation which accounts for information derived from thorough literature reviews and three detailed work-history questionnaires,
- Use of DCCs and other dose-related parameters based on our current understanding of x-ray technical parameters over time,
- A significant effort to minimize bias in models and input data,
- Derivation of uncertainty on individual level derived from Monte Carlo calculations using empirical and subjective PDFs of parameters to generate multiple realizations of entire cohort dose distribution.

Follow the study at http://www.radtechstudy.nci.nih.gov/

Investigators contributing to dose reconstruction

2006

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2009

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THANK YOU FOR YOUR ATTENTION.

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