Draft

Advisory Board on Radiation and Worker Health
National Institute for Occupational Safety and Health

A Review of ORAUT-RPRT-0085 for Probability of Causation Evaluation of ICRP 116 Anterior-Posterior, Isotropic, and Rotational Geometries

Contract No. 75D30119C04183
Document No. SCA-TR-2023-PR085, Revision 1

Prepared by

Ron Buchanan, PhD, CHP
Douglas Farver, CHP
Kathleen Behling

SC&A, Inc.
2200 Wilson Blvd., Suite 300
Arlington, VA 22201-3324

May 11, 2023

DISCLAIMER

This is a working document provided by the Centers for Disease Control and Prevention (CDC) technical support contractor, SC&A for use in discussions with the National Institute for Occupational Safety and Health (NIOSH) and the Advisory Board on Radiation and Worker Health (ABRWH), including its Working Groups or Subcommittees. Documents produced by SC&A, such as memorandum, white paper, draft or working documents are not final NIOSH or ABRWH products or positions, unless specifically marked as such. This document prepared by SC&A represents its preliminary evaluation on technical issues.

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the [Privacy Act 5 U.S.C. § 552a] and has been cleared for distribution.*

SC&A, Inc. technical support for the Advisory Board on Radiation and Worker Health's review of NIOSH dose reconstruction program

Document title	A Review of ORAUT-RPRT-0085 for Probability of Causation Evaluation of ICRP 116 Anterior-Posterior, Isotropic, and Rotational Geometries
Document number	SCA-TR-2023-PR085
Revision number	1 (Draft)
Supersedes	0
Effective date	May 11, 2023
Task manager	Kathleen Behling [signature on file]
Project manager	Bob Barton, CHP [signature on file]
Document reviewer(s)	Bob Barton, CHP [signature on file]

Record of revisions

Revision number	Effective date	Description of revision
0 (Draft)	4/25/2023	Initial issue
1 (Draft)	5/11/2023	Corrected description of SC&A's calculation of 30–250 keV photon DCFs in section 3.4.4. Two minor editorial corrections.

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

Table of Contents

List of Tables

Abbreviations and Acronyms

ABRWH	Advisory Board on Radiation and Worker Health
AP	anterior-posterior
CC	center chest
CW	center waist
DCC	dose conversion coefficient
DCF	dose conversion factor
EE	energy employee
FCF	fluence conversion factors
GSD	geometric standard deviation
Hp(10)	personal deep dose equivalent
Hp(10)/ø	personal deep dose equivalent divided by fluence
ICRP	International Commission on Radiological Protection
IGF	irradiation geometry factor
IREP	Interactive RadioEpidemiological Program
ISO	isotropic
keV	kiloelectron volt
LC	left collar
LCP	left chest pocket
Leuk	leukemia
MeV	mega-electron volt
mrem	millirem
NA	not applicable
NIOSH	National Institute for Occupational Safety and Health
ORAUT	Oak Ridge Associated Universities Team
pGy	picogray
POC	probability of causation
pSv	picosievert
QF	quality factor
RBM	red bone marrow
ROT	rotational
SI	small intestine
SRDB	Site Research Database
yr	year
UB	urinary bladder

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

1 Introduction and Background

In 2005, SC&A reviewed OCAS-IG-001, revision 1, "External Dose Reconstruction Implementation Guideline" (NIOSH, 2002), and determined that applying the OCAS-IG-001 rotational (ROT) and isotropic (ISO) dose conversion factors (DCFs) could lead to an underestimate of the external dose (SC&A, 2005). This underestimate is due to the fact that the DCFs were developed assuming that the radiation beam is perpendicular (incident angle = 0) in relation to the personal deep dose equivalent, ambient deep dose equivalent, and exposure measurements using either film badge or thermoluminescent dosimetry. In the interim, the National Institute for Occupational Safety and Health (NIOSH) directed dose reconstructors to use only the anterior-posterior (AP) geometry. However, NIOSH determined the AP DCF values were not the most claimant favorable for the bone (red marrow and surface), esophagus, and lung when the dosimeter is worn on the chest. Therefore, ROT and ISO DCF correction factors were developed. NIOSH published these correction factors in table 4.1a of OCAS-IG-001, revision 3 (NIOSH, 2007, p. 39: "IG-001"). It should be noted that IG-001, revision 3, erroneously contains two tables designated as table 4.1a. The table 4.1a referenced in this report is the second table 4.1a, shown on page 39 of IG-001, not the first table 4.1a on page 38. NIOSH has been made aware of this error but to date has not revised IG-001 to correct the table numbers.

In anticipation of introducing International Commission on Radiological Protection (ICRP) Publication 116 (ICRP, 2010; "ICRP 116") dose conversion coefficients (DCCs) in the dose reconstruction process, NIOSH issued ORAUT-RPRT-0085, revision 00, "Probability of Causation Evaluation of ICRP 116 Anterior-Posterior, Isotropic, and Rotational Geometries," on November 6, 2017 (NIOSH, 2017; "RPRT-0085"). The purpose of RPRT-0085 was to determine if the ROT and ISO DCFs for bone (red marrow and surface), esophagus, and lung listed in table 4.1a of IG-001, revision 3, are still valid.

On October 26, 2022, SC&A was tasked with the technical review of RPRT-0085. This report presents SC&A's evaluation of the technical approach, methods used, and documentation in RPRT-0085, revision 00.

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

2 RPRT-0085, Revision 00

2.1 NIOSH's methods and approach for assessing data in RPRT-0085

NIOSH's method for assessing the most claimant-favorable exposure geometries was to derive a probability of causation (POC) and dose for each combination of ICRP 116 organs, gender, dosimeter location, exposure type, and energy range.

For assessing POC values, NIOSH used the Monte Carlo method to generate Interactive RadioEpidemiological Program (IREP) sheets for the following:

- All ICRP 116 organs (RPRT-0085, table 2-1)
  - 29 organs
  - 33 IREP models
- Gender
  - male
  - female
- Radiation types
  - neutrons
  - photons
- Exposure geometries
  - AP
  - ROT
  - ISO
- IREP energy ranges
  - 32 neutron energies between 0.000000001 and 20 mega-electron volts (MeV)
  - 20 photon energies between 0.01 and 3 MeV
- Dose type
  - Hp(10) (personal deep dose equivalent)
  - exposure
- 4 dosimeter locations (RPRT-0085, table 2-2)
  - center chest
  - left collar
  - center waist
  - left chest pocket

Doses were calculated using irradiation geometry factors (IGFs) developed in ORAUT-RPRT-0068, revision 00, "Correction Factors for Use with ICRP Publication 116 Isotropic and Rotational Dose Conversion Coefficients" (NIOSH, 20016a; "RPRT-0068"). RPRT-0068 determined IGFs for ISO and ROT geometries for neutrons (RPRT-0085, tables 2-3 and 2-4) and photons (RPRT-0085, tables 2-5 and 2-6).

NIOSH performed IREP calculations assuming a 5-year work period starting at age 35 with a latency period of 3 years for leukemia, 7 for thyroid, and 10 for all other cancers. NIOSH applied a dose of 2,000 millirem per year (mrem/yr) as a normal distribution with a 30 percent error.

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

In addition to determining POC values, NIOSH also performed a dose-only analysis. This analysis assumed 500 mrem of measured dose and 500 mrem of missed dose combined with ICRP 116 DCCs and RPRT-0068 IGFs for the four dosimeter locations. Based on the method described in ORAUT-RPRT-0069, revision 00, "Updated ICRP 116 Dose Conversion Factors and Comparison to ICRP 74 Dose Conversion Factors" (NIOSH, 2016b; "RPRT-0069"), the DCC is treated as a continuous distribution. NIOSH used a four-point Lagrange interpolation, as recommended by ICRP 116 (ICRP, 2010), to determine DCF values between discrete points.

2.2 NIOSH's data analysis results

2.2.1 POC analysis results

Using data generated in RPRT-0085, NIOSH found that concise geometry determinations could not be drawn, as listed in table 4.1a of IG-001. For most radiation types, organs, and dosimeter location, the AP and ROT geometries were found to deliver the largest POC, except for the female adrenals, for which ISO was more prominent for photons. Attachment A of RPRT-0085 shows the results of the POC analysis.

In addition, NIOSH evaluated a subset of the data for photon energies of 30 to 250 kiloelectron volts (keV) and neutrons from 100 keV to 2 MeV. These radiation energies represent the most consequential to POC determination. NIOSH's analysis determined which geometries result in the highest dose for each pairing of organ and dosimeter location. POC results for consequential radiation energies are presented in attachment B of RPRT-0085.

In summary, the ROT geometry resulted in the highest POC for most pairings for energy ranges of 30–250 keV photons. However, for the left chest pocket, either AP or ISO delivered the highest POC for 13 of the ICRP 116 organs. Table 3-1 of RPRT-0085 lists the organs for each dosimeter location where ROT was found not to result in the most favorable geometry.

For male and female, the organs with the higher POCs for 30–250 keV photons are mostly the same, except for the adrenals, where ISO is most favorable.

For 0.1–2 MeV neutrons, the ROT geometry also delivers the highest POC for most locations. However, for many organs, the AP or ISO geometries are more claimant favorable for both the center waist and left chest pocket dosimeter locations. Table 3-2 of RPRT-0085 list the organs for which ROT is not the most favorable geometry for 100 keV–2 MeV neutrons.

2.2.2 Dose analysis results

NIOSH's derived dose-only results provided an additional comparison of data. These results showed with few exceptions an overwhelming agreement between the dose and POC analysis results. Attachment C of RPRT-0085 provides the dose analysis results.

2.2.3 Summary of results

Table 4.1a of IG-001 provides a concise list of organs in which geometries other than AP are more claimant favorable. The use of ICRP 116 DCCs in combination with the IGFs in RPRT-0068 does not produce a list that agrees with IG-001. Inconsistent with current recommendations in IG-001, the analysis using ICRP 116 heavily favors the ROT geometry.

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

3 SC&A's Evaluation of RPRT-0085

The following sections summarize SC&A's evaluation of the technical approach and documentation used by NIOSH to assess the most claimant-favorable exposure geometries. It should be noted that in performing this assessment, SC&A found that NIOSH relied on data published in RPRT-0068 and RPRT-0069. SC&A has not been tasked to review these documents; therefore, these data were used without verification of their accuracy, since the assessment of these reports is beyond the scope of this review.

3.1 IREP models

3.1.1 NIOSH's IREP models

In table 2-1 of RPRT-0085, NIOSH list the ICRP 116 cancers and the associated IREP model used in their POC evaluation. SC&A's review of table 2-1 included a comparison of listed IREP models for ICRP 116 organs and tissues to those identified in ORAUT-OTIB-0005, revision 05, "Internal Dosimetry Organ, External Dosimetry Organ, and IREP Model Selection by ICD-9 Code" (NIOSH, 2012; "OTIB-0005").

3.1.2 SC&A's evaluation of IREP models

Based on SC&A's review of the IREP models used in RPRT-0085, SC&A concluded that NIOSH's selection of associated IREP models agrees with those identified in OTIB-0005, revision 05. For the muscle, which is not specifically listed in OTIB-0005, SC&A considers NIOSH's selection of connective tissues to be appropriate.

3.2 Dosimeter locations

3.2.1 NIOSH's dosimeter location selection

NIOSH calculated doses for four dosimeter locations considered to approximate the standard locations of the dosimeters worn by energy employees (EEs). These locations included the center chest (CC), left collar (LC), center waist (CW), and left chest pocket (LCP). Table 2-2 of RPRT-0085 provides a detailed description of where the dosimeter was placed on the adult male and adult female phantoms.

3.2.2 SC&A's evaluation of dosimeter locations

SC&A considered these dosimeter locations as reasonable, although the center waist location is less likely for EEs. Based on knowledge of site-specific practices and information in the computer-assisted telephone interview reports, SC&A assumed that the most likely dosimeter placement would be the left chest pocket or left collar.

3.3 Irradiation geometry factors

3.3.1 NIOSH's IGF values

RPRT-0085 used the IGFs developed in RPRT-0068 for calculating ISO and ROT photon and neutron doses. All AP IGFs are 1, because that is the geometry of the ICRP 116 DCCs. The RPRT-0068 IGFs are based on the incident energy of the particle. The IGFs are the quotient of the particle fluence in the dosimeter cell for AP irradiations divided by the particle fluence in the dosimeter cell for the ROT or ISO irradiation geometry, as appropriate.

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

Tables 3-1 and 3-2 of RPRT-0068 list the IGF factors developed in RPRT-0068 for photons that irradiated the adult female and male phantoms in the ROT and ISO irradiation geometries respectively, averaged over the IREP energy regions (i.e., <30 keV, 30–250 keV, and >250 keV). The IGF factors for neutrons that irradiated the phantoms in the ROT and ISO irradiation geometries, averaged over the IREP energy regions (i.e., <10 keV, 10–100 keV, 100 keV–2 MeV, and 2–20 MeV), are listed in tables 3-3 and 3-4, respectively, of RPRT-0068.

Tables 2-3 and 2-4 of RPRT-0085 list ROT and ISO IGFs, respectively, for 32 neutron energies for the four dosimeter locations on the adult female and adult male phantoms. Tables 2-5 and 2-6 of RPRT-0085 list ROT and ISO IGFs, respectively, for 20 photon energies for the four dosimeter locations on the adult female and adult male phantoms.

3.3.2 SC&A's evaluation of IGF values

For our evaluation of IGF values, SC&A derived IGFs using an arithmetic mean value of the IGFs in RPRT-0085, tables 2-3 through 2-6, for the typical IREP photon and neutron energy ranges. It should be noted that RPRT-0085 IGF values were listed for 200 keV and 300 keV. To assess the 30–250 keV photon energy range, SC&A averaged the 200–300 keV values to derive the 250 keV IGF. For neutrons, SC&A used the 2 MeV IGF value for both the 100 keV– 2 MeV and 2–20 MeV ranges. Thereafter, SC&A compared its mean IGF value to those values in RPRT-0068, tables 3-1 through 3-4. Tables 1–4 of this report show the results of SC&A's IGF calculations and RPRT-0068 comparison.

Table 1. SC&A's ROT neutron IGFs based on RPRT-0085, table 2-3, ROT IGFs

Dosimeter location and energy regions for Hp(10), adult phantom	SC&A adult female IGF	RPRT-0068 adult female IGF	SC&A adult male IGF	RPRT-0068 adult male IGF
CC ≤10 keV	2.09	1.68	2.03	1.74
CC 10–100 keV	2.05	2.02	2.01	2.00
CC 100 keV–2 MeV	1.98	2.04	1.98	2.02
CC 2–20 MeV	1.57	2.11	1.63	2.05
LC ≤10 keV	2.00	1.68	1.88	1.64
LC 10–100 keV	1.99	1.97	1.86	1.86
LC 100 keV–2 MeV	1.94	1.99	1.84	1.86
LC 2–20 MeV	1.56	2.03	1.54	1.90
CW ≤10 keV	1.82	1.58	1.86	1.64
CW 10–100 keV	1.79	1.77	1.83	1.82
CW 100 keV–2 MeV	1.76	1.79	1.80	1.84
CW 2–20 MeV	1.50	1.84	1.55	1.88
LCP ≤10 keV	1.59	1.43	1.67	1.51
LCP 10–100 keV	1.58	1.57	1.65	1.65
LCP 100 keV–2 MeV	1.55	1.58	1.63	1.66
LCP 2–20 MeV	1.38	1.60	1.45	1.69
Average ≤10 keV	1.88	1.53	1.86	1.63
Average 10–100 keV	1.85	1.83	1.84	1.83

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

Dosimeter location and energy regions for Hp(10), adult phantom	SC&A adult female IGF	RPRT-0068 adult female IGF	SC&A adult male IGF	RPRT-0068 adult male IGF
Average 100 keV–2 MeV	1.81	1.85	1.81	1.84
Average 2–20 MeV	1.50	1.89	1.54	1.88

Table 2. SC&A's ISO neutron IGFs based on RPRT-0085, table 2-4, ISO IGFs

Dosimeter location and energy regions for Hp(10), adult phantom	SC&A adult female IGF	RPRT-0068 adult female IGF	SC&A adult male IGF	RPRT-0068 adult male IGF
CC ≤10 keV	2.02	1.65	2.05	1.77
CC 10–100 keV	1.98	1.95	2.02	2.01
CC 100 keV–2 MeV	1.92	1.98	1.99	2.02
CC 2–20 MeV	1.59	2.05	1.68	2.07
LC ≤10 keV	2.26	1.80	2.12	1.77
LC 10–100 keV	2.22	2.17	2.08	2.06
LC 100 keV–2 MeV	2.13	2.21	2.03	2.08
LC 2–20 MeV	1.68	2.28	1.67	2.15
CW ≤10 keV	1.85	1.65	1.92	1.72
CW 10–100 keV	1.82	1.81	1.89	1.88
CW 100 keV–2 MeV	1.79	1.82	1.86	1.89
CW 2–20 MeV	1.57	1.88	1.64	1.94
LCP ≤10 keV	1.59	1.43	1.65	1.50
LCP 10–100 keV	1.57	1.56	1.63	1.62
LCP 100 keV–2 MeV	1.55	1.57	1.61	1.63
LCP 2–20 MeV	1.38	1.60	1.45	1.67
Average ≤10 keV	1.93	1.64	1.93	1.69
Average 10–100 keV	1.90	1.87	1.91	1.89
Average 100 keV–2 MeV	1.85	1.90	1.87	1.90
Average 2–20 MeV	1.56	1.95	1.61	1.96

Table 3. SC&A's ROT photon IGFs based on RPRT-0085, table 2-5, ROT IGFs

Dosimeter location and energy regions for Hp(10), adult phantom	SC&A adult female IGF	RPRT-0068 adult female IGF	SC&A adult male IGF	RPRT-0068 adult male IGF
CC ≤30 keV	2.06	2.02	2.02	2.00
CC 30–250 keV	1.78	1.77	1.84	1.84
CC >250 keV	1.48	1.37	1.56	1.44
LC ≤30 keV	2.00	1.97	1.87	1.86
LC 30–250 keV	1.79	1.79	1.75	1.75
LC >250 keV	1.51	1.40	1.50	1.40

Dosimeter location and energy regions for Hp(10), adult phantom	SC&A adult female IGF	RPRT-0068 adult female IGF	SC&A adult male IGF	RPRT-0068 adult male IGF
CW ≤30 keV	1.80	1.78	1.85	1.82
CW 30–250 keV	1.65	1.65	1.71	1.71
CW >250 keV	1.44	1.35	1.50	1.40
LCP ≤30 keV	1.58	1.56	1.66	1.65
LCP 30–250 keV	1.49	1.49	1.57	1.49
LCP >250 keV	1.33	1.27	1.41	1.27
Average ≤30 keV	1.86	1.83	1.85	1.83
Average 30–250 keV	1.68	1.68	1.72	1.72
Average >250 keV	1.44	1.35	1.49	1.39

Table 4. SC&A's ISO photon IGFs based on RPRT-0085, table 2-6, ISO IGFs

Dosimeter location and energy regions for Hp(10), adult phantom	SC&A adult female IGF	RPRT-0068 adult female IGF	SC&A adult male IGF	RPRT-0068 adult male IGF
CC ≤30 keV	1.99	1.96	2.03	2.00
CC 30–250 keV	1.77	1.76	1.85	1.85
CC >250 keV	1.52	1.42	1.59	1.54
LC ≤30 keV	2.23	2.18	2.10	2.07
LC 30–250 keV	1.91	1.91	1.87	1.87
LC >250 keV	1.58	1.46	1.59	1.53
CW ≤30 keV	1.85	1.82	1.90	1.88
CW 30–250 keV	1.70	1.71	1.77	1.77
CW >250 keV	1.53	1.43	1.58	1.53
LCP ≤30 keV	1.59	1.57	1.65	1.63
LCP 30–250 keV	1.48	1.48	1.55	1.55
LCP >250 keV	1.35	1.28	1.42	1.40
Average ≤30 keV	1.91	1.88	1.92	1.90
Average 30–250 keV	1.72	1.71	1.76	1.76
Average >250 keV	1.49	1.40	1.55	1.50

SC&A's RPRT-0085 and RPRT-0068 IGF comparison found that, for most energy ranges, there was reasonable agreement in IGF values. However, SC&A did identify several RPRT-0085 ROT and ISO neutron IGFs that deviate 20–25 percent from the RPRT-0068 values, as discussed in observation 1.

Observation 1: SC&A questions why NIOSH's neutron IGFs for several dosimeter locations differ from those in RPRT-0068

Using NIOSH's RPRT-0085 IGF values, SC&A's mean IGF values for several neutron ROT and ISO dosimeter placements were generally about 20–25 percent less than those values listed in RPRT-0068. With only one exception (ROT CC ≤10 keV), these differences were noted in the

2–20 MeV neutron energy region. SC&A questions why NIOSH's RPRT-0085 IGF values differed from those listed in RPRT-0068, when NIOSH stated that RPRT-0068 was the basis for their IGFs. Table 5 details these differences.

Table 5. Notable differences between SC&A's IGFs based on RPRT-0085 and RPRT-0068 IGFs

Dosimeter location and neutron energy regions for Hp(10), adult phantom	SC&A adult female IGF	RPRT-0068 adult female IGF	% Diff.	SC&A adult male IGF	RPRT-0068 adult male IGF	% Diff.
ROT CC ≤10 keV	1.68	2.09	+ 24	NA	NA	NA
ROT CC 2–20 MeV	1.57	2.11	– 25	1.63	2.05	– 20
ROT LC 2–20 MeV	1.56	2.03	– 23	NA	NA	NA
ISO CC 2–20 MeV	1.59	2.05	– 22	1.68	2.07	– 18
ISO LC 2–20 MeV	1.68	2.28	– 26	1.67	2.15	– 22

3.4 Probability of causation analysis

3.4.1 NIOSH's POC calculations

NIOSH's IREP calculations assumed a 5-year work period starting at age 35 with an assumed latency period of 3 years for leukemia, 7 for thyroid, and 10 for all other cancers. NIOSH assumed a dose of 2,000 mrem per year was applied as a normal distribution with a 30 percent error.

NIOSH calculated POC values using the enterprise edition of IREP version 5.8. The enterprise edition performed the POC calculation 30 times, each time using a different seed value, and each exposure was sampled 10,000 times. The average of the resultant POC values were used for NIOSH's comparisons.

NIOSH used Monte Carlo simulations to combine the following elements, shown in equation 1 (equation 2-1 in RPRT-0085):

$$IREP\ Exposure = Dose \times DCC \times IGF \tag{1}$$

where:

Dose = 2,000 mrem/yr applied as a normal distribution with a 30 percent error.

DCC = value based on the method in RPRT-0069 (NIOSH, 2016b). The DCC is treated as a continuous distribution. A four-point Lagrange interpolation, as recommended by ICRP 116 (ICRP, 2010), was used to determine DCC values between discrete points.

IGF = 1 for AP, values in RPRT-0085, tables 2-3 through 2-6, for ISO and ROT geometries. The IGF was treated as a continuous distribution using a four-point Lagrange interpolation.

3.4.2 SC&A's approach to evaluating NIOSH's POCs

Considering the vast number of iterations assessed by NIOSH, SC&A's evaluation included only a subset of photon and neutron energy ranges, dosimeter locations, and cancers.

For the energy ranges, SC&A selected the dominate energy ranges of 30–250 keV photons and 0.1–2 MeV neutrons.

SC&A evaluated only two of the four dosimeter locations used by NIOSH. SC&A considered left chest pocket and left collar as the most likely dosimeter badge wear positions for EEs.

For evaluation of cancers, SC&A selected the following eight female and eight male cancers:

1. lung
2. esophagus
3. red bone marrow (RBM) (leukemia)
4. adrenals
5. bladder (upper bowel wall)
6. breast
7. thymus
8. prostate (male)/ovaries (female)

SC&A began our review of RPRT-0085 doses and resulting POC values by familiarizing ourselves with ICRP 116 and RPRT-0069, which were the basis for NIOSH's calculation. A summary of pertinent information from these documents follows.

3.4.2.1 ICRP-116

Photons
ICRP 116 annex B, PDF pages 142–170, lists the picogray (pGy) values, which are absorbed dose per unit fluence (i.e., similar to rad per photon per square centimeter (cm^2), or ergs per photon per cm^2). These values are called "dose conversion coefficients" in ICRP 116 (PDF p. 11). The DCC values are listed as a function of male or female organs and exposure geometries of AP, ROT, and ISO (which are of interest in dose reconstruction) for a photon energy range of 0.01–10 MeV.

Neutrons
ICRP-116 annex C, PDF pages 174–203, lists the pGy values, which are absorbed dose, per unit fluence (i.e., similar to rad per neutron/cm^2, or ergs per neutron/cm^2). The DCC values are listed as a function of male or female organs and exposure geometries of AP, ROT, and ISO, for a neutron energy range of 1E-9 MeV–1E4 MeV.

3.4.2.2 RPRT-0069

Photons
RPRT-0069, table 3-2 (p. 11), lists the "Photon fluence conversion factors" (photon FCF) for photon energies ranging from 0.01 to 3.0 MeV. The values applicable to dose reconstruction are in the second column, personal deep dose equivalent divided by fluence (Hp(10)/ø), in units of picosievert (pSv)-cm^2). The values range from 0.065 to 10.950 pSv-cm^2. This is the dose equivalent per unit fluence (i.e., similar to rem per photon per cm^2).

Equation 3-2

This equation (reproduced here as equation 2) provides the resulting DCF obtained by dividing the photon DCC (pGy-cm^2) from ICRP 116 by the photon FCF (pSv-cm^2) from table 3-2, leaving a fraction with units of pGy/pSv. Therefore, this must be multiplied by the effective dose to absorbed dose factor (i.e., Sv/Gy, the quality factor or QF), which is 1.0 for photons in the dose reconstruction energy range. This results in pGy/pSv × pSv/pGy = a fraction without units, which is what is needed because the DCF is a unitless multiplying factor of dose (2,000 mrem in this case). The values in equation 2 are calculated assuming colon cancer, male, AP geometry, and a photon energy of 0.100 MeV.

$$Hp(10)\left(\frac{pGy}{pSv}\right) = \frac{ICRP\ 116\ Photon\ Organ\ Dose\ (pGy{-}cm^2)}{Photon\ Fluence\ Conversion\ Factor\ (pSv{-}cm^2)} \tag{2}$$

$$= 0.512 / 0.67$$

$$= 0.7776512$$

Although the review of RPRT-0069 is outside the scope of this review, SC&A was able to confirm that equation 2 is correctly using ICRP 116 photon organ dose and RPRT-0069 photon FCF.

Neutrons

RPRT-0069, table 3-3 (p. 12), lists the "Neutron fluence conversion factors" (neutron FCF) for neutron energies ranging from 1E-9 MeV to 20 MeV. The values applicable to DR are in the second column, Hp(10)/ø in units of pSv-cm^2. The values range from 8.19 to 600 pSv-cm^2. This is the dose equivalent per unit fluence (i.e., similar to rem per neutron per cm^2).

Equation 3-3

This equation (reproduced here as equation 3), provides the resulting DCF obtained by dividing the neutron DCC (pGy-cm^2) from ICRP-116 by the neutron FCF (pSv-cm^2) from table 3-3, leaving a fraction with units of pGy/pSv. Therefore, this must be multiplied by the effective dose to absorbed dose factor, which is w_R (equation 3-1 of RPRT-0069, p. 10), as a function of neutron energy. (However, ICRP Publication 74 (1996), table 2, PDF p. 15, provides an averaged w_R for 0.1–2.0 MeV neutrons of 20.) Multiplying equation 3-3 by w_R results in pGy/pSv × pSv/pGy = a fraction without units, which is what is needed because the DCF is a unitless multiplying factor of dose. The values in equation 3 are calculated assuming colon cancer, male, AP geometry, and an energy of 0.100 MeV neutrons.

$$Hp(10)\left(\frac{pGy}{pSv}\right) = \frac{ICRP\ 116\ Neutron\ Organ\ Dose\ (pGy - cm^2)}{Neutron\ Fluence\ Conversion\ Factor\ (pSv - cm^2)} \times w_R$$

$$= \frac{3.85}{90.6} \times \left\{5 + 17\ exp\left[\frac{-(ln\ (2\times 0.1))^2}{6}\right]\right\} = 0.681599 \tag{3}$$

Using the ICRP 116 neutron organ dose and RPRT-0069 neutron FCF, SC&A was able to calculate the same value shown in equation 3.

3.4.3 SC&A's evaluation of NIOSH's IREP exposure equation 2-1

SC&A evaluated NIOSH's equation for calculating doses for entry in IREP. Although NIOSH's equation (reproduced as equation 1 in this report), uses the term DCC in the calculation, SC&A found that it is more accurate to introduce the DCF value, which incorporates the DCC values as shown in equation 4.

$$\begin{aligned}\text{Dose equivalent (rem)} &= Dose\text{ (rem)} \times DCF \times IGF \\ &= Dose\text{ (rem)} \times [(DCC \times 1/FCF) \times (QF \text{ or } w_R)] \times IGF \qquad (4)\end{aligned}$$

where:

DCC = the dose conversion coefficient in units of pGy-cm^2 from ICRP 116 annex B for photons and annex C for neutrons.

FCF = the fluence conversion factor in units of pSv-cm^2 from RPRT-0069 table 3-2 for photons and table 3-3 for neutrons.

QF = the quality factor (or weighting factor, w_R,), which is 1 for photons and an average of 20 for 0.1–2.0 MeV neutrons, in units of pSv/pGy.

IGF = the irradiation geometry factor, which is a function of four dosimeter badge positions.

3.4.4 SC&A's DCF values

As stated in section 2-1, NIOSH employed Monte Carlo methods for calculating doses to be entered in IREP. For evaluating POC values, SC&A did not use Monte Carlo techniques for calculating doses but derived an average DCF values from data in RPRT-0069, attachments A and B. Attachment A of RPRT-0069 lists photon organ DCF values for AP, PA, ROT, and ISO geometries for all ICRP 116 cancers. The photon DCFs are separated into 20 energies within the range 0.01 MeV through 3 MeV. Attachment B lists the neutron organ DCF values divided into 33 energies within the range 1.0E-9 through 2 MeV.

Since RPRT-0069 gives photon DCF values for 0.2 MeV and 0.3 MeV photons, SC&A averaged those values to derive the 250 keV photon energy DCF. Then, SC&A derived a 30–250 keV photon DCF value using the eight DCF energies listed in RPRT-0069 along with the arithmetic mean of the 0.2 MeV and 0.3 MeV photon DCFs. SC&A also used the 10 DCF energy values from RPRT-0069 attachment B to calculate an average 0.1–2 MeV neutron DCF. Tables 6 and 7 show the resulting photon and neutron DCF values, respectively, for the eight female and eight male cancers for the AP, ROT, and ISO geometries.

Table 6. SC&A's 30–250 keV photon DCFs based on RPRT-0069

Organ	Adult female AP DCF	Adult female ROT DCF	Adult female ISO DCF	Adult male AP DCF	Adult male ROT DCF	Adult male ISO DCF
Lung	0.5972	0.4683	0.3777	0.6120	0.4103	0.3379
Esophagus	0.6820	0.4318	0.3152	0.5573	0.3820	0.2897
RBM	0.6330	0.5267	0.4198	0.5816	0.4832	0.3853
Adrenals	0.3260	0.2667	0.3910	0.2765	0.3796	0.2866
UB-wall	0.8814	0.4317	0.3508	0.7252	0.3937	0.2954
Breast	0.8202	0.4769	0.4288	0.8308	0.4677	0.4380
Thymus	0.8778	0.4403	0.3676	0.8727	0.4327	0.3539
Prostate	NA	NA	NA	0.5432	0.3541	0.2711
Uterus	0.5604	0.3557	0.2770	NA	NA	NA

Table 7. SC&A's 0.1–2 MeV neutron DCFs based on RPRT-0069

Organ	Adult female AP DCF	Adult female ROT DCF	Adult female ISO DCF	Adult male AP DCF	Adult male ROT DCF	Adult male ISO DCF
Lung	0.4887	0.3653	0.2800	0.5439	0.3378	0.2654
Esophagus	0.5417	0.3468	0.2551	0.5155	0.3267	0.2397
RBM	0.4452	0.3435	0.2641	0.4273	0.3435	0.2627
Adrenals	0.3341	0.3119	0.2169	0.2137	0.3100	0.2203
UB-wall	0.9220	0.3662	0.2801	0.6675	0.3067	0.2211
Breast	1.2789	0.6185	0.5401	1.4138	0.6811	0.6183
Thymus	0.9940	0.3928	0.3044	1.0410	0.4172	0.3241
Prostate	NA	NA	NA	0.5009	0.2741	0.1982
Uterus	0.4931	0.2676	0.1988	NA	NA	NA

3.4.5 SC&A's POC values

Using IGF values for the LCP and LC from tables 1 through 4 of this report and AP, ISO, and ROT DCF values from tables 6 and 7, SC&A generated POC values assuming a 2.000 rem measured 30–250 keV photon dose per year for 5 years and a 2.000 rem measured 0.1–2.0 MeV neutron dose per year for 5 years. SC&A calculated the POCs using IREP-EE v.5.9 and entered doses in IREP as a normal dose distribution with a geometric standard deviation (GSD) of 30 percent.

Tables 8 through 11 compare SC&A's and NIOSH's POC values generated for 30–250 keV photons and 0.1–2.0 MeV neutrons for the eight female and eight male cancers.

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

Table 8. Comparison of SC&A POC values and NIOSH POC values for eight female organs for photon energies 30–250 keV

Geometry/dosimeter location/female organ	**SC&A photon DCF**	**SC&A photon IGF**	**SC&A photon dose (rem)**	**NIOSH RPRT-0085 POC**	**SC&A calculated POC**	***Ratio of SC&A to NIOSH POC***
AP/LCP/Adrenals	0.3260	1.00	**0.652**	22.78%	18.41%	***0.81***
ISO/LCP/Adrenals	0.3910	1.48	**1.157**	36.00%	29.48%	***0.82***
ROT/LCP/Adrenals	0.2667	1.48	**0.789**	27.06%	21.96%	***0.81***
AP/LC/Adrenals	0.3260	1.00	**0.652**	22.77%	18.41%	***0.81***
ISO/LC/Adrenals	0.3910	1.91	**1.494**	40.73%	35.43%	***0.87***
ROT/LC/Adrenals	0.2667	1.91	**1.019**	30.98%	26.76%	***0.86***
AP/LCP/Breast	0.8202	1.00	**1.640**	24.91%	23.39%	***0.94***
ISO/LCP/Breast	0.4288	1.48	**1.269**	20.99%	18.91%	***0.90***
ROT/LCP/Breast	0.4769	1.48	**1.412**	23.07%	20.70%	***0.90***
AP/LC/Breast	0.8202	1.00	**1.640**	24.82%	23.39%	***0.94***
ISO/LC/Breast	0.4288	1.91	**1.638**	25.57%	23.37%	***0.91***
ROT/LC/Breast	0.4769	1.91	**1.822**	26.52%	25.41%	***0.96***
AP/LCP/Lung	0.5972	1.00	**1.194**	54.03%	50.64%	***0.94***
ISO/LCP/Lung	0.3777	1.48	**1.118**	52.99%	48.88%	***0.92***
ROT/LCP/Lung	0.4683	1.48	**1.386**	58.46%	54.66%	***0.93***
AP/LC/Lung	0.5972	1.00	**1.194**	53.98%	50.64%	***0.94***
ISO/LC/Lung	0.3777	1.91	**1.443**	59.39%	55.07%	***0.93***
ROT/LC/Lung	0.4683	1.91	**1.789**	62.66%	61.23%	***0.98***
AP/LCP/Esophagus	0.6820	1.00	**1.364**	34.22%	31.01%	***0.91***
ISO/LCP/Esophagus	0.3152	1.48	**0.933**	26.90%	22.86%	***0.85***
ROT/LCP/Esophagus	0.4318	1.48	**1.278**	34.00%	29.50%	***0.87***
AP/LC/Esophagus	0.6820	1.00	**1.364**	34.45%	31.01%	***0.90***
ISO/LC/Esophagus	0.3152	1.91	**1.204**	32.23%	28.17%	***0.87***
ROT/LC/Esophagus	0.4318	1.91	**1.650**	38.42%	25.27%	***0.66***
AP/LCP/Uterus	0.5604	1.00	**1.121**	0.72%	0.57%	***0.79***
ISO/LCP/Uterus	0.2770	1.48	**0.820**	0.51%	0.40%	***0.78***
ROT/LCP/Uterus	0.3557	1.48	**1.053**	0.68%	0.53%	***0.78***
AP/LC/Uterus	0.5604	1.00	**1.121**	0.71%	0.57%	***0.80***
ISO/LC/Uterus	0.2770	1.91	**1.058**	0.67%	0.53%	***0.79***
ROT/LC/Uterus	0.3557	1.91	**1.359**	0.84%	0.72%	***0.86***
AP/LCP/RBM-Leuk	0.6330	1.00	**1.266**	79.08%	64.26%	***0.81***
ISO/LCP/RBM-Leuk	0.4198	1.48	**1.243**	78.76%	63.81%	***0.81***
ROT/LCP/RBM-Leuk	0.5267	1.48	**1.559**	82.62%	69.19%	***0.84***
AP/LC/RBM-Leuk	0.6330	1.00	**1.266**	79.03%	64.26%	***0.81***
ISO/LC/RBM-Leuk	0.4198	1.91	**1.604**	82.89%	69.84%	***0.84***
ROT/LC/RBM-Leuk	0.5267	1.91	**2.012**	85.25%	74.77%	***0.88***
AP/LCP/Thymus	0.8778	1.00	**1.756**	21.00%	19.63%	***0.93***

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

Geometry/dosimeter location/female organ	SC&A photon DCF	SC&A photon IGF	SC&A photon dose (rem)	NIOSH RPRT-0085 POC	SC&A calculated POC	*Ratio of SC&A to NIOSH POC*
ISO/LCP/Thymus	0.3676	1.48	**1.088**	14.62%	12.51%	***0.86***
ROT/LCP/Thymus	0.4403	1.48	**1.303**	17.20%	14.91%	***0.87***
AP/LC/Thymus	0.8778	1.00	**1.756**	20.94%	19.63%	***0.94***
ISO/LC/Thymus	0.3676	1.91	**1.404**	18.29%	15.99%	***0.87***
ROT/LC/Thymus	0.4403	1.91	**1.682**	20.07%	18.89%	***0.94***
AP/LCP/UB-Wall	0.8814	1.00	**1.763**	39.66%	37.90%	***0.96***
ISO/LCP/UB-Wall	0.3508	1.48	**1.038**	28.91%	25.67%	***0.89***
ROT/LCP/UB-Wall	0.4317	1.48	**1.278**	33.38%	30.25%	***0.91***
AP/LC/UB-Wall	0.8814	1.00	**1.763**	39.77%	37.90%	***0.95***
ISO/LC/UB-Wall	0.3508	1.91	**1.340**	34.42%	31.33%	***0.91***
ROT/LC/UB-Wall	0.4317	1.91	**1.649**	37.79%	36.24%	***0.96***

Table 9. Comparison of SC&A POC values and NIOSH POC values for eight male organs for photon energies 30–250 keV

Geometry/dosimeter location/male organ	SC&A photon DCF	SC&A photon IGF	SC&A photon dose (rem)	NIOSH RPRT-0085 POC	SC&A calculated POC	*Ratio of SC&A to NIOSH POC*
AP/LCP/Adrenals	0.2765	1.00	**0.553**	10.46%	7.93%	***0.76***
ISO/LCP/Adrenals	0.2866	1.55	**0.888**	15.62%	12.58%	***0.81***
ROT/LCP/Adrenals	0.3796	1.57	**1.192**	19.86%	16.50%	***0.83***
AP/LC/Adrenals	0.2765	1.00	**0.553**	10.41%	7.93%	***0.76***
ISO/LC/Adrenals	0.2866	1.87	**1.072**	18.16%	14.08%	***0.78***
ROT/LC/Adrenals	0.3796	1.75	**1.328**	21.44%	18.15%	***0.85***
AP/LCP/Breast	0.8308	1.00	**1.662**	28.07%	26.53%	***0.95***
ISO/LCP/Breast	0.4380	1.55	**1.358**	24.53%	22.64%	***0.92***
ROT/LCP/Breast	0.4677	1.57	**1.469**	26.39%	24.11%	***0.91***
AP/LC/Breast	0.8308	1.00	**1.662**	27.94%	26.53%	***0.95***
ISO/LC/Breast	0.4380	1.87	**1.638**	28.10%	26.24%	***0.93***
ROT/LC/Breast	0.4677	1.75	**1.637**	28.36%	26.23%	***0.92***
AP/LCP/Lung	0.6120	1.00	**1.224**	30.98%	27.97%	***0.90***
ISO/LCP/Lung	0.3379	1.55	**1.048**	28.91%	24.70%	***0.85***
ROT/LCP/Lung	0.4103	1.57	**1.288**	33.10%	29.13%	***0.88***
AP/LC/Lung	0.6120	1.00	**1.224**	30.91%	27.97%	***0.90***
ISO/LC/Lung	0.3379	1.87	**1.264**	32.85%	28.71%	***0.87***
ROT/LC/Lung	0.4103	1.75	**1.436**	35.61%	31.56%	***0.89***
AP/LCP/Esophagus	0.5573	1.00	**1.115**	20.87%	18.10%	***0.87***
ISO/LCP/Esophagus	0.2897	1.55	**0.898**	18.33%	14.87%	***0.81***
ROT/LCP/Esophagus	0.3820	1.57	**1.199**	23.21%	19.32%	***0.83***

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

Geometry/dosimeter location/male organ	**SC&A photon DCF**	**SC&A photon IGF**	**SC&A photon dose (rem)**	**NIOSH RPRT-0085 POC**	**SC&A calculated POC**	***Ratio of SC&A to NIOSH POC***
AP/LC/Esophagus	0.5573	1.00	**1.115**	20.81%	18.10%	***0.87***
ISO/LC/Esophagus	0.2897	1.87	**1.083**	21.37%	17.62%	***0.82***
ROT/LC/Esophagus	0.3820	1.75	**1.337**	25.21%	21.25%	***0.84***
AP/LCP/Prostate	0.5432	1.00	**1.086**	12.36%	9.92%	***0.80***
ISO/LCP/Prostate	0.2711	1.55	**0.840**	9.79%	7.63%	***0.78***
ROT/LCP/Prostate	0.3541	1.57	**1.112**	12.71%	10.16%	***0.80***
AP/LC/Prostate	0.5432	1.00	**1.086**	12.37%	9.92%	***0.80***
ISO/LC/Prostate	0.2711	1.87	**1.014**	11.67%	9.25%	***0.79***
ROT/LC/Prostate	0.3541	1.75	**1.239**	14.04%	11.32%	***0.81***
AP/LCP/RBM-Leuk	0.5816	1.00	**1.163**	79.77%	64.82%	***0.81***
ISO/LCP/RBM-Leuk	0.3853	1.55	**1.194**	80.61%	65.45%	***0.81***
ROT/LCP/RBM-Leuk	0.4832	1.57	**1.517**	84.12%	70.99%	***0.84***
AP/LC/RBM-Leuk	0.5816	1.00	**1.163**	79.70%	64.82%	***0.81***
ISO/LC/RBM-Leuk	0.3853	1.87	**1.441**	83.84%	69.84%	***0.83***
ROT/LC/RBM-Leuk	0.4832	1.75	**1.691**	85.50%	73.35%	***0.86***
AP/LCP/Thymus	0.8727	1.00	**1.745**	10.85%	10.02%	***0.92***
ISO/LCP/Thymus	0.3539	1.55	**1.097**	7.57%	6.25%	***0.83***
ROT/LCP/Thymus	0.4327	1.57	**1.359**	9.15%	7.80%	***0.85***
AP/LC/Thymus	0.8727	1.00	**1.745**	10.92%	10.02%	***0.92***
ISO/LC/Thymus	0.3539	1.87	**1.323**	9.03%	7.59%	***0.84***
ROT/LC/Thymus	0.4327	1.75	**1.515**	10.10%	8.71%	***0.86***
AP/LCP/UB-Wall	0.7252	1.00	**1.450**	20.13%	17.78%	***0.88***
ISO/LCP/UB-Wall	0.2954	1.55	**0.916**	14.17%	11.63%	***0.82***
ROT/LCP/UB-Wall	0.3937	1.57	**1.236**	18.25%	15.42%	***0.84***
AP/LC/UB-Wall	0.7252	1.00	**1.450**	20.09%	17.78%	***0.89***
ISO/LC/UB-Wall	0.2954	1.87	**1.105**	16.65%	13.90%	***0.83***
ROT/LC/UB-Wall	0.3937	1.75	**1.378**	19.65%	17.02%	***0.87***

Table 10. Comparison of SC&A POC values and NIOSH POC values for eight female organs for neutron energies 0.1–2 MeV

Geometry/dosimeter location/female organ	**SC&A neutron DCF**	**SC&A neutron IGF**	**SC&A neutron dose (rem)**	**NIOSH RPRT-0085 POC**	**SC&A calculated POC**	***Ratio of SC&A to NIOSH POC***
AP/LCP/Adrenals	0.3341	1.00	**0.668**	11.03%	11.15%	**1.01**
ISO/LCP/Adrenals	0.2169	1.49	**0.646**	11.40%	10.82%	**0.95**
ROT/LCP/Adrenals	0.3119	1.49	**0.929**	15.79%	14.85%	**0.94**
AP/LC/Adrenals	0.3341	1.00	**0.668**	11.04%	11.15%	**1.01**
ISO/LC/Adrenals	0.2169	1.79	**0.776**	14.90%	12.72%	**0.85**

Geometry/dosimeter location/female organ	**SC&A neutron DCF**	**SC&A neutron IGF**	**SC&A neutron dose (rem)**	**NIOSH RPRT-0085 POC**	**SC&A calculated POC**	***Ratio of SC&A to NIOSH POC***
ROT/LC/Adrenals	0.3119	1.79	**1.117**	18.92%	17.34%	**0.92**
AP/LCP/Breast	1.2789	1.00	**2.558**	19.17%	18.66%	**0.97**
ISO/LCP/Breast	0.5401	1.49	**1.610**	14.19%	12.62%	**0.89**
ROT/LCP/Breast	0.6185	1.49	**1.843**	15.64%	14.18%	**0.91**
AP/LC/Breast	1.2789	1.00	**2.558**	19.24%	18.66%	**0.97**
ISO/LC/Breast	0.5401	1.79	**1.934**	18.33%	14.78%	**0.81**
ROT/LC/Breast	0.6185	1.79	**2.214**	18.76%	16.57%	**0.88**
AP/LCP/Lung	0.4887	1.00	**0.977**	31.21%	29.09%	**0.93**
ISO/LCP/Lung	0.2800	1.49	**0.834**	28.93%	25.93%	**0.90**
ROT/LCP/Lung	0.3653	1.49	**1.089**	34.60%	31.37%	**0.91**
AP/LC/Lung	0.4887	1.00	**0.977**	31.43%	29.09%	**0.93**
ISO/LC/Lung	0.2800	1.79	**1.002**	35.73%	29.61%	**0.83**
ROT/LC/Lung	0.3653	1.79	**1.308**	39.73%	35.45%	**0.89**
AP/LCP/Esophagus	0.5417	1.00	**1.083**	15.64%	14.54%	**0.93**
ISO/LCP/Esophagus	0.2551	1.49	**0.760**	11.76%	10.66%	**0.91**
ROT/LCP/Esophagus	0.3468	1.49	**1.034**	15.27%	13.97%	**0.91**
AP/LC/Esophagus	0.5417	1.00	**1.083**	15.52%	14.54%	**0.94**
ISO/LC/Esophagus	0.2551	1.79	**0.913**	15.28%	12.54%	**0.82**
ROT/LC/Esophagus	0.3468	1.79	**1.242**	18.42%	16.32%	**0.89**
AP/LCP/Uterus	0.4931	1.00	**0.986**	0.21%	0.20%	**0.95**
ISO/LCP/Uterus	0.1988	1.49	**0.592**	0.13%	0.12%	**0.92**
ROT/LCP/Uterus	0.2676	1.49	**0.797**	0.17%	0.16%	**0.94**
AP/LC/Uterus	0.4931	1.00	**0.986**	0.21%	0.20%	**0.95**
ISO/LC/Uterus	0.1988	1.79	**0.712**	0.17%	0.15%	**0.88**
ROT/LC/Uterus	0.2676	1.79	**0.958**	0.21%	0.20%	**0.95**
AP/LCP/RBM-Leuk	0.4452	1.00	**0.890**	69.60%	54.51%	**0.78**
ISO/LCP/RBM-Leuk	0.2641	1.49	**0.787**	68.05%	51.45%	**0.76**
ROT/LCP/RBM-Leuk	0.3435	1.49	**1.024**	73.77%	57.96%	**0.79**
AP/LC/RBM-Leuk	0.4452	1.00	**0.890**	69.58%	54.51%	**0.78**
ISO/LC/RBM-Leuk	0.2641	1.79	**0.945**	74.31%	55.99%	**0.75**
ROT/LC/RBM-Leuk	0.3435	1.79	**1.230**	77.51%	62.35%	**0.80**
AP/LCP/Thymus	0.9940	1.00	**1.988**	11.65%	10.69%	**0.92**
ISO/LCP/Thymus	0.3044	1.49	**0.907**	5.94%	5.18%	**0.87**
ROT/LCP/Thymus	0.3928	1.49	**1.171**	7.38%	6.59%	**0.89**
AP/LC/Thymus	0.9940	1.00	**1.988**	11.65%	10.69%	**0.92**
ISO/LC/Thymus	0.3044	1.79	**1.090**	7.84%	6.16%	**0.79**
ROT/LC/Thymus	0.3928	1.79	**1.406**	9.03%	7.18%	**0.80**
AP/LCP/UB-Wall	0.9220	1.00	**1.844**	25.40%	23.66%	**0.93**
ISO/LCP/UB-Wall	0.2801	1.49	**0.835**	13.34%	12.31%	**0.92**
ROT/LCP/UB-Wall	0.3662	1.49	**1.091**	16.65%	15.50%	**0.93**

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

Geometry/dosimeter location/female organ	SC&A neutron DCF	SC&A neutron IGF	SC&A neutron dose (rem)	NIOSH RPRT-0085 POC	SC&A calculated POC	*Ratio of SC&A to NIOSH POC*
AP/LC/UB-Wall	0.9220	1.00	**1.844**	25.45%	23.66%	**0.93**
ISO/LC/UB-Wall	0.2801	1.79	**1.003**	17.39%	14.43%	**0.83**
ROT/LC/UB-Wall	0.3662	1.79	**1.311**	19.90%	18.06%	**0.91**

Table 11. Comparison of SC&A POC values and NIOSH POC values for eight male organs for neutron energies 0.1–2 MeV

Geometry/dosimeter location/male organ	SC&A neutron DCF	SC&A neutron IGF	SC&A neutron dose (rem)	NIOSH RPRT-0085 POC	SC&A calculated POC	*Ratio of SC&A to NIOSH POC*
AP/LCP/Adrenals	0.2137	1.00	**0.427**	3.21%	3.52%	***1.10***
ISO/LCP/Adrenals	0.2203	1.61	**0.709**	5.87%	5.71%	***0.97***
ROT/LCP/Adrenals	0.3100	1.63	**1.011**	8.05%	7.94%	***0.99***
AP/LC/Adrenals	0.2137	1.00	**0.427**	3.21%	3.52%	***1.10***
ISO/LC/Adrenals	0.2203	2.03	**0.894**	7.24%	7.09%	***0.98***
ROT/LC/Adrenals	0.3100	1.84	**1.141**	9.03%	8.87%	***0.98***
AP/LCP/Breast	1.4138	1.00	**2.828**	23.72%	23.44%	***0.99***
ISO/LCP/Breast	0.6183	1.61	**1.991**	18.90%	17.73%	***0.94***
ROT/LCP/Breast	0.6811	1.63	**2.220**	20.18%	19.38%	***0.96***
AP/LC/Breast	1.4138	1.00	**2.828**	23.76%	23.44%	***0.99***
ISO/LC/Breast	0.6183	2.03	**2.510**	22.69%	21.37%	***0.94***
ROT/LC/Breast	0.6811	1.84	**2.507**	22.31%	21.35%	***0.96***
AP/LCP/Lung	0.5439	1.00	**1.088**	16.14%	14.30%	***0.89***
ISO/LCP/Lung	0.2654	1.61	**0.855**	12.40%	11.60%	***0.94***
ROT/LCP/Lung	0.3378	1.63	**1.101**	15.28%	14.45%	***0.95***
AP/LC/Lung	0.5439	1.00	**1.088**	15.24%	14.30%	***0.94***
ISO/LC/Lung	0.2654	2.03	**1.078**	15.04%	14.19%	***0.94***
ROT/LC/Lung	0.3378	1.84	**1.243**	17.00%	16.01%	***0.94***
AP/LCP/Esophagus	0.5155	1.00	**1.031**	9.37%	9.03%	***0.96***
ISO/LCP/Esophagus	0.2397	1.61	**0.772**	7.13%	6.92%	***0.97***
ROT/LCP/Esophagus	0.3267	1.63	**1.065**	9.56%	9.30%	***0.97***
AP/LC/Esophagus	0.5155	1.00	**1.031**	9.33%	9.03%	***0.97***
ISO/LC/Esophagus	0.2397	2.03	**0.973**	8.77%	8.57%	***0.98***
ROT/LC/Esophagus	0.3267	1.84	**1.202**	10.67%	10.37%	***0.97***
AP/LCP/Prostate	0.5009	1.00	**1.002**	4.70%	4.53%	***0.96***
ISO/LCP/Prostate	0.1982	1.61	**0.638**	2.96%	2.93%	***0.99***
ROT/LCP/Prostate	0.2741	1.63	**0.894**	4.11%	4.06%	***0.99***
AP/LC/Prostate	0.5009	1.00	**1.002**	4.68%	4.53%	***0.97***
ISO/LC/Prostate	0.1982	2.03	**0.804**	3.69%	3.67%	***0.99***

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

Geometry/dosimeter location/male organ	**SC&A neutron DCF**	**SC&A neutron IGF**	**SC&A neutron dose (rem)**	**NIOSH RPRT-0085 POC**	**SC&A calculated POC**	***Ratio of SC&A to NIOSH POC***
ROT/LC/Prostate	0.2741	1.84	**1.009**	4.61%	4.56%	***0.99***
AP/LCP/RBM-Leuk	0.4273	1.00	**0.855**	71.08%	56.53%	***0.80***
ISO/LCP/RBM-Leuk	0.2627	1.61	**0.846**	71.24%	56.27%	***0.79***
ROT/LCP/RBM-Leuk	0.3435	1.63	**1.120**	76.39%	63.01%	***0.82***
AP/LC/RBM-Leuk	0.4273	1.00	**0.855**	70.98%	56.53%	***0.80***
ISO/LC/RBM-Leuk	0.2627	2.03	**1.067**	75.55%	61.88%	***0.82***
ROT/LC/RBM-Leuk	0.3435	1.84	**1.264**	78.67%	65.79%	***0.84***
AP/LCP/Thymus	1.0410	1.00	**2.082**	5.80%	5.44%	***0.94***
ISO/LCP/Thymus	0.3241	1.61	**1.044**	3.02%	2.81%	***0.93***
ROT/LCP/Thymus	0.4172	1.63	**1.360**	3.91%	3.63%	***0.93***
AP/LC/Thymus	1.0410	1.00	**2.082**	5.82%	5.44%	***0.93***
ISO/LC/Thymus	0.3241	2.03	**1.316**	3.78%	3.51%	***0.93***
ROT/LC/Thymus	0.4172	1.84	**1.535**	4.38%	4.07%	***0.93***
AP/LCP/UB-Wall	0.6675	1.00	**1.335**	9.44%	8.98%	***0.95***
ISO/LCP/UB-Wall	0.2211	1.61	**0.712**	6.09%	5.00%	***0.82***
ROT/LCP/UB-Wall	0.3067	1.63	**1.000**	7.05%	6.88%	***0.98***
AP/LC/UB-Wall	0.6675	1.00	**1.335**	9.43%	8.98%	***0.95***
ISO/LC/UB-Wall	0.2211	2.03	**0.898**	6.35%	6.23%	***0.98***
ROT/LC/UB-Wall	0.3067	1.84	**1.129**	7.89%	7.70%	***0.98***

This comparison shows relatively close agreement between SC&A's POC values and those generated by NIOSH. Some difference in POC values was expected, since NIOSH used Monte Carlo methods to generate dose and SC&A used average values. With only a few exceptions, SC&A's values were less than NIOSH's POC values. SC&A has no findings or observations about NIOSH's RPRT-0085 POC values.

3.5 Dose-only analysis

3.5.1 NIOSH's dose analysis approach

In addition to determining POC values, NIOSH performed a dose-only analysis. This analysis assumed 500 mrem of measured dose and 500 mrem of missed dose combined with ICRP 116 DCCs and RPRT-0068 IGFs for the four dosimeter locations. Doses were derived by applying Monte Carlo methods for generating DCCs and IGFs. The measured dose was assumed to represent a normal distribution with a 30 percent error, and the missed dose was represented by a lognormal distribution with a GSD of 1.52.

3.5.2 SC&A's dose analysis approach

As a means of comparison, SC&A also calculated doses based on NIOSH's approach. However, since SC&A did not apply a Monte Carlo method, our dose equation was simplified as shown in equation 5:

$$\begin{aligned} \text{Total dose} &= (0.5 \text{ rem} \times \text{DCF} \times \text{IGF}) + (0.5 \text{ rem} \times \text{DCF} \times \text{IGF}) \\ &= 1 \text{ rem} \times \text{DCF} \times \text{IGF} \end{aligned} \tag{5}$$

Tables 12–15 compare SC&A and NIOSH doses generated for 30–250 keV photons and 0.1–2.0 MeV neutrons for the eight female and eight male cancers.

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

Table 12. Comparison of SC&A doses and NIOSH doses for eight female organs for 30–250 keV photons

Organ/ dosimeter location	SC&A AP dose (rem)	SC&A ISO dose (rem)	SC&A ROT dose (rem)	NIOSH AP dose (rem)	NIOSH ISO dose (rem)	NIOSH ROT dose (rem)	Percentage AP SC&A/ NIOSH	Percentage ISO SC&A/ NIOSH	Percentage ROT SC&A/ NIOSH
Lung/LCP	0.5972	0.5598	0.6955	0.769	0.749	0.917	77.66%	74.74%	75.84%
Esophagus/LCP	0.6820	0.4671	0.6413	0.810	0.580	0.795	84.20%	80.54%	80.67%
RBM/LCP	0.6330	0.6222	0.7822	0.729	0.723	0.908	86.83%	86.05%	86.15%
Adrenals/LCP	0.3260	0.5796	0.3961	0.426	0.747	0.520	76.53%	77.59%	76.17%
UB-wall/LCP	0.8814	0.5200	0.6411	0.945	0.681	0.835	93.27%	76.35%	76.78%
Breast/LCP	0.8202	0.6355	0.7083	0.881	0.712	0.791	93.09%	89.26%	89.54%
Thymus/LCP	0.8778	0.5449	0.6539	0.949	0.733	0.875	92.50%	74.33%	74.73%
Uterus/LCP	0.5604	0.4106	0.5283	0.701	0.528	0.673	79.95%	77.76%	78.50%
Lung/LC	0.5972	0.7214	0.8381	0.668	0.943	1.096	89.41%	76.50%	76.47%
Esophagus/LC	0.6820	0.6019	0.7728	0.809	0.740	0.940	84.31%	81.34%	82.21%
RBM/LC	0.6330	0.8017	0.9426	0.729	1.008	1.078	86.83%	79.53%	87.44%
Adrenals/LC	0.3260	0.7468	0.4773	0.428	0.944	0.624	76.17%	79.11%	76.49%
UB-wall/LC	0.8814	0.6700	0.7725	0.949	0.862	0.991	92.88%	77.73%	77.95%
Breast/LC	0.8202	0.8189	0.8535	0.888	0.902	0.940	92.36%	90.79%	90.79%
Thymus/LC	0.8778	0.7021	0.7879	0.952	0.923	1.037	92.21%	76.07%	75.98%
Uterus/LC	0.5604	0.5291	0.6366	0.702	0.672	0.808	79.83%	78.73%	78.79%

Table 13. Comparison of SC&A doses and NIOSH doses for eight male organs for 30–250 keV photons

Organ/ dosimeter location	SC&A AP dose (rem)	SC&A ISO dose (rem)	SC&A ROT dose (rem)	NIOSH AP dose (rem)	NIOSH ISO dose (rem)	NIOSH ROT dose (rem)	Percentage AP SC&A/ NIOSH	Percentage ISO SC&A/ NIOSH	Percentage ROT SC&A/ NIOSH
Lung/LCP	0.6120	0.5249	0.6432	0.689	0.655	0.792	88.82%	80.14%	81.21%
Esophagus/LCP	0.5573	0.4499	0.5987	0.757	0.583	0.767	73.62%	77.17%	78.06%
RBM/LCP	0.5816	0.5984	0.7574	0.680	0.710	0.889	85.52%	84.28%	85.20%
Adrenals/LCP	0.2765	0.4451	0.5949	0.369	0.573	0.747	74.94%	77.69%	79.64%

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

Organ/ dosimeter location	SC&A AP dose (rem)	SC&A ISO dose (rem)	SC&A ROT dose (rem)	NIOSH AP dose (rem)	NIOSH ISO dose (rem)	NIOSH ROT dose (rem)	Percentage AP SC&A/ NIOSH	Percentage ISO SC&A/ NIOSH	Percentage ROT SC&A/ NIOSH
UB-wall/LCP	0.7252	0.4588	0.6170	0.860	0.576	0.765	84.32%	79.66%	80.66%
Breast/LCP	0.8308	0.6803	0.7331	0.893	0.746	0.813	93.04%	91.19%	90.17%
Thymus/LCP	0.8727	0.5496	0.6783	0.947	0.752	0.902	92.15%	73.09%	75.19%
Prostate/LCP	0.5432	0.4211	0.5550	0.701	0.548	0.718	77.49%	76.84%	77.29%
Lung/LC	0.6120	0.6334	0.7168	0.798	0.780	0.879	76.69%	81.21%	81.54%
Esophagus/LC	0.5573	0.5429	0.6672	0.752	0.694	0.946	74.10%	78.23%	70.53%
RBM/LC	0.5816	0.7221	0.8441	0.681	0.844	0.993	85.40%	85.56%	85.00%
Adrenals/LC	0.2765	0.5372	0.6630	0.369	0.677	0.831	74.94%	79.35%	79.78%
UB-wall/LC	0.7252	0.5537	0.6876	0.861	0.692	0.847	84.22%	80.01%	81.18%
Breast/LC	0.8308	0.8209	0.8170	0.891	0.893	0.895	93.25%	91.93%	91.28%
Thymus/LC	0.8727	0.6632	0.7559	0.951	0.894	1.005	91.77%	74.19%	75.21%
Prostate/LC	0.5432	0.5081	0.6185	0.696	0.654	0.793	78.05%	77.69%	77.99%

Table 14. Comparison of SC&A doses and NIOSH doses for eight female organs for 0.1–2.0 MeV neutrons

Organ/ Dosimeter location	SC&A AP dose (rem)	SC&A ISO dose (rem)	SC&A ROT dose (rem)	NIOSH AP dose (rem)	NIOSH ISO dose (rem)	NIOSH ROT dose (rem)	Percentage AP SC&A/ NIOSH	Percentage ISO SC&A/ NIOSH	Percentage ROT SC&A/ NIOSH
Lung/LCP	0.4887	0.4331	0.5678	0.535	0.472	0.623	91.35%	91.76%	91.13%
Esophagus/LCP	0.5417	0.3946	0.5390	0.586	0.418	0.573	92.44%	94.41%	94.07%
RBM/LCP	0.4452	0.4085	0.5339	0.466	0.436	0.570	95.54%	93.69%	93.66%
Adrenals/LCP	0.3341	0.3355	0.4847	0.330	0.339	0.494	101.23%	98.95%	98.12%
UB-wall/LCP	0.9220	0.4333	0.5692	1.006	0.462	0.597	91.65%	93.78%	95.35%
Breast/LCP	1.2789	0.8355	0.9612	1.356	0.926	1.046	94.31%	90.22%	91.90%
Thymus/LCP	0.9940	0.4709	0.6106	1.093	0.514	0.657	90.95%	91.62%	92.93%
Uterus/LCP	0.4931	0.3075	0.4159	0.512	0.307	0.416	96.31%	100.15%	99.97%
Lung/LC	0.4887	0.5971	0.7093	0.535	0.649	0.770	91.35%	92.00%	92.11%
Esophagus/LC	0.5417	0.5440	0.6734	0.582	0.572	0.712	93.08%	95.11%	94.58%

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

Organ/ Dosimeter location	SC&A AP dose (rem)	SC&A ISO dose (rem)	SC&A ROT dose (rem)	NIOSH AP dose (rem)	NIOSH ISO dose (rem)	NIOSH ROT dose (rem)	Percentage AP SC&A/ NIOSH	Percentage ISO SC&A/ NIOSH	Percentage ROT SC&A/ NIOSH
RBM/LC	0.4452	0.5631	0.6670	0.471	0.597	0.709	94.52%	94.32%	94.07%
Adrenals/LC	0.3341	0.4624	0.6055	0.328	0.462	0.616	101.85%	100.09%	98.30%
UB-wall/LC	0.9220	0.5973	0.7111	1.007	0.630	0.746	91.56%	94.80%	95.32%
Breast/LC	1.2789	1.1517	1.2008	1.355	1.273	1.304	94.38%	90.47%	92.09%
Thymus/LC	0.9940	0.6492	0.7627	1.094	0.699	0.817	90.86%	92.87%	93.36%
Uterus/LC	0.4931	0.4239	0.5195	0.511	0.419	0.515	96.50%	101.16%	100.87%

Table 15. Comparison of SC&A doses and NIOSH doses for eight male organs for 0.1–2.0 MeV neutrons

Organ/ Dosimeter location	SC&A AP dose (rem)	SC&A ISO dose (rem)	SC&A ROT dose (rem)	NIOSH AP dose (rem)	NIOSH ISO dose (rem)	NIOSH ROT dose (rem)	Percentage AP SC&A/ NIOSH	Percentage ISO SC&A/ NIOSH	Percentage ROT SC&A/ NIOSH
Lung/LCP	0.5439	0.4275	0.5518	0.586	0.461	0.585	92.81%	92.74%	94.33%
Esophagus/LCP	0.5155	0.3861	0.5337	0.541	0.396	0.550	95.29%	97.50%	97.04%
RBM/LCP	0.4273	0.4232	0.5610	0.444	0.445	0.586	96.24%	95.10%	95.74%
Adrenals/LCP	0.2137	0.3548	0.5064	0.194	0.362	0.513	110.14%	98.01%	98.72%
UB-wall/LCP	0.6675	0.3561	0.5010	0.697	0.362	0.508	95.76%	98.38%	98.63%
Breast/LCP	1.4138	0.9959	1.1126	1.470	1.085	1.181	96.17%	91.79%	94.21%
Thymus/LCP	1.0410	0.5220	0.6815	1.121	0.561	0.730	92.86%	93.06%	93.35%
Prostate/LCP	0.5009	0.3192	0.4478	0.511	0.317	0.442	98.03%	100.68%	101.31%
Lung/LC	0.5439	0.5384	0.6221	0.583	0.574	0.665	93.29%	93.79%	93.54%
Esophagus/LC	0.5155	0.4862	0.6017	0.543	0.498	0.618	94.94%	97.63%	97.36%
RBM/LC	0.4273	0.5329	0.6324	0.442	0.561	0.666	96.67%	94.99%	94.96%
Adrenals/LC	0.2137	0.4468	0.5709	0.193	0.455	0.581	110.71%	98.19%	98.26%
UB-wall/LC	0.6675	0.4485	0.5648	0.708	0.454	0.575	94.28%	98.78%	98.22%
Breast/LC	1.4138	1.2540	1.2542	1.464	1.374	1.345	96.57%	91.27%	93.25%
Thymus/LC	1.0410	0.6574	0.7682	1.125	0.707	0.826	92.53%	92.98%	93.00%
Prostate/LC	0.5009	0.4019	0.5048	0.509	0.396	0.498	98.41%	101.49%	101.36%

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

This comparison shows relatively close agreement between SC&A's doses and those generated by NIOSH. Some difference in dose was expected, since NIOSH used Monte Carlo methods and SC&A used average values. With only a few exceptions, SC&A's photon and neutron doses were less than NIOSH's doses.

As expected, SC&A's dose calculations for AP geometry are the same for the LCP as for the LC badge location. This is due to applying an IGF value of 1.0 because radiation beam is perpendicular (incident angle = 0) for the AP geometry. SC&A checked a subset of RPRT-0085 attachment C organ doses and found that, in general, the 30–250 keV photon Hp(10) doses and neutron doses are within a few percentage points of each other for the four different badge positions. However, SC&A did notice for the male lung that the AP photon dose was different for the LCP (0.689 rem vs. about 0.798 rem for the other positions) and that the female lung AP photon dose was different for the LC (0.668 rem vs. about 0.769 rem for the other positions).

Since NIOSH used MCNP and 4-point averaging for each of their runs, this may explain the small variance in the dose results. However, for the female and male lung, the difference in AP geometries for the four badge positions appears excessive, as discussed in observation 2. SC&A also noticed some difference for the male small intestine (SI) wall AP doses on p. 85 of RPRT-0085 for the LCP dosimeter position; there may be others, but because of the large amount of data, SC&A did not check them all.

Observation 2: SC&A questions why NIOSH's AP doses for a few cancers deviate beyond expected values

SC&A cannot explain why NIOSH's AP doses differ beyond a few percentage points, since the IGF values are 1.0. Although SC&A did not assess all ICRP 116 cancers, we did note that the female and male lung as well as the male SI-wall appeared to deviate beyond what is considered normal. Table 16 shows the percentage difference between the female and male AP geometry doses for those cancers assessed by SC&A.

Table 16. LCP-to-LC ratios for the AP doses in RPRT-0085, attachment C, for the nine cancers assessed by SC&A

Organ	Female AP	Male AP
Lung	1.15	0.86
Esophagus	1.00	1.00
RBM	1.00	0.99
Adrenals	0.99	1.00
UB-wall	0.	0.99
Breast	0.99	1.00
Thymus	0.99	0.99
Prostate	NA	1.00
Uterus	0.99	NA

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

3.6 Documentation

SC&A evaluated the documentation used in RPRT-0085 for evaluating when an exposure geometry other than AP should be considered during the dose reconstruction process. SC&A found that NIOSH's explanation of their approach and methods were relatively brief, and their calculations relied on several supporting documents. To gain an understanding of NIOSH's process, SC&A needed to spend a relatively lengthy period of time evaluating the data used in the supporting documents.

In addition, SC&A found some key terminology to be confusing and inconsistent, as discussed in observation 3.

Observation 3: NIOSH used the terms "DCC" and "DCF" incorrectly

It appears that RPRT-0085 is using the terms "DCC" and "DCF" inconsistently and incorrectly. RPRT-0085 equation 2-1 (p. 12) uses the term "DCC" incorrectly because the dose conversion coefficients in ICRP 116 have units of pGy-cm^2 and, therefore, need to be divided by the fluence conversion factor as shown in equations 3-2 and 3-3 of RPRT-0069 (p. 11). Therefore, the "DCC" in equation 2-1 of RPRT-0085 should be DCF, not DCC.

Additionally, the title of RPRT-0069, "Updated ICRP 116 Dose Conversion Factors and Comparison to ICRP 74 Dose Conversion Factors," appears to be incorrect because a search of ICRP 116 does not show that it uses the terms "dose conversion factor" or "DCF." Therefore, a more accurate title for RPRT-0069 would appear to be, "Updated ICRP 116 Dose Conversion Coefficients and Comparison to ICRP 74 Dose Conversion Coefficients."

4 Summary Conclusions

SC&A evaluated the technical approach, methods, and documentation in RPRT-0085, revision 00 (NIOSH, 2017). SC&A assessed POC values and doses for eight female and eight male cancers listed in ICRP 116. SC&A's POC values and doses were in relatively close agreement with those derived by NIOSH. However, SC&A did have three observations:

- **Observation 1**: Using NIOSH's RPRT-0085 IGF values, SC&A's mean IGF values for several neutron ROT and ISO dosimeter placements were generally about 20–25 percent less than those values listed in RPRT-0068.

- **Observation 2**: SC&A questions why several of NIOSH's AP doses differ beyond a few percentage points, since the IGF values are 1.0.

- **Observation 3:** It appears that RPRT-0085 is using the terms DCC and DCF inconsistently and incorrectly.

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*

5 References

International Commission on Radiological Protection. (1996). Conversion coefficients for use in radiological protection against external radiation (Publication 74). *Ann. ICRP, 26*(3-4).

International Commission on Radiological Protection. (2010). Conversion coefficients for radiological protection quantities for external radiation exposures (Publication 116). *Ann. ICRP, 40*(2-5).

National Institute for Occupational Safety and Health. (2002). *External dose reconstruction implementation guideline* (OCAS-IG-001, rev. 1).

National Institute for Occupational Safety and Health. (2007). External dose reconstruction implementation guideline (OCAS-IG-001, rev. 3). https://www.cdc.gov/niosh/ocas/pdfs/dr/oc-ig-001-r3.pdf

National Institute for Occupational Safety and Health. (2012). *Internal dosimetry organ, external dosimetry organ, and IREP model selection by ICD-9 code* (ORAUT-OTIB-0005, rev. 05). SRDB Ref ID 121336

National Institute for Occupational Safety and Health. (2016a). *Correction factors for use with ICRP Publication 116 isotropic and rotational dose conversion coefficients* (ORAUT-RPRT-0068, rev. 00). https://www.cdc.gov/niosh/ocas/pdfs/orau/oraurpts/or-rprt-68-r0-508.pdf

National Institute for Occupational Safety and Health. (2016b). *Updated ICRP 116 dose conversion factors and comparison to ICRP 74 dose conversion factors* (ORAUT-RPRT-0069, rev. 00). SRDB Ref. ID 153955

National Institute for Occupational Safety and Health. (2017). *Probability of causation evaluation of ICRP 116 anterior-posterior, isotropic, and rotational geometries* (ORAUT-RPRT-0085, rev. 00). https://www.cdc.gov/niosh/ocas/pdfs/orau/oraurpts/or-rprt-85-r0-508.pdf

SC&A, Inc. (2005). *The review of NIOSH/ORAUT procedures and methods used for dose reconstruction* (SCA-TR-Task3, rev. 0). https://www.cdc.gov/niosh/ocas/pdfs/abrwh/scarpts/sca-drprocs-r0.pdf

NOTICE: *This document has been reviewed to identify and redact any information that is protected by the Privacy Act 5 U.S.C. § 552a and has been cleared for distribution.*