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

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June 21, 2023

OCAS-IG-001 dose conversion factors

- SC&A's review of OCAS-IG-001 in 2005 determined that applying rotational (ROT) and isotropic (ISO) dose conversion factors (DCFs) could lead to an underestimate of external dose
- NIOSH directed dose reconstructors to use anterior-posterior (AP) geometry
- NIOSH determined for bone (red marrow and surface), esophagus, and lung the AP geometry for a dosimeter worn on chest was not most claimant favorable
- NIOSH developed ROT and ISO DCF correction factors for these organs

ORAUT-RPRT-0085 purpose

- NIOSH issued RPRT-0085 in anticipation of introducing International Commission on Radiological Protection Publication 116 (ICRP 116) dose conversion coefficients (DCCs) in the dose reconstruction process
- To determine if the ROT and ISO DCFs for bone (red marrow and surface), esophagus, and lung listed in IG-001, rev. 3, are still valid

RPRT-0085 overview

- For assessing the most claimant-favorable exposure geometries, NIOSH derived a probability of causation (POC) and dose for:
  - All ICRP 116 organs (33 IREP models)
  - Male and female
  - Neutrons (32 neutron energies) and photons (20 photon energies)
  - AP, ROT, and ISO geometries
  - Hp(10) (personal deep dose equivalent) and exposure dose
  - 4 dosimeter locations (center chest, left collar, center waist, left chest pocket)

RPRT-0085 POC calculations

- Calculated doses using irradiation geometry factors (IGFs) developed in ORAUT-RPRT-0068, rev. 00, “Correction Factors for Use with ICRP Publication 116 Isotropic and Rotational Dose Conversion Coefficients”
- IREP dose calculations assumed 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 mrem/year as a normal distribution with a 30% error

RPRT-0085 dose-only calculations

- Analysis assumed 500 mrem of measured dose and 500 mrem of missed dose
- Dose combined with ICRP 116 DCCs and RPRT-0068 IGFs for the four dosimeter locations using Monte Carlo methods
- DCC treated as a continuous distribution based on the method described in ORAUT-RPRT-0069, rev. 00, “Updated ICRP 116 Dose Conversion Factors and Comparison to ICRP 74 Dose Conversion Factors”

RPRT-0085 conclusions

- The data generated in RPRT-0085 did not yield the concise geometry determinations listed in table 4.1a of IG-001
- For most radiation types, organs, and dosimeter locations, the AP and ROT geometries were found to deliver the largest POC
- Exceptions included the female adrenals, for which ISO was more prominent for photons
- Dose-only results showed with few exceptions an overwhelming agreement between the dose and POC analysis results

SC&A's evaluation of RPRT-0085

- SC&A evaluated the technical approach and documentation NIOSH used to assess the most claimant-favorable exposure geometries
- 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
- These data were used without verification of their accuracy, since the assessment of these reports is beyond the scope of this review

SC&A's evaluation of IREP models

- SC&A compared the RPRT-0085, table 2-1 listed IREP models for ICRP 116 organs and tissues to those identified in ORAUT-OTIB-0005, rev. 05, "Internal Dosimetry Organ, External Dosimetry Organ, and IREP Model Selection by ICD-9 Code"
- SC&A concluded NIOSH's selection of associated IREP models agrees with those identified in OTIB-0005, rev. 05
- For the muscle, which is not specifically listed in OTIB-0005, SC&A considers NIOSH's selection of connective tissues to be appropriate

SC&A's evaluation of dosimeter locations

- SC&A considered the four dosimeter locations to be reasonable
- Center waist location may be less likely for energy employees
- 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 (LCP) or left collar (LC)

SC&A's evaluation of IGF values

- SC&A derived IGFs using an arithmetic mean value of the IGFs in RPRT-0085
  - IGFs were calculated for the typical IREP photon energies of <30 keV, 30–250 keV, and >250 keV
  - IGFs were calculated for neutron energy ranges of <10 keV, 10–100 keV, 100 keV–2 MeV, and 2–20 MeV
- SC&A compared its mean IGF values to those values in RPRT-0068
- For most energy ranges, SC&A IGF values derived from RPRT-0085 were within reasonable agreement of RPRT-0068 IGF values
- SC&A did identify deviations in several RPRT-0085 ROT and ISO neutron IGFs (observation 1)

SC&A's observation 1

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

- Using RPRT-0085 IGF values, SC&A's mean female and male IGF values for several neutron ROT and ISO dosimeter placements were generally about 20–25% less than values in RPRT-0068
- With only one exception (ROT center chest <10 keV), these differences were in the 2–20 MeV neutron energy region
- SC&A questions why NIOSH's RPRT-0085 IGF values differed from those in RPRT-0068, when NIOSH stated that RPRT-0068 was the basis for their IGFs

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
- 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 (left chest pocket and left collar), which were considered most likely dosimeter badge wear positions
- SC&A selected eight female and eight male cancers: lung, esophagus, red bone marrow (RBM) (leukemia), adrenals, bladder (upper bowel wall), breast, thymus, and prostate (male)/ovaries (female)

SC&A's method for assessing DCF values

- NIOSH calculated DCF values using Monte Carlo techniques and data from ICRP 116 and RPRT-0069
- To assess NIOSH's DCF values, SC&A calculated average DCF values using RPRT-0069
- This required SC&A to become familiar with data in ICRP 116 and RPRT-0069

Familiarization with ICRP 116

- ICRP 116 lists the picogray (pGy) values, which are absorbed dose per unit fluence (i.e., similar to rad per photon per cm^2)
- These values are called “dose conversion coefficients”
- DCC values are listed as a function of male or female organs and AP, ROT, and ISO exposure geometries
- DCCs are listed for 55 separate photon energies between the range 0.01–10 MeV
- For neutrons, DCCs are listed for 68 separate energies between 1.0E-9 and 10,000 MeV

Familiarization with ORAUT-RPRT-0069

- Report applies photon and neutron fluence conversion factors to ICRP 116 values to derive DCF values
- RPRT-0069 lists photon and neutron organ DCF values for AP, PA, ROT, and ISO geometries for all ICRP 116 cancers
- Photon DCFs are separated into 20 energies in the range of 0.01 MeV through 3 MeV
- Neutron DCFs divided into 33 energies in the range of 1.0E-9 through 2 MeV

SC&A's method for deriving DCF values

- SC&A reviewed RPRT-0069 photon and neutron example DCF equations and found them to be appropriate and correct with the exception of terminology
- 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
- SC&A derived a 30–250 keV photon DCF value using the 8 DCF energies listed in RPRT-0069 and the SC&A-calculated arithmetic mean of the 0.2 MeV and 0.3 MeV photon DCFs
- A mean neutron DCF value was calculated using the 10 DCF values listed within the range 0.1–2.0 MeV
- DCF values were derived for the 8 female and 8 male SC&A-selected organs

SC&A's method for deriving POC values

- SC&A used its derived IGF values for the LCP and LC and the AP, ISO, and ROT geometry DCF values
- SC&A generated POC values assuming a 2.000 rem measured 30–250 keV photon dose and 0.1–2.0 MeV neutron dose per year for 5 years
- SC&A calculated the POCs using IREP-EE v.5.9
- Doses were entered in IREP as normal dose distributions with a geometric standard deviation of 30%

SC&A's evaluation of POC values

- SC&A compared its POC values to NIOSH's POC values
- Comparison showed close agreement between POC values
- Some difference was expected, since NIOSH used Monte Carlo methods and SC&A used average values to estimate dose
- 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 POC values

SC&A's method for deriving dose-only values

- SC&A generated doses assuming exposures of 1.000 rem of 30–250 keV photon dose and 1.000 rem of 0.1–2.0 MeV neutron
- SC&A-derived IGF values and DCF values were used to calculate dose for the LCP and LC dosimeter locations for AP, ISO, and ROT geometries
- Doses were calculated for the 8 female and 8 male organs selected by SC&A

SC&A's evaluation of dose-only values

- SC&A compared its doses to NIOSH-generated doses
- Comparison showed relatively close agreement between doses
- Some difference was expected, since NIOSH used Monte Carlo methods and SC&A used average values to estimate dose
- With only a few exceptions, SC&A's doses were less than NIOSH's doses

SC&A's evaluation of AP geometry doses

- SC&A's dose calculations for AP geometry are the same for the LCP as for the LC badge location since the IGF value is 1.0 (incident angle = 0)
- 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, for a few organs and badge locations, NIOSH's AP dose differences appeared excessive (observation 2)

SC&A's observation 2

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

- Since NIOSH used MCNP and 4-point averaging for each of their runs, a small variance in the dose results is expected
- Larger than expected variance identified for:
  - male lung (AP photon dose for the LCP = 0.689 rem vs. ~0.798 rem for other positions)
  - female lung (AP photon dose for the LC = 0.668 rem vs. ~0.769 rem for other positions)
  - male small intestine wall (AP dose =0.895 rem vs. ~0.780 rem for other positions)

SC&A's evaluation of RPRT-0085 documentation

- NIOSH's explanation of their approach and methods was relatively brief
- RPRT-0085 calculations relied on several supporting documents
- SC&A needed to spend a relatively lengthy period of time evaluating the data used in the supporting documents to gain an understand of NIOSH's assessment process
- SC&A found some key terminology to be confusing and inconsistent (observation 3)

SC&A's observation 3

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

- RPRT-0085, equation 2-1, uses "DCC" incorrectly because dose conversion coefficients in ICRP 116 have units of pGy-cm^2 and need to be divided by the fluence conversion factor, as shown in equations 3-2 and 3-3 of RPRT-0069
- The "DCC" in equation 2-1 of RPRT-0085 should be DCF, not DCC

Additional terminology issue

- SC&A also noted that the title of RPRT-0069, “Updated ICRP 116 Dose Conversion Factors and Comparison to ICRP 74 Dose Conversion Factors,” appears to be incorrect because ICRP 116 does not use the terms “dose conversion factor” or “DCF.”
- 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.”

Summary of SC&A's evaluation of RPRT-0085

- SC&A evaluated the methods and approach used in RPRT-0085 for determining if ROT and ISO DCFs for bone (red marrow and surface), esophagus, and lung listed in table 4.1a of IG-001, rev. 3, are still valid
- SC&A identified 3 observations:
  - Observation 1: SC&A questions why NIOSH's neutron IGFs for several dosimeter locations differ from those in RPRT-0068
  - Observation 2: SC&A questions why NIOSH's AP doses for a few cancers deviate beyond expected values
  - Observation 3: NIOSH used the terms "DCC" and "DCF" incorrectly

Questions?