

To: Subcommittee for Procedure Reviews  
From: SC&A, Inc.  
Date: February 3, 2021  
Subject: Focused Review of ORAUT-OTIB-0006, revision 06, for Resolution of Issues

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On January 21, 2021, the Chair of the Subcommittee for Procedure Reviews (SCPR) tasked SC&A with a focused review of ORAUT-OTIB-0006, revision 06, “Dose Reconstruction from Occupational Medical X-Ray Procedures” (NIOSH, 2019; hereafter “OTIB-0006”). The following documents are pertinent to this review.

- ORAUT-OTIB-0006, revision 05, August 13, 2018 (NIOSH, 2018)
- SCA-TR-2019-PR002, revision 0, “SC&A’s Evaluation of ORAUT-OTIB-0006, revision 05, ‘Dose Reconstruction from Occupational Medical X-Ray Procedures,’” January 14, 2019 (SC&A, 2019)
- ORAUT-OTIB-0006, revision 06, September 27, 2019 (NIOSH, 2019)

SC&A performed a focused review of OTIB-0006, revision 06 (NIOSH, 2019), to determine if the issues raised in SC&A’s review (SC&A, 2019) of OTIB-0006, revision 05 (NIOSH, 2018), were addressed and resolved. The following is a summary of SC&A’s review.

### **Evaluation of Resolution of Observations**

SC&A’s review (SC&A, 2019) of OTIB-0006, revision 05 (NIOSH, 2018), identified seven observations and no findings. The seven observations and their current status are listed below.

#### ***Observation 1: Need Clarification for DCF Units in Attachment B***

Tables B-1, B-2, and B-3 (captions on pages 87, 88, and 89, respectively) list DCFs for various x-ray projections in units of “(mGy/Gy  $\times 10^{-3}$  rem-cGy/cGy-mGy)” where Gy = gray, cGy = centigray, and mGy = milligray.

It is not obvious what unit the multiplication factor of  $10^{-3}$  applies to and why it is there, because 1.0 rem is equal to 1.0 cGy for photon dose, and there are units of mGy/mGy and Gy/Gy that cancel each other out.

**Status of observation 1:** SC&A found the units used in Tables B-1, B-2, and B-3 (captions on pages 110, 111, and 112, respectively) of OTIB-0006, revision 06, list the correct units (rem/cGy). This observation has been resolved, and SC&A recommends closure.

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### **Observation 2: Need Clarification for Changing Chest Thickness**

OTIB-0006 Table 3-1 lists the body part thickness for various x-ray procedures. Table 3-1 lists 24 centimeters (cm) for the thickness of the chest and abdomen; Footnote a of Table 3-1 states this value without citing a reference in the footnote. The description of revisions on page 3 of OTIB-0006 states:

*Changed part thickness in Table 3-1 for anterior-posterior and posterior-anterior projections to 24 cm, except the cervical spine.*

Other sources list the chest thickness as ranging from 20 cm to 25 cm (Cahoon 1961, PDF page 33), and 20 cm to 26 cm (Kereiakes and Rosenstein, 1980, PDF pages 34–35). While a selection of 24 cm for the standard chest thickness is reasonable, it would be helpful to clarify the reasoning for changing the value from 23 cm in the previous ORAUT-OTIB-0006, Revision 04 (NIOSH 2011), to 24 cm in OTIB-0006, Revision 05.

**Status of observation 2:** SC&A reviewed the reference (ICRP, 2009) provided in footnote b of table 3-2 of OTIB-0006, revision 06, concerning the use of 24-cm chest thickness. However, SC&A was unable to locate any text in the 84-page International Commission on Radiological Protection (ICRP) Publication 110 (2009) reference that lists a chest thickness of 24 cm. Therefore, SC&A recommends the National Institute for Occupational Safety and Health (NIOSH) provide the page number of the reference used for selecting a 24-cm chest thickness. SC&A recommends that this observation remain open.

### **Observation 3: Difference in Source-to-Image Distance**

OTIB-0006 Table 3-1 lists the source-to-image distance (SID) for various x-ray procedures. For a cervical spine lateral procedure, Table 3-1 lists the SID as 72 inches/183 cm, with Footnote d stating:

*The 72-in. [183 cm] SID is used for the LAT cervical spine to reduce magnification.*

However, International Commission on Radiological Protection (ICRP) Publication 34 (ICRP 1982), Table A9, PDF page 36, lists a SID of 102 cm for a cervical spine view. The use of a SID of 183 cm in OTIB-0006 instead of 102 cm needs further clarification.

**Status of observation 3:** SC&A reviewed the two references (Bontragher & Lampignano, 2005, pp. 3–4; General Electric, 1956, p. 4) provided in footnote f of table 3-2 of OTIB-0006, revision 06, concerning cervical spine lateral source-to-image distance and found that both recommend a distance of 72 inches. This observation has been resolved, and SC&A recommends closure.

### **Observation 4: Need References and Derivation of Kerma Values in Table 4-1**

OTIB-0006 Table 4-1 lists incident air kerma values for various x-ray procedures. However, while some of the footnotes provide site research database (SRDB)

references, most do not provide PDF page numbers. These are generally large documents and PDF page numbers would be very helpful. Additionally, it would be helpful to indicate the numerical value of the original data used, such as the number of milliroentgen, etc., used to derive the resulting kerma values listed in Table 4-1. As it presently stands, it is very difficult to use the references listed to verify the values recommended in Table 4-1.

**Status of observation 4:** This issue has been clarified in OTIB-0006, revision 06, by the addition of page numbers and references to sections in the report concerning the derivation of the values. SC&A spot checked several of the many values in table 4-1 and was able to trace their origins back to the cited references. This observation has been resolved, and SC&A recommends closure.

*Observation 5: Thoracic and Cervical Spine Dose Assignments after 1970 Need Clarification*

Table B-1 lists DCF values for determining dose equivalents from thoracic and cervical spine procedures through 1970. OTIB-0006 provides DCF values after 1970 for other x-ray procedures, such as for the chest. It needs to be clarified if dose from thoracic and cervical spine procedures are to be assigned after, since DCFs are not provided post-1970 for thoracic and cervical spine procedures.

**Status of observation 5:** SC&A finds that this issue has been clarified by footnote a to table 4-1 of OTIB-0006, revision 06, which indicates that the cervical spine procedure was not used after 1970. This observation has been resolved, and SC&A recommends closure.

*Observation 6: Breast Dose Reference Needs Clarification*

OTIB-0006 Table B-3, Footnote e on page 89, and Table B-13, Footnote f on page 108, both list a reference to Huda and Bissessur (1990) for deriving dose to the breast. However, Huda and Bissessur (1990) only mention the breast in Table II, PDF page 5, and lists dose fraction values for the breast as a function of x-ray procedure. Dose fraction values for the breast listed in Huda and Bissessur relevant to Tables B-3 and B-13 of OTIB-0006 are 0.10 for the lumbar-spine anterior-posterior procedure, and 0.00 for lumbar-spine lateral and pelvis anterior-posterior procedures. It is not obvious how the dose values for the breast in Table B-13, page 107, were derived using the dose fractions from the Huda and Bissessur (1990) reference.

**Status of observation 6:** SC&A finds that this issue is no longer applicable to OTIB-0006, revision 06, because the term “derived” is no longer used for the breast dose conversion factor (DCF) in table B-3. Instead, NIOSH provides numerical values in table B-3, which allow derivation of values in table B-13. This observation has been resolved, and SC&A recommends closure.

**Observation 7: Need to Retain Important Information from Attachment C of ORAUT-PROC-0061**

There are three situations regarding the amount of information provided for occupational medical dose reconstruction in a site's profile document:

1. **Site profile provides complete skin dose information for the various skin locations** – In this situation, the skin doses in OTIB-0006 and information in Attachment C of ORAUT-PROC-0061, Revision 03, *Occupational Medical X-ray Dose Reconstruction for DOE Sites* (NIOSH 2010), are not needed.
2. **Site profile does not provide any occupational medical dose data** – In this situation, the skin doses in OTIB-0006 can be used.
3. **Site profile provides some skin dose information** – Some site profiles provide basic information on skin dose, such as ENSD, but do not provide detailed dose values as is contained in Tables B-10 through B-16 of OTIB-0006 for various skin cancer locations. Since the ENSD for that site may be different than that recommended in OTIB-0006, Tables B-10 through B-16 of OTIB-0006 would not be applicable. It then becomes necessary to manually calculate the EXSD, RSD, and the ENSD near but outside the primary beam, using equations provided on page 20 of ORAUT-PROC-0061, Revision 03 (NIOSH 2010), in conjunction with data in Tables C-3 and C-4 of ORAUT-PROC-0061, Revision 03. However, it appears that this necessary information in Attachment C of ORAUT-PROC-0061, Revision 03, is being phased out without being retained in either ORAUT-PROC-0061, Revision 04 (NIOSH 2017), or OTIB-0006. The description of changes on page 2 of ORAUT-PROC-0061, Revision 04 (NIOSH 2017), states:

*Revision initiated to ensure consistency with ORAUT-OTIB-0006. Appendix C on the calculation of skin dose **deleted** as duplicate of ORAUT-OTIB-0006 content. [Emphasis added.]*

SC&A recommends that the essential information for skin dose that is contained in Attachment C, pages 20–22 of ORAUT-PROC-0061, Revision 03 (NIOSH 2010), be retained and carried forward for further use in dose reconstructions for sites without detailed skin dose data.

**Status of observation 7:** SC&A included this observation to emphasize the need to retain the information in attachment C of ORAUT-PROC-0061, revision 03 (NIOSH, 2010), because some of it is not duplicated in any version of ORAUT-OTIB-0006. SC&A recommends closure of this observation.

## Evaluation of Resolution of Documentation Issues

In SC&A's evaluation of the documentation used in OTIB-0006, revision 05, for assigning occupational medical x-ray dose, SC&A found the document was well written and informative. It is a relatively complex and large document, and, as such, SC&A found several items of documentation that needed to be corrected or clarified (SC&A, 2019). The following list summarizes the documentation issues and their present status.

- **Page 3:** The description in this paragraph of the revisions that took place in OTIB-0006, revision 05, is difficult to follow because many of the tables are labeled incorrectly: it applies the old table numbers from attachment A to revision 04 (NIOSH, 2011) to the new tables in attachment B to revision 05. The following are some examples:
  - “Added dose for bone surface anterior-posterior lordotic in Table B-7 for 1971 to 1985” – It appears that this should be table B-10, not table B-7.
  - “Corrected Table B-10 entrance skin dose through 1970 for anterior-posterior and lateral lumbar spine to account for proper backscatter factor.” – It appears that this should be table B-13, not table B-10.
  - “Corrected Table B-11 lateral lumbar spine through 1970 for back torso: buttocks (iliac crest and below) to include E-02.” – It appears that this should be table B-14, not table B-11.
  - “Corrected Table B-13 fourth column title to left posterior oblique thoracic spine.” – It appears that this should be table B-16, not table B-13, and the fifth column, not the fourth column (counting all columns from left to right).
  - “Corrected Table B-1 to B-3 anterior-posterior lordotic chest dose conversion factors and added footnote.” – It appears that this should be table B-2, not table B-1 to B-3, because the term “AP [anterior-posterior] lordotic” only appears in table B-2.

**Status:** The table reference errors on page 3 are still present in OTIB-0006, revision 06. SC&A recommends that this issue remain open.

- **Page 14:** The last paragraph on this page states:

An assumption of poor collimation of radiographs through 1970 might necessitate the use of DCFs from ICRP Publication 34 (ICRP 1982) **other than those for the intended examination**, because ICRP Publication 34 DCFs are based on properly collimated beams. [Emphasis added.]

Additionally, the captions of tables A-2, A-3, A-4, and A-5 use the following terminology:

Selection of organs for [various procedures] X-ray dose reconstruction based on ICD-9 code when different organ selection required based on view

SC&A assumes that this means that the dose reconstructor may need to use a different organ than would normally be used because of the x-ray procedure (i.e., view) used in the exam. However, this is not very obvious from the wording and it would be helpful to have this concept more clearly stated. It would also be beneficial to provide an example or more details regarding appropriate organ selection.

**Status:** OTIB-0006, revision 06, added a sentence on page 15 at the end of this section and used different captions in tables A-2, A-3, A-4, and A-5 that clarify this issue. SC&A recommends closure of this issue.

- **Page 18:** Footnote m after table 4-1 of revision 06 states to see section 7.2 for additional chest lateral air kerma information. However, this should refer to section 7.1, page 27, for the 2.5 factor concerning this information.

**Status:** This is a new documentation issue SC&A recently found. The reference should be to section 7.1 instead of 7.2.

- **Page 26:** The second paragraph on this page states:

The incident air kerma for a LAT chest X-ray is assumed to be 2.5 times that of a PA chest, a conservative value based on measurements from Hanford (Kirklin et al. ca. 1969) where a factor of 1.94 was observed.

Because of the many pages in the referenced document, it would have been helpful for the page number to have been included. It appears that the factor of 1.94 was derived from dividing the lateral (LAT) chest dose of 0.153 roentgen by the posterior-anterior (PA) chest dose of 0.079 roentgen, as provided on PDF pages 161 and 162, respectively, of the reference (Kirklin et al., ca. 1969).

**Status:** This issue was not addressed in OTIB-0006, revision 06. However, SC&A pointed this issue out to clarify how the 1.94 factor was apparently derived. It does not affect dose reconstruction; therefore, SC&A recommends closure of this issue.

- **Page 27:** The last paragraph on this page states:

The resolution of PFG systems was not as good as conventional film screen systems; only 6 line/pairs per mm rather than about **9 or** per mm... [Emphasis added.]

SC&A found that, according to Goodwin, Quimby, and Morgan (1970), page 108 (PDF p. 63), this should read:

The resolution of PFG systems was not as good as conventional film screen systems; only 6 line/pairs per mm rather than about **9 or 10 line/pairs** per mm. [Emphasis added.]

**Status:** This issue was corrected at the bottom of page 27 in OTIB-0006, revision 06. SC&A recommends closure of this issue.

- **Page 36:** Table 7-2, column six, uses units of inches for the source-to-skin distance (SSD) values. These should be in units of centimeters.

**Status:** This is a new documentation issue SC&A recently found. The units should be changed to centimeters.

- **Page 37:** The last paragraph on this page states:

Using the inverse square law, the entrance skin dose is calculated based **on the part** thickness for PA Chest and LAT . . . [Emphasis added.]

SC&A found that this apparently should read:

Using the inverse square law, the entrance skin dose is calculated based **in part on the** thickness for PA Chest and LAT . . . [Emphasis added.]

**Status:** The same wording appears at the bottom of page 39 in OTIB-0006, revision 06, as was in revision 05, page 37. However, from SC&A's review of other instances of the use of the term "part" in the document, it appears that NIOSH is apparently using the term "part" in this context to refer to the "part" of the body under consideration. SC&A recommends closure of this issue.

- **Page 38:** The second column, second row, of table 8.1 reads:

Lumb. Vert 37-32

SC&A found that for the lumbar vertical (Lum. Vert.) view, the thickness value (according to Cahoon 1961, PDF page 33) should read:

Lumb. Vert 27-32

This error did not affect the derivation of the 7.5 cm chest thickness value quoted at the top of page 38, which was derived from averaging the maximum and minimum values already correctly listed in table 8.1 (i.e.,  $34.4 \text{ cm} - 27 \text{ cm} = 7.4 \text{ cm}$ , rounded to 7.5 cm).

**Status:** This issue was corrected in table 8-1, page 40, in OTIB-0006, revision 06. SC&A recommends closure of this issue.

- **Page 52:** The fourth column (for the lumbar spine view) in the table on this page for International Classification of Diseases (ICD)-9 code 170.4 should instruct the dose reconstructor to "See Table A-3," not table A-5.

**Status:** ICD-9 code 170.4 corresponds to ICD-10 code C40.0 that is listed in table A-1, page 50, of OTIB-0006, revision 06. Revision 06 does not refer to another table, as was done in revision 05, but recommends using 10 percent of the entrance skin dose (ENSD). Therefore, this issue is no longer applicable. SC&A recommends closure of this issue.

- **Page 52:** The fourth column (for the lumbar spine view) in the table on this page for ICD-9 code 170.5 should instruct the dose reconstructor to “See Table A-3,” not table A-5.

**Status:** ICD-9 code 170.5 corresponds to ICD-10 code C40.10 that is listed in table A-1, page 50, of OTIB-0006, revision 06. Revision 06 refers to table A-4, which is the correct table. Therefore, this issue has been resolved. SC&A recommends closure of this issue.

- **Page 60:** The fourth column (for the lumbar spine view) in the table on this page for ICD-9 code 195.4 should instruct the dose reconstructor to “See Table A-3,” not table A-5.

**Status:** ICD-9 code 195.4 corresponds to ICD-10 code C76.40 that is listed in table A-1, page 57, of OTIB-0006, revision 06. Revision 06 does not refer to another table, as was done in revision 05, but recommends using 10 percent of the ENSD. Therefore, this issue is no longer applicable. SC&A recommends closure of this issue.

- **Page 113:** Footnote a for table B-15 provides the following references:

Dose equivalents through 1970 are based on measured values (Lincoln and Gupton 1958) for skin, testes, and ovaries for the thoracic spine, and measured values (Braestrup and Wyckoff 1958) for testes, ovaries, and uterus for the cervical spine.

Lincoln and Gupton (1958), table IX, PDF page 8, do provide the dose values listed in table B-15 of OTIB-0006, revision 05, for the thoracic spine view for the skin, testes, and ovaries. However, Braestrup and Wyckoff (1958) is a textbook and does not provide the doses for the testes, ovaries, and uterus for the cervical spine view. This may be an incorrect reference.

**Status:** This issue was corrected by adding the page number (p. 81) to footnote a for the Braestrup and Wyckoff (1958) reference used at the bottom of table B-15 on page 138 of OTIB-0006, revision 06. SC&A recommends closure of this issue.

## Summary and Conclusions

SC&A performed a focused review of OTIB-0006, revision 06 (NIOSH, 2019), to determine if the current revision addressed and resolved the seven observations and the documentation issues from SC&A’s previous review (SC&A, 2019) of OTIB-0006, revision 05 (NIOSH, 2018). The following is a summary of SC&A’s focused review.

### Observations

SC&A found that observations 1, 3, 4, 5, 6, and 7 had been adequately addressed, resolved, and recommends closure.

SC&A found that observation 2 appears to still lack the complete reference and page number for recommending the use of 24 cm for chest thickness. SC&A was unable to locate any text in the



84-page reference (ICRP, 2009) that lists a chest thickness of 24 cm. Therefore, SC&A recommends NIOSH provide the reference and page number used for selecting a 24-cm chest thickness. SC&A recommends that this observation remain open.

### *Documentation issues*

SC&A found that the documentation issues were addressed by changes made in revisions 06 (NIOSH, 2019), with the following exceptions:

- Page 3 – The table reference errors on page 3 are still present in OTIB-0006, revision 06. SC&A recommends that this issue remain open.
- Page 18 – Footnote m after table 4-1 of revision 06 should state to see section 7.1 for additional chest lateral air kerma information, not section 7.2. (This is a new documentation issue SC&A recently found.)
- Page 36 – Table 7-2, column six, uses units of inches for the SSD values; these should be in units of centimeters. (This is a new documentation issue SC&A recently found.)

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