Ascension
St. Vincent
Hospital

September 29, 2023

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RE: Radiation exposure reconstruction for Ascension St. Vincent Hospital Interventional Radiology Physicians.

Estimates of Deep Dose Equivalent, Lens Dose Equivalent, Shallow Dose Equivalent, and Effective Dose Equivalent.

A radiation exposure reconstruction was requested for all three of the Interventional Radiologists (IRs) who perform services utilizing both fluoroscopy and radioactive materials at Ascension St. Vincent hospital for the years 2019 through 2022. The average Dose Area Product (DAP) per procedure was calculated by taking the DAP from the most recently performed 50 procedures for each IR physician. This average DAP was then multiplied by the number of procedures performed per year to find a yearly DAP. An exposure (Roentgen) per unit DAP was measured at the location in the room where the IR physician stands. Multiplying the Exposure per unit DAP by the average DAP per procedure by the number of procedures per year provided an estimated exposure at the location where the IR physician stands during the procedures. Utilizing the DAP instead of fluoro time or entrance skin exposure was deemed most accurate as it accounts for different patient sized and radiation field sizes (1).

$$\frac{Exposure\ (mR)}{DAP\ \left(\frac{Gy}{cm2}\right)} x \frac{DAP\ (\frac{Gy}{cm2})}{\#\ IR\ Procedures} x \frac{\#\ IR\ Procedures}{Year} x \frac{0.876\ mrem}{1\ mR} = \frac{Effective\ dose\ (mrem)}{Year}$$

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Table one provides the average DAP per procedure and the workload per IR physician per year.

Table 1:

Physician Name	DAP/Interventional Procedure	Number of Procedures 2018	Number of Procedures 2019	Number of Procedures 2020	Number of procedures 2021	Number of Procedures 2022
[IR 1]	11.92 Gy/cm2	611	671	658	750	711
[IR 2]	25.38 Gy/cm2	553	595	612	675	683
[IR 3]	19.26 Gy/cm2	932	944	717	698	48

Note: [IR 3] ended his employment with Ascension St. Vincent on 2/3/2022

Phantom Measurements:

Direct measurement of scatter radiation was performed utilizing a CIRS model 903 radiography/fluoroscopy phantom and Fluke 451 ion chamber survey meter (SN:3315, calibrated on May 16, 2023). Measurements were performed in IR room 1 which is a Siemens Artis Q system.

Exposure measurements were taken in a clinical equivalent machine setup. Measurements were taken at approximately 75cm from the midline of the patient at two locations, the collar equivalent location, and the abdomen equivalent location (perpendicular to the gap between the face shield and the under-table shield). The hanging shield was conservatively assumed to be utilized for 50% of the time during the IR's procedures therefore the exposure per unit DAP was measured with the hanging shield in place for 50% of the exposure time. Measurements were made in the PA orientation at 100cm SID and a field of view of 42 cm with no collimation used (maximum scatter field). The distance from the x-ray tube to the patient skin was approximately 68cm. Normal fluoroscopy mode was utilized at 15 pulses per second. There was no need to evaluate CINE mode, DSA mode, and high dose fluoro mode separately as those high doses would provide higher DAPs which is accounted for in our reconstruction model.

Phantom Data:

Table 2: Total integrated scatter (mR) for 2 minutes of fluoroscopy. Measurements taken at 75 cm from the center of the phantom.

Measurements	Collar	Midline (abd/waist)
Total Exp at IR physician location (mR)	0.840	1.370
Displayed DAP (Gy/cm2)	3.10	3.012
Exposure per unit DAP (mR/(Gy/cm2))	0.271	.455

Calculation of DDE, LDE, SDE, and EDE dose estimates:

ANSI/HPS N13.41-1997 outlined methodology for determining effective dose equivalent with multiple dosimeters; one under apron worn at the waist and one at the collar external to shielding. Table 2

above provides the ratio of DAP to the patient vs. the expected exposure at the location of the IR physician. The collar Exposure per unit DAP factor can be utilized directly to estimate the deep dose equivalent (DDE), Lens Dose Equivalent (LDE), and the Shallow Dose equivalent (SDE) of a dosimeter worn at the collar on the exterior of personal shielding garments. The midline factor that is presented in table 2 assumes that the dosimeter is external to shielding garments at the waist. ANSI/HPS N14.41 methodology assumes that the dosimeter is worn at the waist but UNDER the shielding garments. The shielding garments utilized by the IR physicians have a lead equivalency of 0.5mm. NCRP report 168 section 5.5, p 127 indicates that "a 0.5 mm lead garment attenuated over 95% of incident radiation". Additionally, the attenuation of the lead garment was measured in the IR lab and it was found to be 95.6%. Using a conservative value of 0.05 (95% attenuation) and applying it to the midline ratio in table 2 results in the ratios of expected dosimeter reading vs DAP (mrem/DAP) presented in table 3. These ratios when multiplied by the estimated annual DAP used would estimate annual DDE, SDE, and LDE measured by a dosimeter worn at the collar exterior to the shielding garments and a dosimeter worn at the waist level under the shielding garments.

Table 3: Ratio of expected dosimeter reading vs. DAP (mrem/DAP) including relevant shielding.

Collar	Midline
.237	0.0199

ANSI/HPS N13.41 provides the following formula to determine effective dose equivalent (referred to as the "assigned DDE" by Landauer dosimetry) when one dosimeter is worn under-apron and one dosimeter is worn unshielded at the collar.

Effective dose equivalent = 0.89 x under apron dosimeter + 0.11 x unshielded collar dosimeter

Combining the DAP per procedure and the number of procedures per year from table 1, the ratio of expected dosimeter reading vs. DAP from table 3, and the methodology described in ANSI/HPS N13.41 yields the estimated collar dosimeter DDE, and waist dosimeter DDE, the effective dose equivalent (EDE) for each IR physician for 2019, 2020, 2021, and 2022 was estimated. The LDE and SDE can conservatively be assumed to equal the collar DDE. These estimated dosimeter readings and resultant EDE are presented in table 4a through 4d.

Table 4a: estimated occupational exposure for 2019

Physician Name	Collar Dosimeter, SDE, and LDE (mrem)	Waist Dosimeter DDE (mrem)	EDE (mrem)
Dr. [IR 1]	1896	159	350
Dr. [IR 2]	3579	301	661
Dr. [IR 3]	4309	362	796

Table 4b: estimated occupational exposure for 2020

Physician Name	Collar Dosimeter, SDE, and LDE (mrem)	Waist Dosimeter DDE (mrem)	EDE (mrem)
Dr. [IR 1]	1859	156	343
Dr. [IR 2]	3681	309	680
Dr. [IR 3]	3273	275	605

Table 4c: estimated occupational exposure for 2021

Physician Name	Collar Dosimeter, SDE, and LDE (mrem)	Waist Dosimeter DDE (mrem)	EDE (mrem)
Dr. [IR 1]	2119	178	391
Dr. [IR 2]	4060	341	750
Dr. [IR 3]	3186	268	589

Table 4d: estimated occupational exposure for 2022

Physician Name	Collar Dosimeter, SDE, and LDE (mrem)	Waist Dosimeter DDE (mrem)	EDE (mrem)
Dr. [IR 1]	2009	169	317
Dr. [IR 2]	4108	345	759
Dr. [IR 3]	219	18	40

*Note: [IR 3] ended his employment with Ascension St. Vincent on 2/3/2022

Estimates of Extremity Exposure.

The dose to the extremities is a combination of both exposure from the Y-90 microspheres and exposure from scatter x-ray radiation from fluoroscopy.

$$\frac{Extremity\ (R)}{DAP\ \left(\frac{Gy}{cm2}\right)} x\ \frac{DAP\ \left(\frac{Gy}{cm2}\right)}{Interventional\ Procedure} x\ \frac{\#\ Interventional\ Procedures}{Year} x\ \frac{0.876\ mrem}{1\ mR}$$
$$+ \frac{Extremity\ (mrem)}{Y-90\ Procedures} x\ \frac{\#Y-90\ Procedures}{Year} = \frac{Extremity\ (mrem)}{Year}$$

Extremity Dose from Scattered X-rays:

The dose from the x-ray portion can be estimated in a similar way as the waist badge only assuming no lead apron utilized as shield. Using the midline exposure per unit DAP of 0.455 from table 2, the DAP per interventional procedure from table 1, and the number of interventional procedures per year from table 1 we estimated the extremity dose from x-ray in table 5.

Table 5:

Year	[IR1] X-ray Extremity Estimate (mrem)	[IR2] X-ray Extremity Estimate (mrem)	[IR3] X-ray Extremity Estimate (mrem)
2019	3183	6010	7236
2020	3122	6182	5496
2021	3558	6818	5351
2022	3373	6899	368

Extremity Dose from Y-90 Microspheres:

The dose from the Y-90 to the IR physicians was estimated using the extremity exposure data from the nuclear medicine technologist that prepared the doses. Table 6 provides the number of Y-90 procedures that the nuclear medicine technologist prepared by year, the nuclear medicine technologist's extremity dosimeter reading by year, and the number of Y-90 procedures that each AU performed.

Table 6:

Year	Number of Y-90 doses prepared	Technologist extremity dose (mrem)	#[IR1] Y-90s	#[IR2] Y-90s	#[IR3] Y90s
2019	41	683	5	12	24
2020	41	767	9	20	12
2021	52	602	18	11	23
2022	31	451	11	18	2

Note: One nuclear medicine technologist prepared these doses and had minimal other responsibilities requiring the routine handling of radioactive materials.

The average extremity dose to the technologist preparing these doses was 15.2 mrem per Y-90 procedure. The average time the technologist handled the doses during preparation was approximately 100 to 120 seconds per dose prepared some of which time the dose was unshielded. The AUs handle the source directly for approximately 10 to 15 seconds during which the source was shielded the entire time. We can then conservatively estimate that the AUs received no more than 20% of the dose to the extremity per procedure that the technologist received. Table 7 gives the estimated extremity dose to the AUs due to Y-90 exposure alone.

Table 7:

Year	Y-90 Estimated [IR1] Extremity dose (mrem)	Y-90 Estimated [IR2] Extremity dose (mrem)	Y-90 Estimated [IR3] Extremity dose (mrem)
2019	15	36	73
2020	27	61	36
2021	55	33	70
2022	33	55	6

The doses from the Y-90 exposure can be added to the estimated x-ray dose to the extremity in Table 6 to give the total estimated extremity dose in Table 8.

Table 8:

Year	Total Estimated [IR 1] Extremity dose (mrem)	Total Estimated [IR 2] Extremity dose (mrem)	Total Estimated [IR 3] Extremity dose (mrem)
2019	3198	6046	7309
2020	3149	6243	5532
2021	3613	6851	5421
2022	3406	6954	374

Conclusion:

Combining scatter fluoroscopy x-ray radiation (table 4a though 4d) with the extremity exposure from Y-90 (table 8) the estimated EDE, LDE, SDE, and Extremity dose are shown in Table 9a though 9d.

Table 9a: Total estimated occupational exposure for 2019

Physician Name	Collar DDE, LDE, and SDE (mrem)	EDE (mrem)	Extremity (mrem)
[IR 1]	1896	350	3198
[IR 2]	3579	661	6046
[IR 3]	4309	796	7309

Table 9b: Total estimated occupational exposure for 2020

Physician Name	Collar DDE, LDE, and SDE (mrem)	EDE (mrem)	Extremity (mrem)
[IR 1]	1859	343	3149
[IR 2]	3681	680	6243
[IR 3]	3273	605	5532

Table 9c: Total estimated occupational exposure for 2021

Physician Name	Collar DDE, LDE, and SDE (mrem)	EDE (mrem)	Extremity (mrem)
[IR 1]	2119	391	3613
[IR 2]	4060	750	6851
[IR 3]	3186	589	5421

Table 9d: Total estimated occupational exposure for 2022

Physician Name	Collar DDE, LDE, and SDE (mrem)	EDE (mrem)	Extremity (mrem)
[IR 1]	2009	317	3406
[IR 2]	4108	759	6954
[IR 3]	219	40	374

*Note: [IR 3] ended his employment with Ascension St. Vincent on 2/3/2022

Based on the physician workload, scatter exposure data collected, and the effective dose equivalent formula from ANSI/HPS 13.41 effective dose equivalents for all three occupationally exposed employees utilizing Y-90 and fluoroscopy were estimated. As indicated in tables 8a though 8d, the estimated EDE, LDE, and extremity dose for all physicians would not have exceeded the occupational dose limit of 5000mrem/year, 15000mrem/year, and 50000mrem/ year respectively for any year in question.

Performed by:

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References

1) The dose-area product and assessment of the occupational dose in interventional radiology. Radiation Protection Dosimetry 2001;96 (1-3):235-6
2) ANSI/HPS N13.41 "Criteria for Performing Multiple Dosimetry" – 1997
3) NCRP 168 "Radiation Dose Management for Fluoroscopically-Guided Interventional Medical Procedures" - 2010

From:	Timothy Greist
To:	Deborah Piskura; William Breeden
Subject:	[External_Sender] Fwd: ASTV-INDIANAPOLIS: IR LAB PHYSICIAN RADIATION DOSIMETRY.SEPTEMBER 2023
Date:	Tuesday, November 28, 2023 1:54:33 PM
Attachments:	IR LAB PHYSICIAN RADIATION DOSIMETRY.SEPTEMBER 2023.pdf

Debbie and Will,

Please see the revised IR lab physician dose estimates report attached. Let me know if you have any questions.

Thanks,

Tim

---------- Forwarded message ---------
From: **Edward Wroblewski** <eewroble@ascension.org>
Date: Fri, Sep 29, 2023 at 1:23 PM
Subject: ASTV-INDIANAPOLIS: IR LAB PHYSICIAN RADIATION DOSIMETRY.SEPTEMBER 2023
To: <debbie.piskura@nrc.gov>
Cc: Timothy Greist <Timothy.Greist@ascension.org>

Debbie:

Please the attached & revised: ASTV-INDIANAPOLIS: IR LAB PHYSICIAN RADIATION DOSIMETRY.SEPTEMBER 2023 as requested by your stated deadline of today (September 29, 2023).

If you have any questions regarding this document and/or the contents contained therein, as always, please do not hesitate to contact me at your earliest convenience.

--

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