TR-007-DHF-001/DHF-002 (M1128 V2, L148-MPS, L148-TMS) Rev A

Rampart Radiation Scatter Report

A comprehensive analysis of the combined effect of the Rampart M1128 V2.0, L148 & MPS on radiation scatter in the cardiac catheterization lab as compared to conventional shielding methods such as lead-lined table drapes, overhead acrylic shielding, and lead aprons.

Disclosure of Unbiased Research

Dear Reader,

It is important to clarify that while Rampart funded this research, the opinions and conclusions presented in this report are entirely those of the researchers involved and have been formed independently based on the collected data and objective analysis. The funding provided by Rampart facilitated the execution of the study, including equipment, materials, and research efforts. Still, it did not influence the findings' integrity or their interpretation's objectivity.

A commitment to scientific rigor and unbiased analysis was upheld throughout the research process, regardless of the funding source. The data, results, and conclusions derived from the study were scrutinized through a lens of scientific integrity, ensuring that the presentation of findings accurately reflects the observed outcomes of the experimental procedures. The author has maintained their autonomy in critically evaluating the research outcomes and drawing conclusions based solely on the evidence gathered.

This declaration underscores the importance of transparency and intellectual independence in scientific research. While Rampart's financial support enabled this investigation, it did not compromise the researchers' ability to exercise unbiased judgment or convey the findings candidly. This report aims to provide an honest representation of the study's outcomes and implications while preserving the intellectual freedom of the researchers.

Though funded by Rampart, this research remains an authentic expression of independent scientific inquiry. The opinions expressed herein reflect the researchers' objective analysis of the collected data, and the integrity of the study's findings remains unaltered by the funding source.

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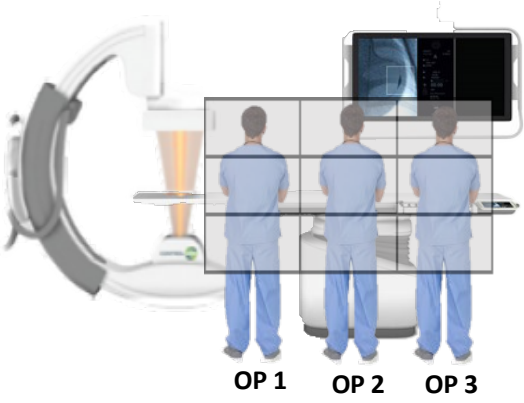
PROTOCOL

Objective

This test aims to evaluate the effectiveness of simultaneously using the Rampart M1128 V2.0, L148, and MPS shielding products to provide radiation protection for staff in cardiac catheterization laboratories. This shielding combination will be compared against conventional radiation protective devices such as lead-lined table drapes, overhead acrylic shields, and 0.5mm lead aprons.

Equipment and Setup

- Utilize the RaySafe 452 survey meter with Air Kerma plate for precise measurement of radiation attenuation.
- Measure radiation attenuation in µR/hr.
- Simulate patient radiation scatter using SuperTech 76-215 chest, abdomen, and extremity phantoms. Position these phantoms on the table to mimic patient placement.
- Perform scatter measurements in three locations within the room, corresponding to staff positions as shown in the image below.
- Take scatter measurements at three heights: waist (34”), chest (52”), and head (63”), producing a comprehensive vertical gradient exposure map representing staff exposure at each position.
- Configure the Rampart M1128 V2.0 in its standard 180° position.
- Measure scatter radiation using multiple C-arm positions including AP, Cranial 30°, Cranial 30° LAO 30°, LAO 30°, Caudal 30° LAO 30°, and Caudal 30°.
- All scatter will be generated using 15 fps medium dose fluoro focused on the chest cavity phantom for approximately seven seconds to simulate scattered radiation exposure rates.



The image shows the locations of each operator. Operator position 1 is 28 inches down the table from the x-ray tube. Operator position 2 is 56 inches, and operator position 3 is 80 inches. When the Rampart M1128 V2.0 is placed, it is 10 inches down the table from the x-ray tube.

METHODOLOGY

Procedure

1. **Baseline Measurements in AP Position:** Begin testing the effectiveness of the conventional shielding devices (lead-lined drapes and overhead acrylic shield) in the AP (Anterior-Posterior) position. Perform measurements using the RaySafe 452.
   a. Place the chest, abdomen, and extremity phantoms on the table to mimic patient location and scatter dynamics.
   b. Position the RaySafe 452 radiation detector at the specified operator locations and heights.
   c. Take scatter radiation peak exposure rate measurements at all locations and heights, recording the data from the RaySafe 452.
2. **Angle Position Testing:** Proceed to assess the effectiveness of shielding in different C-arm positions using conventional shielding devices (lead-lined drapes and overhead acrylic shields).
   a. Position the C-arm in the angle position desired.
   b. Place the RaySafe 452 at the specified operator locations and heights.
   c. Repeat the measurements for the conventional shielding devices, recording the peak exposure rate displayed by the RaySafe 452.
3. **Testing with Rampart Shielding Products:** After completing measurements with the conventional shielding devices, proceed to evaluate the combined shielding effectiveness of the M1128 V2.0, L148, and MPS products at all angles.
   a. Configure the Rampart M1128 V2.0 in its standard 180° position.
   b. Roll the MPS and place it on the table against the L148 where the patients right arm would rest.
   c. Place the RaySafe 452 at the specified operator positions and heights.
   d. Take measurements for the combined Rampart shielding products at all locations and heights, recording the peak exposure rate displayed by the RaySafe 452.

Data and Analysis

Analyze the collected data to determine the significance of the difference in peak exposure rates between the conventional shielding devices and the combined M1128 V2.0, L148, and MPS configuration. Consider differences based on location, height, and C-arm position. Use the conversion factor from NCRP 122 of 0.3 on the chest and waist height data from the conventional table drapes and overhead acrylic shield to account for lead aprons being worn by staff. Finally, use equation 4.6 from NCRP 147 to calculate the transmission ratio of 0.5mm lead aprons.

METHODOLOGY

Effective Dose Equivalent (EDE) Conversion Factor

The typical protocol for dosimetry monitoring on cardiac catheterization lab (CCL) workers is to wear a single dosimeter at the collar level outside the protective apron and towards the radiation source. Since the dosimeter is worn outside the lead apron, it overestimates the dose received by the vital organs. For this reason, NCRP 122 recommends a dose reduction factor to estimate the dose more accurately to the staff while wearing lead aprons.

> "When only one individual monitoring device is used, and it is located at the neck outside the protective apron, and the reported dose exceeds 25 percent of the limit specified…, the reported deep dose equivalent value multiplied by 0.3 shall be the effective dose equivalent for external radiation…" – NCRP 122

This dose reduction factor does not account for the lead equivalent thickness of the aprons worn. This may be an oversimplification of estimating the deep dose received for the staff, but it is common practice in many hospital settings.

We thought it valuable to compare not only the exposure rate measurements with conventional shielding to the Rampart shielding but to assume the staff is wearing lead aprons, and thus applying the recommended dose reduction factor of 0.3 to the exposure measurements of the chest and waist of the conventional shielding data set.

By applying the dose reduction factor, we can further analyze the effectiveness of the Rampart shielding vs. conventional shielding, including estimating the dose rate comparison of staff between the two shielding scenarios.

This further emphasizes the need for education of CCL workers when using the Rampart without lead aprons. It may be a long-standing practice that the EDE conversion factor is applied to dosimetry reports. Suppose the EDE conversion factor is still applied, even after the Rampart system is in place and lead aprons are no longer worn. In that case, it can artificially reduce the dose of record on the dosimetry reports. We recommend informing staff who use the Rampart shielding with no lead aprons to remove the EDE conversion factor from dosimetry reports.

METHODOLOGY

Estimating Exposure to Staff While Wearing a 0.5mm Lead Apron

The EDE conversion factor is likely a safe overestimation of staff exposure levels under the lead aprons. However, estimating the exposure behind a barrier is possible if the barrier material and thickness are known, and exposure without the barrier is known. It is a standard recommendation that CCL workers wear a 0.5mm lead or lead equivalent apron during exposures, and this research gathered data on exposure rates in air. Calculating an estimated exposure rate is possible, assuming a 0.5mm lead apron is worn.

This calculation can be done with a modified form of NCRP Report 147 equation 4.6...

$$x = \frac{1}{\alpha\gamma}\, ln\left[\frac{(\frac{\dot{X}}{\dot{X}_o})^{-\gamma} + \frac{\beta}{\alpha}}{1 + \frac{\beta}{\alpha}}\right]$$

where x is the barrier thickness in mm, $\dot{X}$ is the exposure with the barrier in place, $\dot{X}_o$ is the exposure without the barrier in place, and the variables α, β, and γ are fitting parameters from NCRP 147 Table C.1 for cardiac angiography (2.345, 14.94, and 0.7481 respectively).

If the equation is rearranged to solve for $\dot{X}/\dot{X}_o$ like so…

$$\frac{\dot{X}}{\dot{X}_o} = (e^{x\alpha\gamma}\left(1 + \frac{\beta}{\alpha}\right) - \frac{\beta}{\alpha})^{\frac{1}{-\gamma}}$$

we will have a ratio to multiply our in-air exposure measurements and be able to obtain an estimated exposure rate to the chest and waist of the CCL workers.

When this calculation is executed, we find that $\dot{X}/\dot{X}_o = 0.03877$. This means that we can estimate the exposure behind a 0.5mm lead apron to be approximately 3.877% of the exposure at the same location without a lead apron.

Solution:

$$x = 0.5mm$$
$$\alpha = 2.345$$
$$\beta = 14.94$$
$$\gamma = 0.7481$$

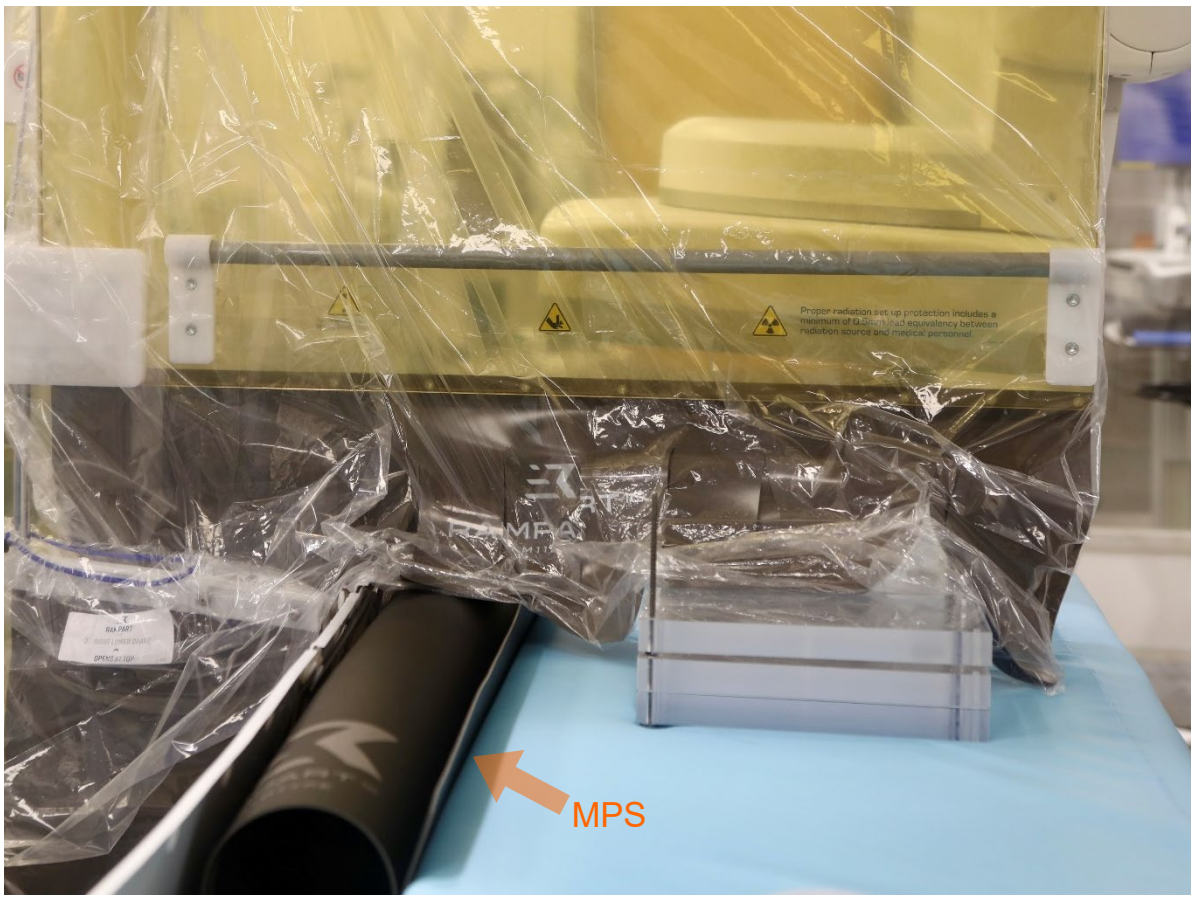
$$\frac{\dot{X}}{\dot{X}_o} = (e^{x\alpha\gamma}\left(1 + \frac{\beta}{\alpha}\right) - \frac{\beta}{\alpha})^{\frac{1}{-\gamma}}$$

$$\frac{\dot{X}}{\dot{X}_o} = (e^{0.5mm \times 2.345 \times 0.7481}\left(1 + \frac{14.94}{2.345}\right) - \frac{14.94}{2.345})^{\frac{1}{-0.7481}}$$

$$\frac{\dot{X}}{\dot{X}_o} = 0.03877$$

METHODOLOGY

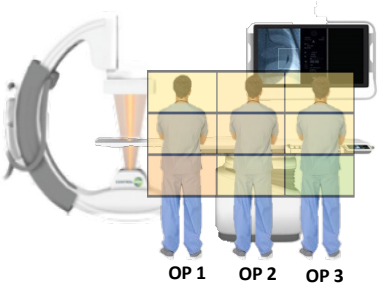
METHODOLOGY

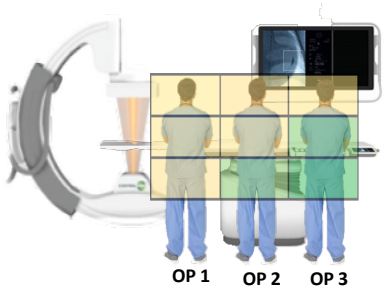


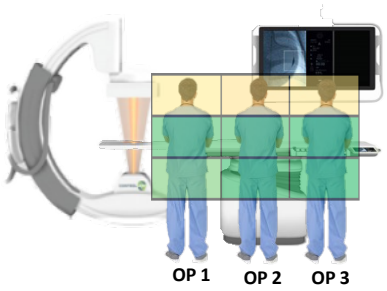
DATA

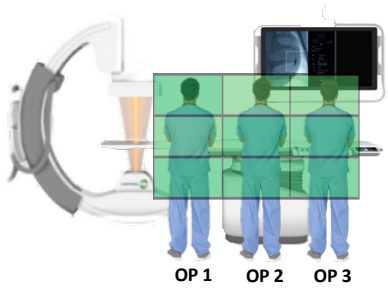
C-Arm Configuration: AP

Height	µR/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	504	504	504	17
Chest	OP 1	2400	720	93	102
Waist	OP 1	4450	1335	173	18
Head	OP 2	1510	1510	1510	136
Chest	OP 2	1990	597	77	28
Waist	OP 2	820	246	32	20
Head	OP 3	776	776	776	130
Chest	OP 3	717	215	28	28
Waist	OP 3	328	98	13	23





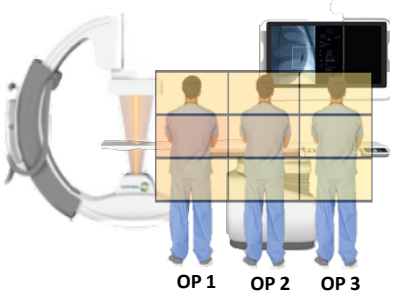


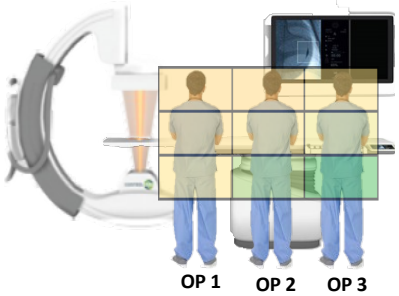


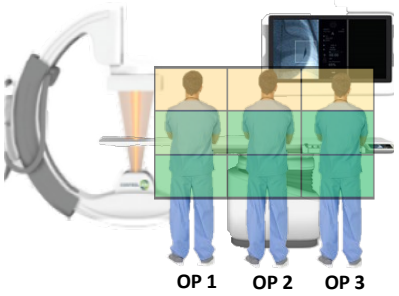
DATA

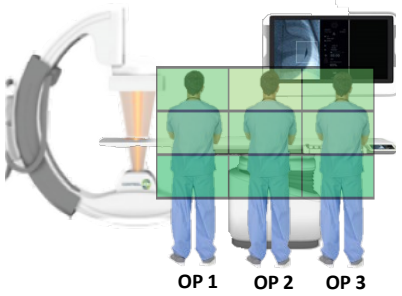
C-Arm Configuration: Cranial 30°

Height	µR/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	2220	2220	2220	154
Chest	OP 1	5940	1782	230	184
Waist	OP 1	2930	879	114	21
Head	OP 2	2130	2130	2130	256
Chest	OP 2	3210	963	124	153
Waist	OP 2	995	299	39	25
Head	OP 3	1050	1050	1050	179
Chest	OP 3	1380	414	54	181
Waist	OP 3	464	139	18	22





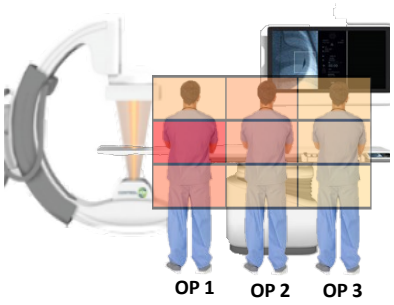


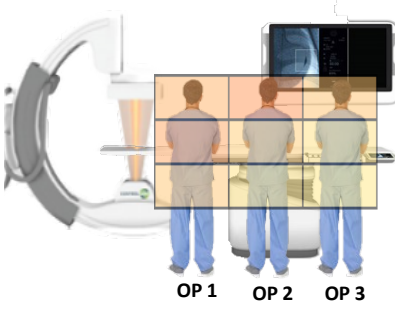


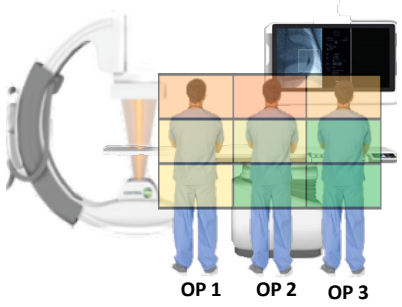
DATA

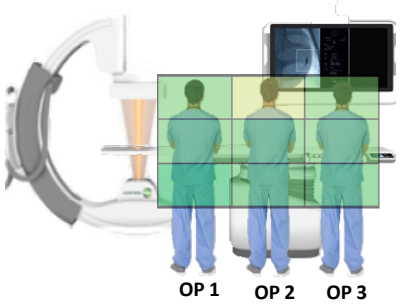
C-Arm Configuration: Cranial 30° LAO 30°

Height	µR/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	5270	5270	5270	174
Chest	OP 1	21000	6300	814	153
Waist	OP 1	11800	3540	457	11
Head	OP 2	7590	7590	7590	354
Chest	OP 2	10100	3030	392	163
Waist	OP 2	3920	1176	152	127
Head	OP 3	4000	4000	4000	204
Chest	OP 3	4200	1260	163	174
Waist	OP 3	2290	687	89	110





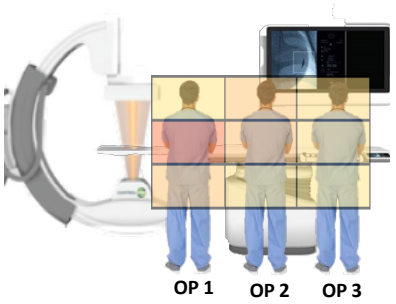


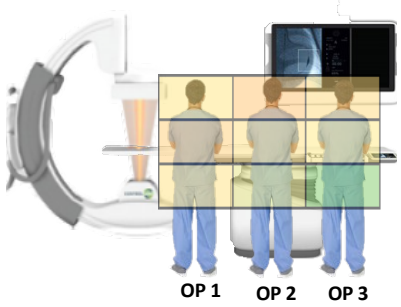


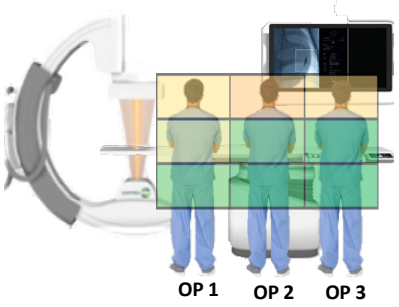
DATA

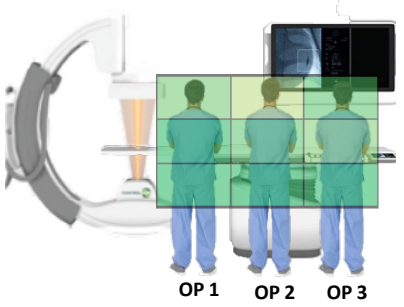
C-Arm Configuration: LAO 30°

Height	µR/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	783	783	783	170
Chest	OP 1	9640	2892	374	34
Waist	OP 1	3710	1113	144	22
Head	OP 2	3740	3740	3740	308
Chest	OP 2	4420	1326	171	128
Waist	OP 2	1320	396	51	20
Head	OP 3	1860	1860	1860	131
Chest	OP 3	1730	519	67	193
Waist	OP 3	748	224	29	22





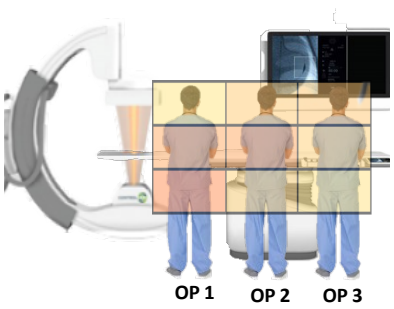


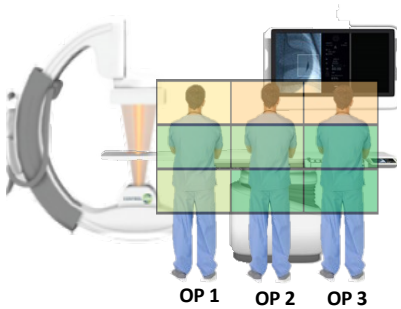


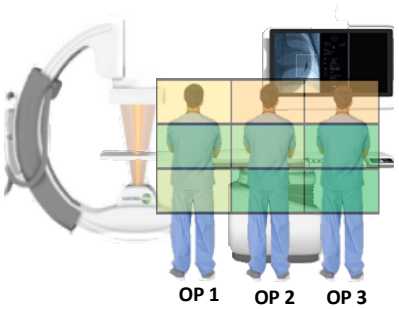
DATA

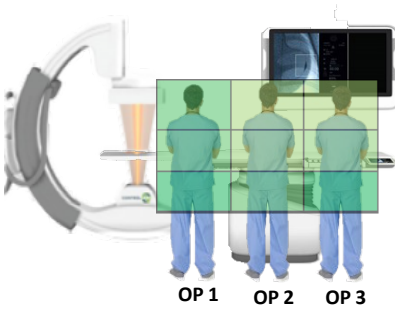
C-Arm Configuration: Caudal 30° LAO 30°

Height	µR/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	859	859	859	116
Chest	OP 1	6040	1812	234	143
Waist	OP 1	8430	2529	327	15
Head	OP 2	3320	3320	3320	281
Chest	OP 2	6260	1878	243	257
Waist	OP 2	2470	741	96	145
Head	OP 3	3550	3550	3550	288
Chest	OP 3	2640	792	102	229
Waist	OP 3	1200	360	47	14





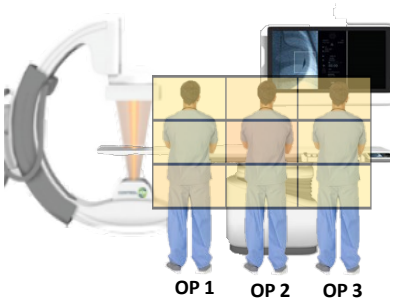


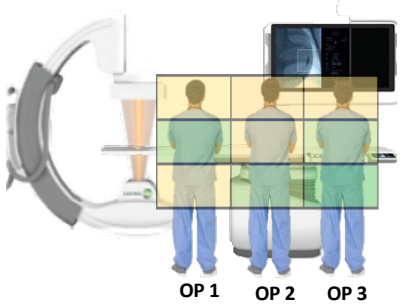


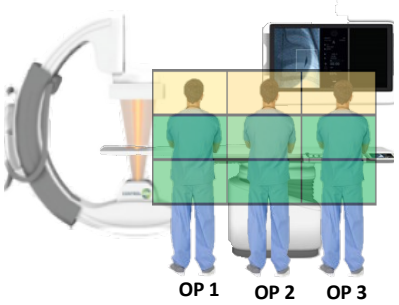
DATA

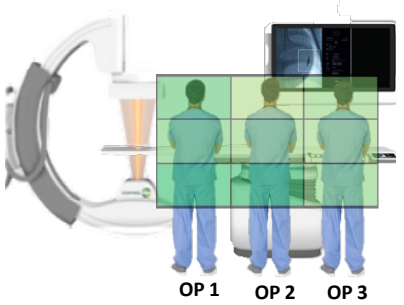
C-Arm Configuration: Caudal 30°

Height	µR/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	568	568	568	112
Chest	OP 1	952	286	37	164
Waist	OP 1	2370	711	92	28
Head	OP 2	1720	1720	1720	285
Chest	OP 2	4050	1215	157	228
Waist	OP 2	990	297	38	31
Head	OP 3	1440	1440	1440	217
Chest	OP 3	1090	327	42	244
Waist	OP 3	544	163	21	195









DATA ANALYSIS

After thoroughly analyzing the collected data, several key conclusions can be drawn regarding the effectiveness of the Rampart M1128 V2.0, L148, and MPS combination shielding compared to conventional table drapes and overhead acrylic shielding in the cardiac catheterization laboratory (CCL). This is not an exhaustive list of conclusions but pertinent conclusions that the author deems valuable.

The combination of Rampart shielding showed overall reduced occupational radiation exposure rates compared to conventional shielding methods, including the use of 0.5mm lead aprons. The areas where the Rampart shielding most significantly outperforms conventional shielding include operator position 1 and the head height for all three operator positions.

The effectiveness of the Rampart shielding at all heights and positions is exceptional and optimal in positions closer to the M1128 V2.0. Furthermore, those in positions further away from the center of the M1128 V2.0 and within its protective shadow still experience significant reductions in radiation exposure. Strategic positioning relative to the Rampart M1128 V2.0 represents a valuable tactic when using the Rampart shielding devices to mitigate radiation scatter exposure.

Conventional shielding does not effectively protect all body parts from radiation exposure – such as the head and arms, particularly the left arm. This is another area where Rampart shielding is far more effective than conventional shielding. The estimated exposure to the upper left arm can be gathered from the in-air measurements and no EDE conversion factor or lead apron conversion factor.

The reduced exposure to the head decreases the biological consequences of long-term radiation exposure to the brain and eyes. Recent research argues that the eye's lens is more sensitive to radiation than previously thought. This has caused the ICRP and NCRP to recommend lower occupational exposure levels to the lens of the eye. Not all regulating bodies have adopted the lower lens dose equivalent (LDE) recommendations. Yet, facilities should create internal policies and action limits for lower LDE. Although it is possible to reduce eye exposure with lead-lined glasses, many CCL workers feel they obstruct their vision, and the glasses do not minimize exposure to the brain. Some CCL workers wear lead-lined caps to reduce exposure to the brain. However, these lead-lined caps have been found to marginally reduce brain exposure due to the geometry between the scatter radiation and the cap.

It is important to note that the drapes designed to lay across the patient should be overlapping and have minimal to no gaps during radiation exposures. This will ensure optimal integrity of the M1128 V2.0 shielding and maintain maximum effectiveness of the radiation shadow.

THOUGHTFUL DATA UTILIZATION

When interpreting the results of this study, it is essential to approach the data with thoughtful consideration and understand its limitations and intended scope. The primary purpose of this analysis was to assess the relative effectiveness of the Rampart M1128 V2.0, L148, and MPS combination shielding compared to conventional lead-lined table drapes, overhead acrylic shielding, and lead aprons. As such, while the data provides valuable insights, it should not be utilized to estimate actual radiation doses to radiation workers.

The data collected offers a comparative evaluation of the performance of different shielding methods in reducing scatter radiation exposure. It is important to emphasize that the presented exposure rates should not be extrapolated to infer individual or cumulative radiation doses experienced by radiation workers during clinical procedures. Instead, these values should be exclusively employed to assess the efficacy of the Rampart shielding system compared to conventional methods within the controlled experimental setting. Recognizing that the data collected in a controlled experimental scenario may only capture some nuances and variables encountered in real-world clinical settings is crucial.

No experiment is without its limitations, and despite our best efforts to ensure accuracy, factors may influence the results and the broader applicability of the findings. Nevertheless, meticulous precautions were taken to minimize potential sources of error and ensure the collected data's reliability. The systematic approach to data collection, rigorous measurement techniques, and consistent experimental conditions enhance the validity of our conclusions.

This data serves as a comparative framework for assessing the relative performance of the Rampart shielding system against conventional methods. The consistent performance of the Rampart shielding system and the rigor of our experimental approach give confidence to its clinical benefits. However, the complexities of clinical environments and individual variability must be considered for complete contextual understanding.

APPENDIX

Conversions from µR/hr to mSv/hr

$$\dot{D} = 0.0088 \times \frac{\dot{X}}{1000} \times \frac{{\mu_{en}}/{\rho_{tissue}}}{{\mu_{en}}/{\rho_{air}}} \times W_R \times W_T$$

$$\dot{X} = exposure\ rate\ in \frac{\mu R}{hr}$$

$${\mu_{en}}/{\rho_{tissue}} = mass\ energy\ absorption\ coefficient\ of\ tissue = 0.0307$$

$${\mu_{en}}/{\rho_{air}} = mass\ energy\ absorption\ coefficient\ of\ air = 0.0279$$

$$W_R = Radiation\ weighting\ factor = 1\ for\ x - rays$$

$$W_T = Tissue\ weighting\ factor = 1\ for\ whole\ body$$

$$\dot{D} = dose\ rate\ in \frac{mSv}{hr}$$

Conversions from µR/hr to mrem/hr

$$\dot{D} = 0.0088 \times \frac{\dot{X}}{10} \times \frac{{\mu_{en}}/{\rho_{tissue}}}{{\mu_{en}}/{\rho_{air}}} \times W_R \times W_T$$

$$\dot{X} = exposure\ rate\ in \frac{\mu R}{hr}$$

$${\mu_{en}}/{\rho_{tissue}} = mass\ energy\ absorption\ coefficient\ of\ tissue = 0.0307$$

$${\mu_{en}}/{\rho_{air}} = mass\ energy\ absorption\ coefficient\ of\ air = 0.0279$$

$$W_R = Radiation\ weighting\ factor = 1\ for\ x - rays$$

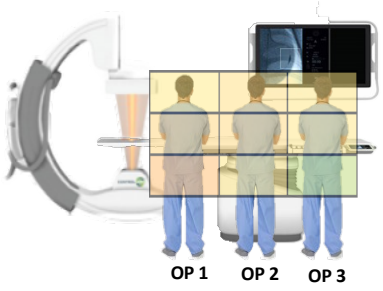
$$W_T = Tissue\ weighting\ factor = 1\ for\ whole\ body$$

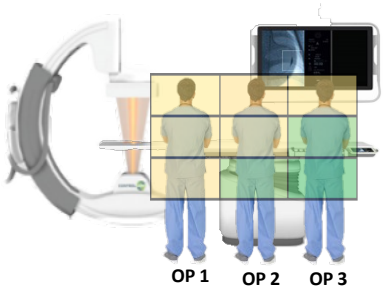
$$\dot{D} = dose\ rate\ in \frac{mrem}{hr}$$

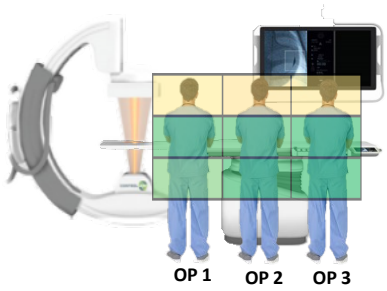
APPENDIX

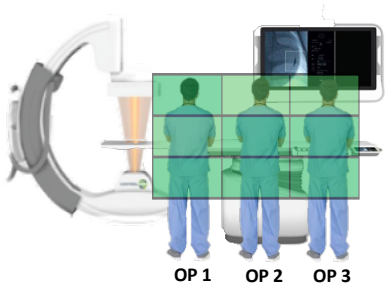
C-Arm Configuration: AP

Height	mSv/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	0.0049	0.0049	0.0049	0.0002
Chest		0.0233	0.0070	0.0009	0.0010
Waist		0.0432	0.0129	0.0017	0.0002
Head	OP 2	0.0146	0.0146	0.0146	0.0013
Chest		0.0193	0.0058	0.0007	0.0003
Waist		0.0080	0.0024	0.0003	0.0002
Head	OP 3	0.0075	0.0075	0.0075	0.0013
Chest		0.0070	0.0021	0.0003	0.0003
Waist		0.0032	0.0010	0.0001	0.0002





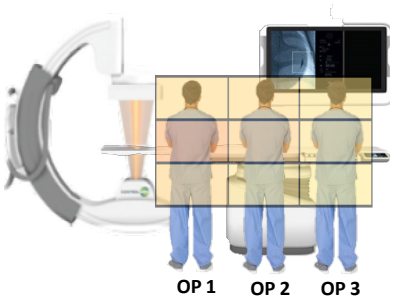


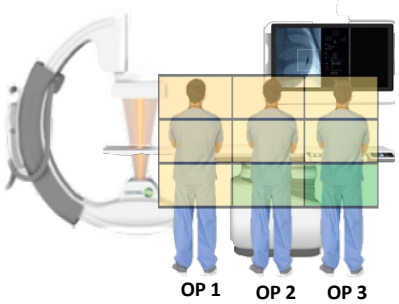


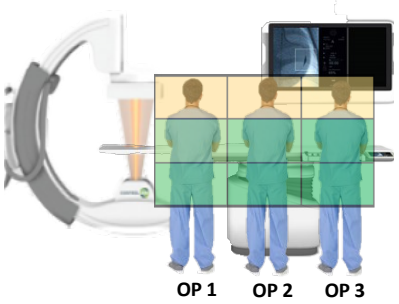
APPENDIX

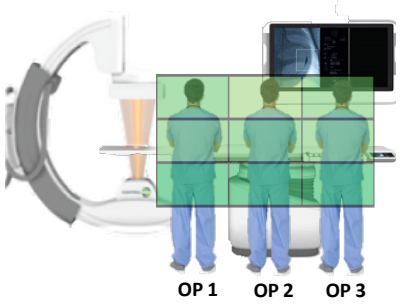
C-Arm Configuration: Cranial 30°

Height	mSv/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	0.0215	0.0215	0.0215	0.0015
Chest	OP 1	0.0576	0.0173	0.0022	0.0018
Waist	OP 1	0.0284	0.0085	0.0011	0.0002
Head	OP 2	0.0207	0.0207	0.0207	0.0025
Chest	OP 2	0.0311	0.0093	0.0012	0.0015
Waist	OP 2	0.0097	0.0029	0.0004	0.0002
Head	OP 3	0.0102	0.0102	0.0102	0.0017
Chest	OP 3	0.0134	0.0040	0.0005	0.0018
Waist	OP 3	0.0045	0.0014	0.0002	0.0002





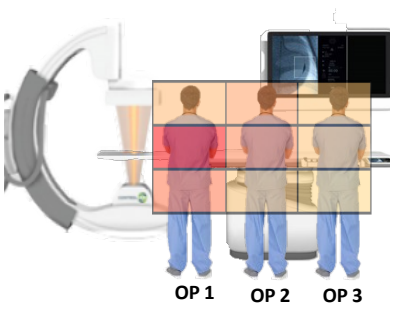


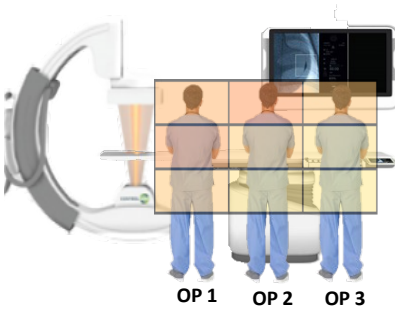


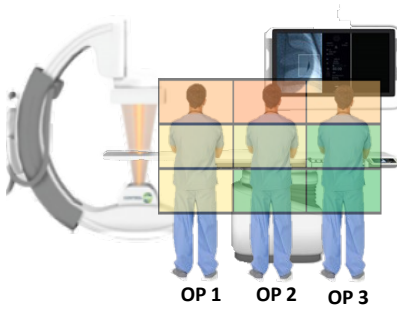
APPENDIX

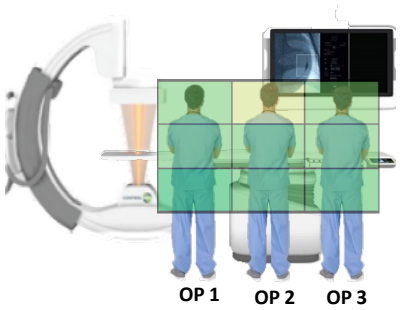
C-Arm Configuration: Cranial 30° LAO 30°

Height	mSv/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	0.0511	0.0511	0.0511	0.0017
Chest	OP 1	0.2037	0.0611	0.0079	0.0015
Waist	OP 1	0.1145	0.0343	0.0044	0.0001
Head	OP 2	0.0736	0.0736	0.0736	0.0034
Chest	OP 2	0.0980	0.0294	0.0038	0.0016
Waist	OP 2	0.0380	0.0114	0.0015	0.0012
Head	OP 3	0.0388	0.0388	0.0388	0.0020
Chest	OP 3	0.0407	0.0122	0.0016	0.0017
Waist	OP 3	0.0222	0.0067	0.0009	0.0011





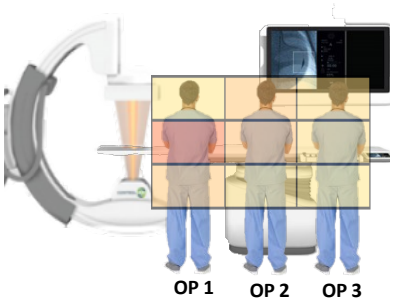


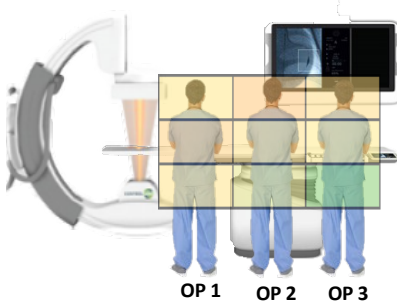


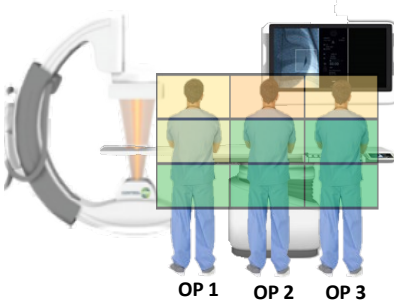
APPENDIX

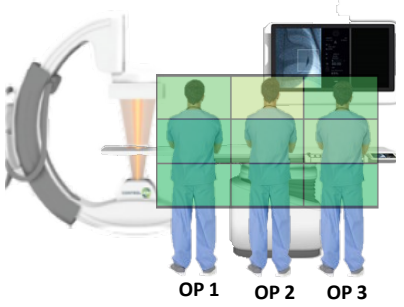
C-Arm Configuration: LAO 30°

Height	mSv/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	0.0076	0.0076	0.0076	0.0016
Chest	OP 1	0.0935	0.0281	0.0036	0.0003
Waist	OP 1	0.0360	0.0108	0.0014	0.0002
Head	OP 2	0.0363	0.0363	0.0363	0.0030
Chest	OP 2	0.0429	0.0129	0.0017	0.0012
Waist	OP 2	0.0128	0.0038	0.0005	0.0002
Head	OP 3	0.0180	0.0180	0.0180	0.0013
Chest	OP 3	0.0168	0.0050	0.0007	0.0019
Waist	OP 3	0.0073	0.0022	0.0003	0.0002





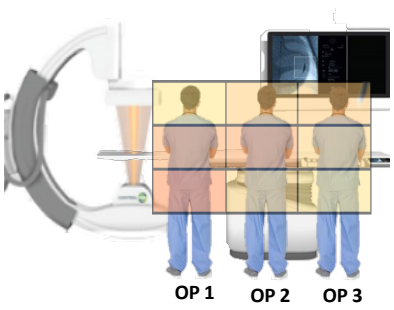


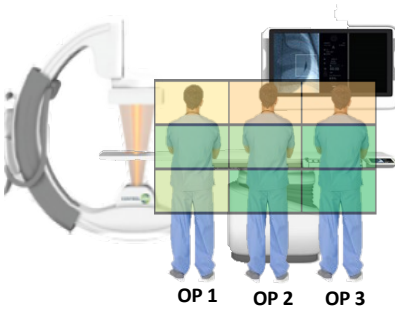


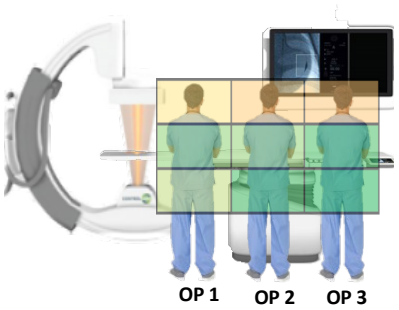
APPENDIX

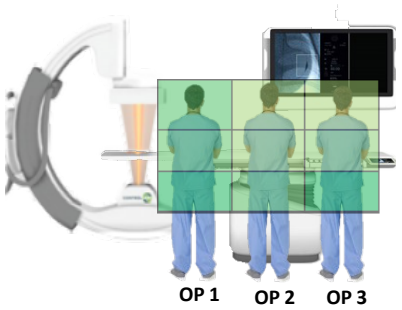
C-Arm Configuration: Caudal 30° LAO 30°

Height	mSv/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	0.0083	0.0083	0.0083	0.0011
Chest	OP 1	0.0586	0.0176	0.0023	0.0014
Waist	OP 1	0.0818	0.0245	0.0032	0.0001
Head	OP 2	0.0322	0.0322	0.0322	0.0027
Chest	OP 2	0.0607	0.0182	0.0024	0.0025
Waist	OP 2	0.0240	0.0072	0.0009	0.0014
Head	OP 3	0.0344	0.0344	0.0344	0.0028
Chest	OP 3	0.0256	0.0077	0.0010	0.0022
Waist	OP 3	0.0116	0.0035	0.0005	0.0001





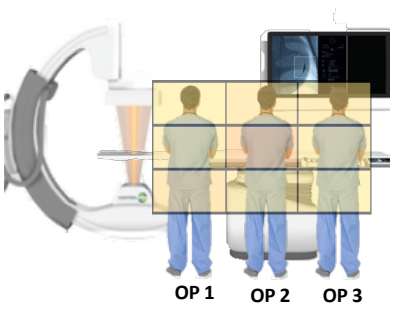


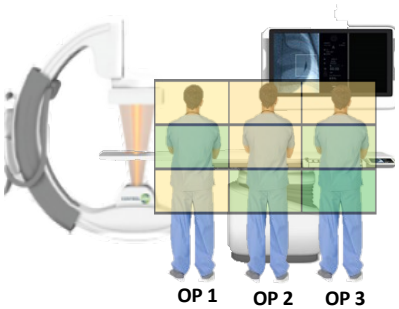


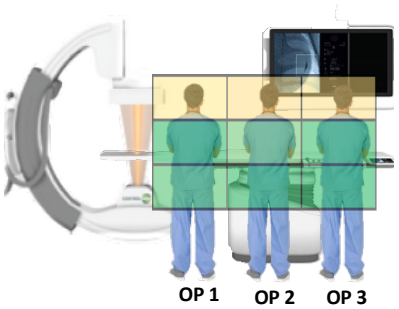
APPENDIX

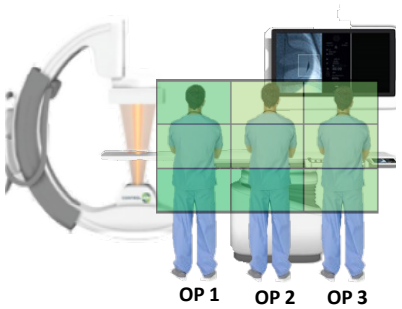
C-Arm Configuration: Caudal 30°

Height	mSv/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	0.0055	0.0055	0.0055	0.0011
Chest		0.0092	0.0028	0.0004	0.0016
Waist		0.0230	0.0069	0.0009	0.0003
Head	OP 2	0.0167	0.0167	0.0167	0.0028
Chest		0.0393	0.0118	0.0015	0.0022
Waist		0.0096	0.0029	0.0004	0.0003
Head	OP 3	0.0140	0.0140	0.0140	0.0021
Chest		0.0106	0.0032	0.0004	0.0024
Waist		0.0053	0.0016	0.0002	0.0019





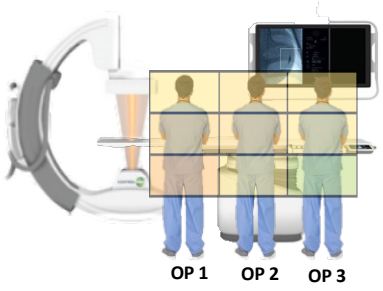


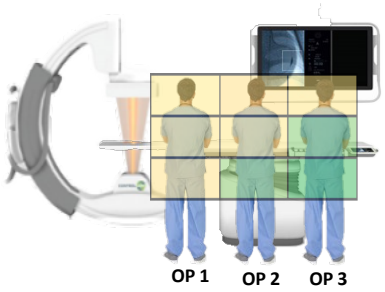


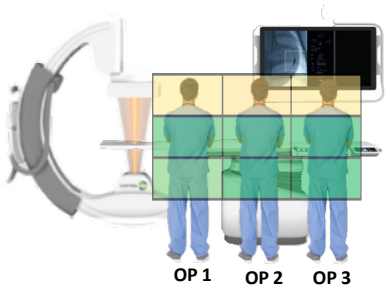
APPENDIX

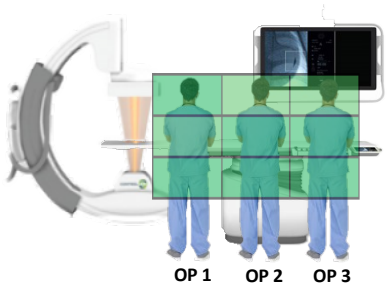
C-Arm Configuration: AP

Height	µSv/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	4.9	4.9	4.9	0.2
Chest		23.3	7.0	0.9	1.0
Waist		43.2	12.9	1.7	0.2
Head	OP 2	14.6	14.6	14.6	1.3
Chest		19.3	5.8	0.7	0.3
Waist		8.0	2.4	0.3	0.2
Head	OP 3	7.5	7.5	7.5	1.3
Chest		7.0	2.1	0.3	0.3
Waist		3.2	1.0	0.1	0.2





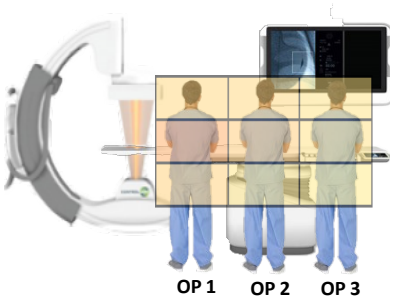


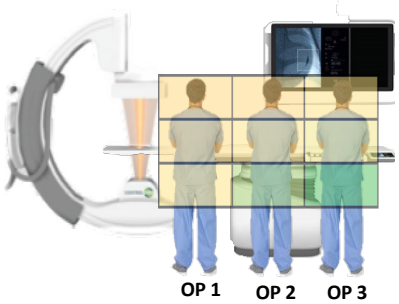


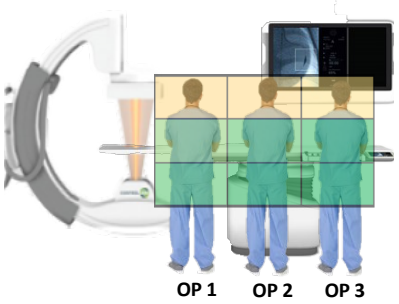
APPENDIX

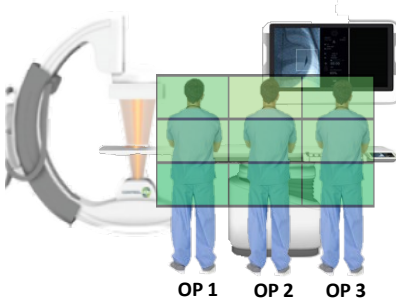
C-Arm Configuration: Cranial 30°

Height	µSv/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	21.5	21.5	21.5	1.5
Chest	OP 1	57.6	17.3	2.2	1.8
Waist	OP 1	28.4	8.5	1.1	0.2
Head	OP 2	20.7	20.7	20.7	2.5
Chest	OP 2	31.1	9.3	1.2	1.5
Waist	OP 2	9.7	2.9	0.4	0.2
Head	OP 3	10.2	10.2	10.2	1.7
Chest	OP 3	13.4	4.0	0.5	1.8
Waist	OP 3	4.5	1.4	0.2	0.2





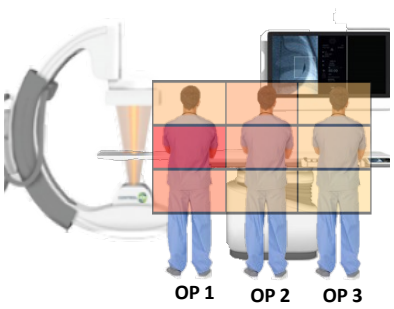


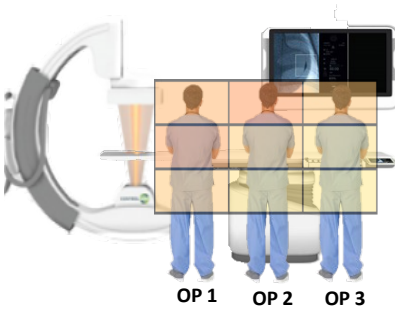


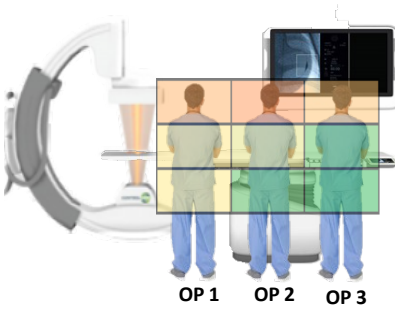
APPENDIX

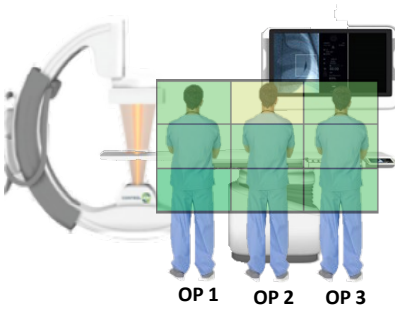
C-Arm Configuration: Cranial 30° LAO 30°

Height	µSv/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	51.1	51.1	51.1	1.7
Chest	OP 1	203.7	61.1	7.9	1.5
Waist	OP 1	114.5	34.3	4.4	0.1
Head	OP 2	73.6	73.6	73.6	3.4
Chest	OP 2	98.0	29.4	3.8	1.6
Waist	OP 2	38.0	11.4	1.5	1.2
Head	OP 3	38.8	38.8	38.8	2.0
Chest	OP 3	40.7	12.2	1.6	1.7
Waist	OP 3	22.2	6.7	0.9	1.1





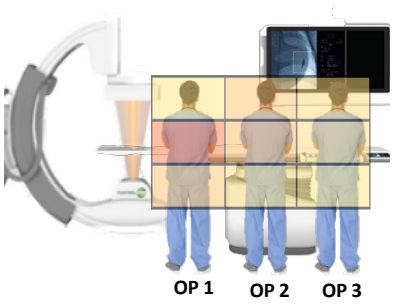


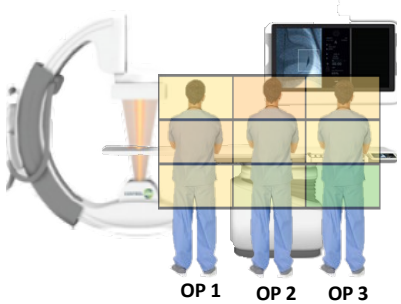


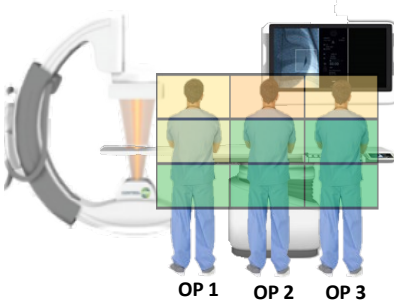
APPENDIX

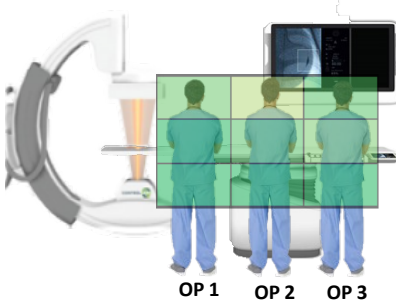
C-Arm Configuration: LAO 30°

Height	µSv/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	7.6	7.6	7.6	1.6
Chest	OP 1	93.5	28.1	3.6	0.3
Waist	OP 1	36.0	10.8	1.4	0.2
Head	OP 2	36.3	36.3	36.3	3.0
Chest	OP 2	42.9	12.9	1.7	1.2
Waist	OP 2	12.8	3.8	0.5	0.2
Head	OP 3	18.0	18.0	18.0	1.3
Chest	OP 3	16.8	5.0	0.7	1.9
Waist	OP 3	7.3	2.2	0.3	0.2





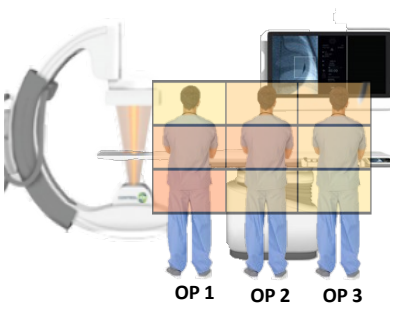


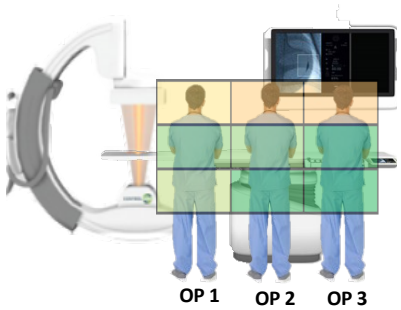


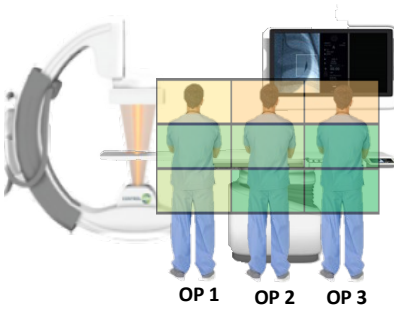
APPENDIX

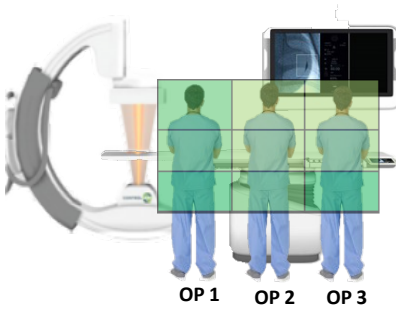
C-Arm Configuration: Caudal 30° LAO 30°

Height	µSv/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	8.3	8.3	8.3	1.1
Chest		58.6	17.6	2.3	1.4
Waist		81.8	24.5	3.2	0.1
Head	OP 2	32.2	32.2	32.2	2.7
Chest		60.7	18.2	2.4	2.5
Waist		24.0	7.2	0.9	1.4
Head	OP 3	34.4	34.4	34.4	2.8
Chest		25.6	7.7	1.0	2.2
Waist		11.6	3.5	0.5	0.1





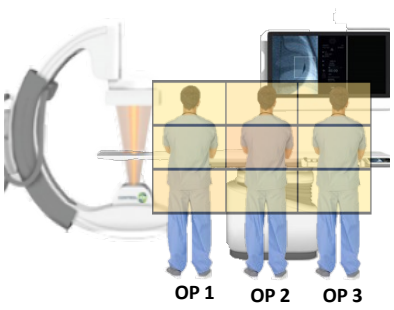


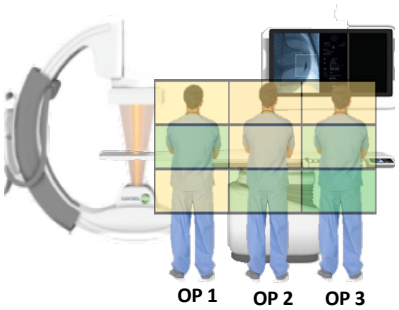


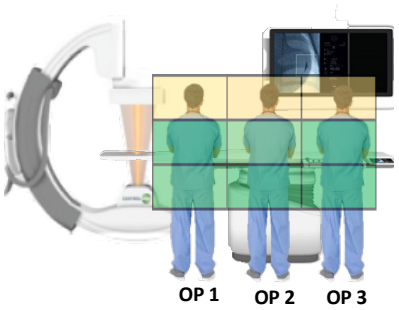
APPENDIX

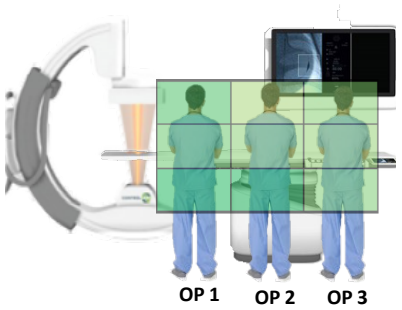
C-Arm Configuration: Caudal 30°

Height	µSv/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	5.5	5.5	5.5	1.1
Chest		9.2	2.8	0.4	1.6
Waist		23.0	6.9	0.9	0.3
Head	OP 2	16.7	16.7	16.7	2.8
Chest		39.3	11.8	1.5	2.2
Waist		9.6	2.9	0.4	0.3
Head	OP 3	14.0	14.0	14.0	2.1
Chest		10.6	3.2	0.4	2.4
Waist		5.3	1.6	0.2	1.9





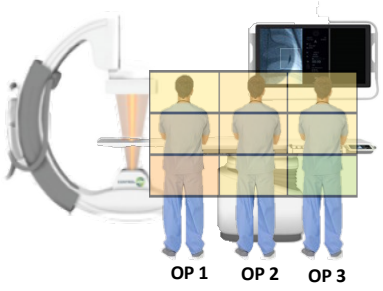


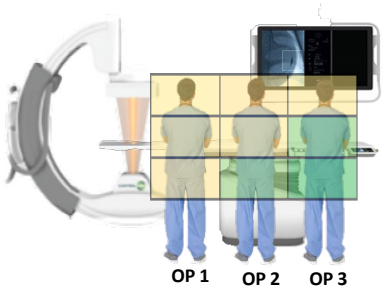


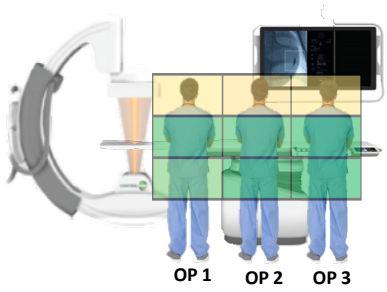
APPENDIX

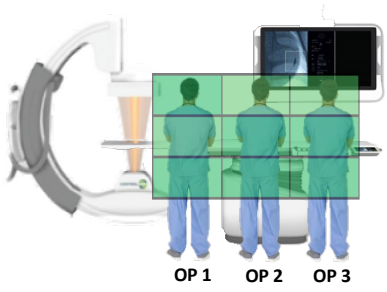
C-Arm Configuration: AP

Height	mrem/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	0.4889	0.4889	0.4889	0.0165
Chest	OP 1	2.3280	0.6984	0.0903	0.0989
Waist	OP 1	4.3165	1.2950	0.1674	0.0175
Head	OP 2	1.4647	1.4647	1.4647	0.1319
Chest	OP 2	1.9303	0.5791	0.0748	0.0272
Waist	OP 2	0.7954	0.2386	0.0308	0.0194
Head	OP 3	0.7527	0.7527	0.7527	0.1261
Chest	OP 3	0.6955	0.2086	0.0270	0.0272
Waist	OP 3	0.3182	0.0954	0.0123	0.0223





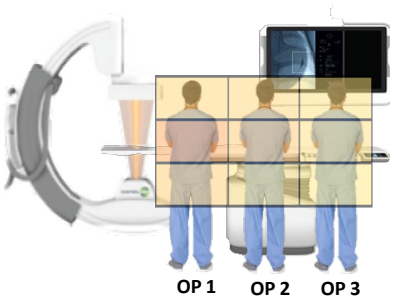


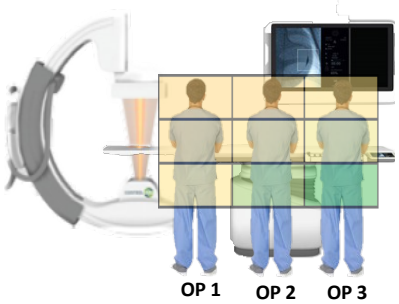


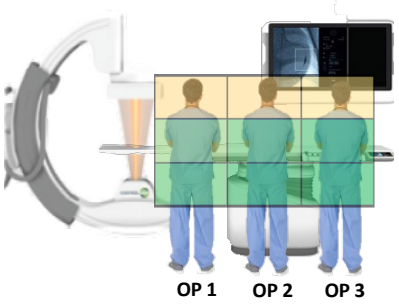
APPENDIX

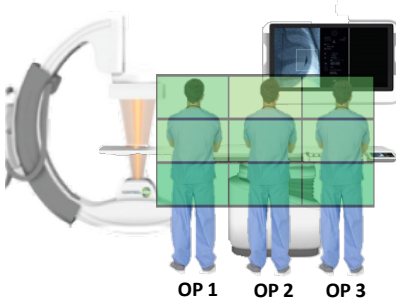
C-Arm Configuration: Cranial 30°

Height	mrem/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	2.1534	2.1534	2.1534	0.1494
Chest	OP 1	5.7618	1.7285	0.2234	0.1785
Waist	OP 1	2.8421	0.8526	0.1102	0.0204
Head	OP 2	2.0661	2.0661	2.0661	0.2483
Chest	OP 2	3.1137	0.9341	0.1207	0.1484
Waist	OP 2	0.9652	0.2895	0.0374	0.0243
Head	OP 3	1.0185	1.0185	1.0185	0.1736
Chest	OP 3	1.3386	0.4016	0.0519	0.1756
Waist	OP 3	0.4501	0.1350	0.0174	0.0213





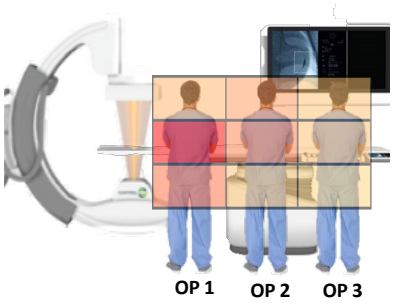


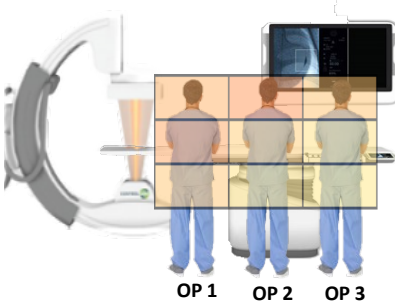


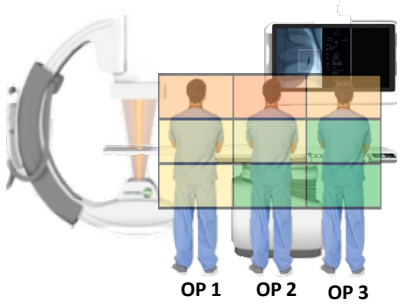
APPENDIX

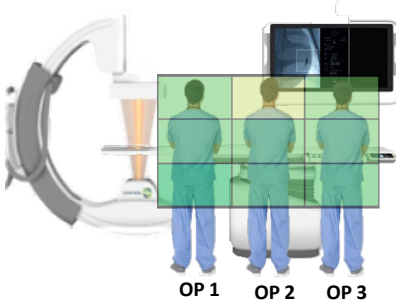
C-Arm Configuration: Cranial 30° LAO 30°

Height	mrem/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	5.1119	5.1119	5.1119	0.1688
Chest	OP 1	20.3700	6.1110	0.7897	0.1484
Waist	OP 1	11.4460	3.4338	0.4438	0.0107
Head	OP 2	7.3623	7.3623	7.3623	0.3434
Chest	OP 2	9.7970	2.9391	0.3798	0.1581
Waist	OP 2	3.8024	1.1407	0.1474	0.1232
Head	OP 3	3.8800	3.8800	3.8800	0.1979
Chest	OP 3	4.0740	1.2222	0.1579	0.1688
Waist	OP 3	2.2213	0.6664	0.0861	0.1067





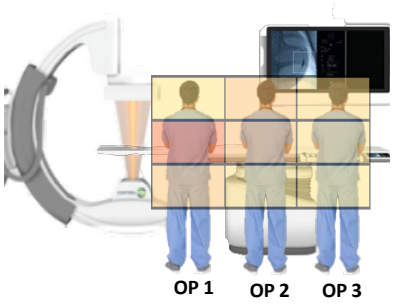


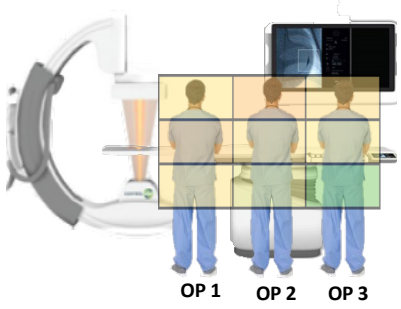


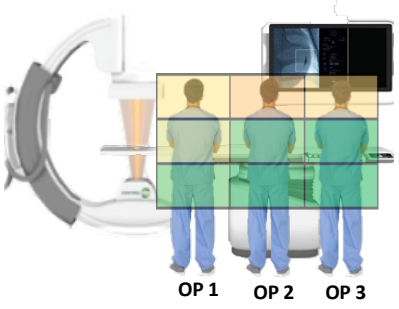
APPENDIX

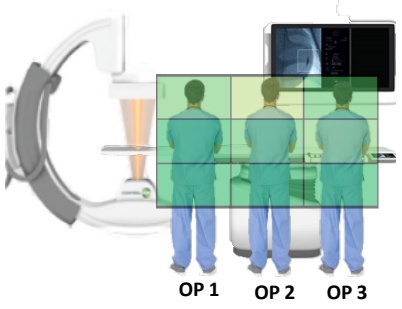
C-Arm Configuration: LAO 30°

Height	mrem/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	0.7595	0.7595	0.7595	0.1649
Chest	OP 1	9.3508	2.8052	0.3625	0.0330
Waist	OP 1	3.5987	1.0796	0.1395	0.0213
Head	OP 2	3.6278	3.6278	3.6278	0.2988
Chest	OP 2	4.2874	1.2862	0.1662	0.1242
Waist	OP 2	1.2804	0.3841	0.0496	0.0194
Head	OP 3	1.8042	1.8042	1.8042	0.1271
Chest	OP 3	1.6781	0.5034	0.0651	0.1872
Waist	OP 3	0.7256	0.2177	0.0281	0.0213





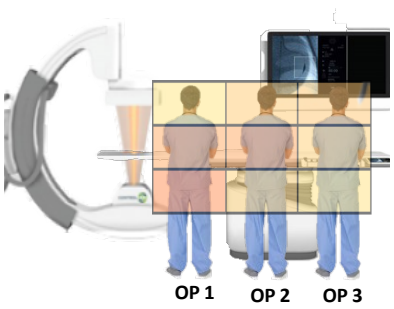


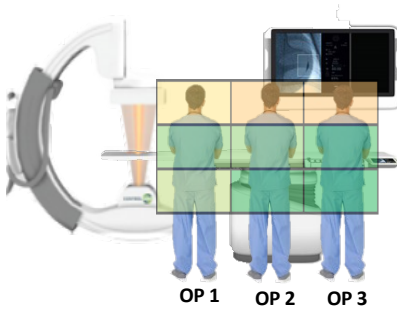


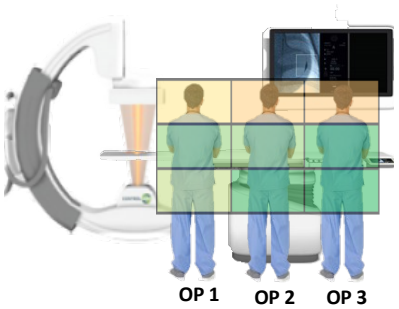
APPENDIX

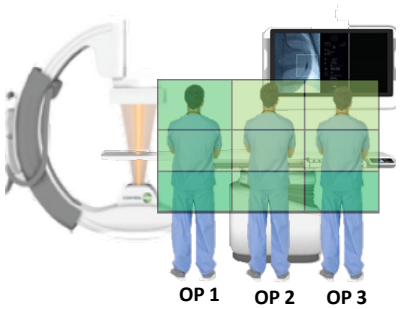
C-Arm Configuration: Caudal 30° LAO 30°

Height	mrem/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	0.8332	0.8332	0.8332	0.1125
Chest	OP 1	5.8588	1.7576	0.2271	0.1387
Waist	OP 1	8.1771	2.4531	0.3170	0.0146
Head	OP 2	3.2204	3.2204	3.2204	0.2726
Chest	OP 2	6.0722	1.8217	0.2354	0.2493
Waist	OP 2	2.3959	0.7188	0.0929	0.1407
Head	OP 3	3.4435	3.4435	3.4435	0.2794
Chest	OP 3	2.5608	0.7682	0.0993	0.2221
Waist	OP 3	1.1640	0.3492	0.0451	0.0136





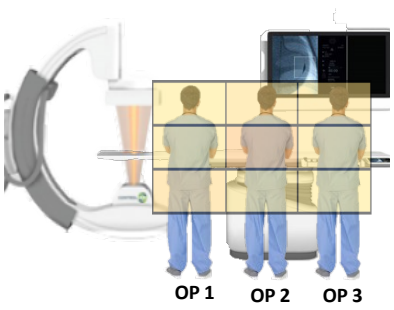


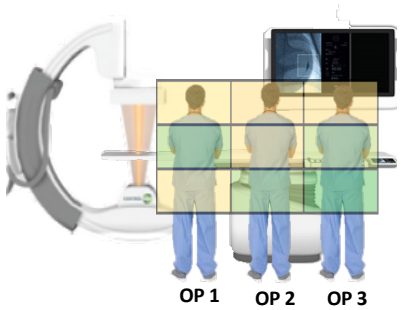


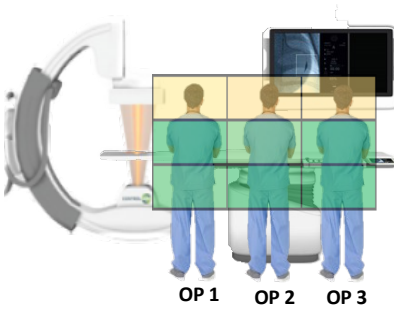
APPENDIX

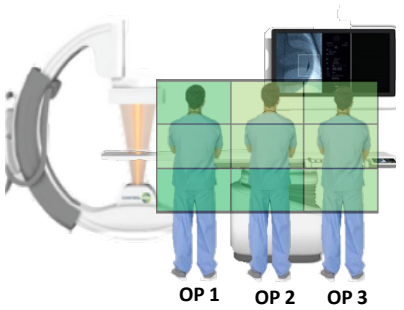
C-Arm Configuration: Caudal 30°

Height	mrem/hr	Conventional table drapes and overhead acrylic shield (no lead aprons)	Conventional table drapes and overhead acrylic shield (lead apron worn and EDE conversion factor applied)	Conventional table drapes and overhead acrylic shield (with 0.5mm lead apron)	Rampart M1128 V2.0, L148 and MPS (no lead apron)
Head	OP 1	0.5510	0.5510	0.5510	0.1086
Chest	OP 1	0.9234	0.2770	0.0358	0.1591
Waist	OP 1	2.2989	0.6897	0.0891	0.0272
Head	OP 2	1.6684	1.6684	1.6684	0.2765
Chest	OP 2	3.9285	1.1786	0.1523	0.2212
Waist	OP 2	0.9603	0.2881	0.0372	0.0301
Head	OP 3	1.3968	1.3968	1.3968	0.2105
Chest	OP 3	1.0573	0.3172	0.0410	0.2367
Waist	OP 3	0.5277	0.1583	0.0205	0.1892









APPENDIX

Equipment and Facility Information

Facility	Ascension St. Vincent's East
Address	50 Medical Park Dr. E Birmingham, AL 35235
Unit Make & Model	Philips Azurion FlexArm Clarity IQ
Test Date	8/14/2023
Physicist	Lancer Smith
Detector Used	RaySafe 452
Serial Number	294597
Detector Calibration Date	11/28/2022

AP		**Cranial 30°**	
Imaging Mode	15 fps medium dose fluoro	**Imaging Mode**	15 fps medium dose fluoro
Table Height	39.5 in	**Table Height**	39.5 in
Focal Spot to Table	27 in	**Focal Spot to Table**	27 in
FOV	19 in	**FOV**	19 in
SID	104 cm	**SID**	112
Tested kVp	60	**Tested kVp**	62
Tested mA	3.3	**Tested mA**	4.2
Cranial 30° LAO 30°		**LAO 30°**	
Imaging Mode	15 fps medium dose fluoro	**Imaging Mode**	15 fps medium dose fluoro
Table Height	39.5 in	**Table Height**	39.5 in
Focal Spot to Table	27 in	**Focal Spot to Table**	27 in
FOV	19 in	**FOV**	19 in
SID	119	**SID**	119
Tested kVp	65	**Tested kVp**	62
Tested mA	6	**Tested mA**	4.1
Caudal 30° LAO 30°		**Caudal 30°**	
Imaging Mode	15 fps medium dose fluoro	**Imaging Mode**	15 fps medium dose fluoro
Table Height	39.5 in	**Table Height**	39.5 in
Focal Spot to Table	27 in	**Focal Spot to Table**	27 in
FOV	19 in	**FOV**	19 in
SID	119	**SID**	119
Tested kVp	64	**Tested kVp**	62
Tested mA	5.5	**Tested mA**	4.5