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ORIGINAL RESEARCH

Innovative radiation protection system enables reduction in the weight of lead aprons during electrophysiological procedures

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Abstract

Background Fluoroscopy-guided medical procedures require medical personnel to wear lead aprons (typically 0.5-mm Pb), which weigh up to 7 kg and can cause significant occupational injuries. A novel robotic radiation-blocking system, Radiaction, reduces full-body scattered radiation by 92% for all Cath-lab staff.

Objectives This study aimed to determine if lighter lead aprons, when combined with Radiaction, can provide protection comparable to the standard 0.5-mm Pb aprons.

Methods Three setups were tested: (1) 0.5-mm Pb apron without Radiaction (control), (2) 0.25-mm Pb apron with Radiaction, and (3) 0.125-mm Pb apron with Radiaction. Radiation attenuation was measured through analytic calculations, bench tests, and clinical prospective controlled evaluations in an electrophysiology laboratory.

Results According to analytical calculations, radiation reduction was 98% for 0.5-mm Pb aprons, 98.5% for 0.25-mm Pb with Radiaction, and 97% for 0.125-mm Pb with Radiaction. Bench tests showed reductions of 97%, 98.9%, and 98%, respectively. Clinical evaluations showed reductions of 99.2% for ablation procedures (98.8% upper- and 99.6% lower body) and 97.1% reductions for cardiovascular implantable electronic devices (CIED) procedures (94.4% upper- and 99.7% lower body) with the 0.25-mm Pb apron and Radiaction. With the 0.125-mm Pb apron and Radiaction, reductions were 97.9% for ablations (97.4% upper- and 98.4% lower body) and 81.7% for CIED procedures (65% upper- and 98.5% lower body).

Conclusions The 0.25-mm Pb apron with Radiaction appears to surpass the standard 0.5-mm Pb apron in radiation protection, while the 0.125-mm Pb apron with Radiaction offers comparable protection. This suggests that Radiaction enables significant apron weight reduction during electrophysiologic procedures without compromising safety and potentially reducing orthopedic injuries.

Keywords Cardiovascular implantable electronic devices (CIED) · Electrophysiology · Lead aprons · Occupational hazards · Radiation protection · X-ray radiation

Abbreviations

CIED	Cardiac implantable electronic devices
CCL	Cardiac catheterization laboratories
DAP	Dose area product
EP	Electrophysiologic
Gy	Gray
Sv	Sievert

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1 Introduction

Advances in medical technology have increased the use of ionizing radiation in cardiology, particularly in electrophysiology (EP) laboratories and cardiac catheterization laboratories (CCL). While essential for diagnostic and interventional EP procedures, radiation exposure poses long-term risks to medical personnel, including increased malignancy risks, early cataract development, and DNA damage [1, 2]. Indeed, the most active interventional and

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EP cardiologists had exposures equating to an excess lifetime risk of cancer of 1 in 100 [3], and they are at high risk of developing radiation-induced cataracts [4]. The long-term effects of occupational X-ray radiation on staff can be mitigated by adopting proper radiation protection measures, such as lead aprons and other protective gear [5].

Lead aprons, which attenuate approximately 95%–98% of scattered radiation, are a common protective measure. However, these aprons are heavy, usually weighing around 7 kg (~15.4 lb), and only cover parts of the body, while other parts (e.g. head, eyes, and arms) are still left exposed. Furthermore, heavy-weight aprons place a lot of strain on the spine and hips, resulting in sore backs, necks, and shoulders, and can lead to severe musculoskeletal injuries [5, 6]. Orthopedic injuries are more frequent among CCL personal as physicians, nurses, and technicians [6]. There is a substantial difference in orthopedic injuries between those wearing lead aprons working in the fluoroscopic laboratory compared to colleagues working in the same department not working in the fluoroscopic laboratory and thus not bearing the burden of wearing lead aprons [4]. Other protective measures include ceiling-mounted shields, table skirts, and lightweight protective clothing, but these often provide incomplete protection from radiation [7–9].

The Radiaction system, an innovative robotic radiation protection system, offers full body shielding by blocking scattered radiation at its source [10, 11]. This study aimed to test the effectiveness of the Radiaction system combined with lightweight aprons (0.25-mm Pb and 0.125-mm Pb) compared to the standard 0.5-mm Pb aprons.

2 Methods

2.1 The radiaction system

The Radiaction system is a robotic radiation shielding system that provides full-body protection to all medical personnel in the CCL and EP laboratories during fluoroscopy-guided procedures by confining the imaging beam and blocking the scattered radiation at its origin. It is comprised of upper and lower extendable shields mounted on the C-arm, creating a barrier around the imaging beam to block scatter radiation. The system deploys and retracts its shields to accommodate C-arm movement and table positioning, as previously described in detail [10, 11].

2.2 Analytical calculations

Radiation attenuation for 0.5-mm Pb, 0.25-mm Pb, and 0.125-mm Pb aprons was measured by FERO Labs, UK. FERO Labs had previously conducted tests to determine the radiation reduction achieved solely by the Radiaction system. These results pertain exclusively to the Radiaction system's effectiveness.

To calculate the combined radiation reduction when using the Radiaction system in conjunction with the various weighted lead aprons, the following calculations were performed: (1) The percentage reduction achieved by each lead apron (0.5-mm Pb, 0.25-mm Pb, and 0.125-mm Pb) was obtained from FERO Labs. (2) These percentages were then combined with the radiation reduction percentage achieved by the Radiaction system alone. (3) The resulting combined percentage represented the overall reduction in radiation exposure when both the lead apron and the Radiaction system were used together.

2.3 Bench tests

Radiation measurements were taken with the Toshiba/Canon Infinix-i Core Single Plane, Floor Mounted C-arm system. Measurements were collected before the Radiaction system installation for all three setups and after the Radiaction system installation. These measurements were conducted using mannequins wearing different weighted aprons across various C-arm angles and positions in the CCL. An anthropomorphic phantom (The RANDO® Phantom by The Phantom Laboratory) was used to simulate the patient and generate scatter radiation. Sensors measured radiation at upper body and pelvic levels at four different locations around the table, as indicated in Fig. 1.

All radiation measurements were compared to the baseline of total radiation in the room, established through previous lab tests. These initial tests measured radiation levels at typical angles used in the CCL without any radiation protection in place, providing a benchmark for typical radiation exposure in such an environment. Subsequent measurements, both with the Radiaction system installed and without it, were then compared to this baseline.

2.4 Tissue weighting factor

To further understand the contribution of the Radiaction system in CCL procedures, the tissue weighting factor (TwT) was calculated. TwT refers to the varying sensitivity of different tissues to ionizing radiation. According to the National Research Council (NRC), this factor reflects the relative contribution of each tissue or organ to the overall risk of damage from exposure to radiation [12]. According to the NRC, the overall radiation sensitivity contributed by each body region is 0.10 for the upper head and neck region, 0.38 for the upper torso region, 0.50 for the lower

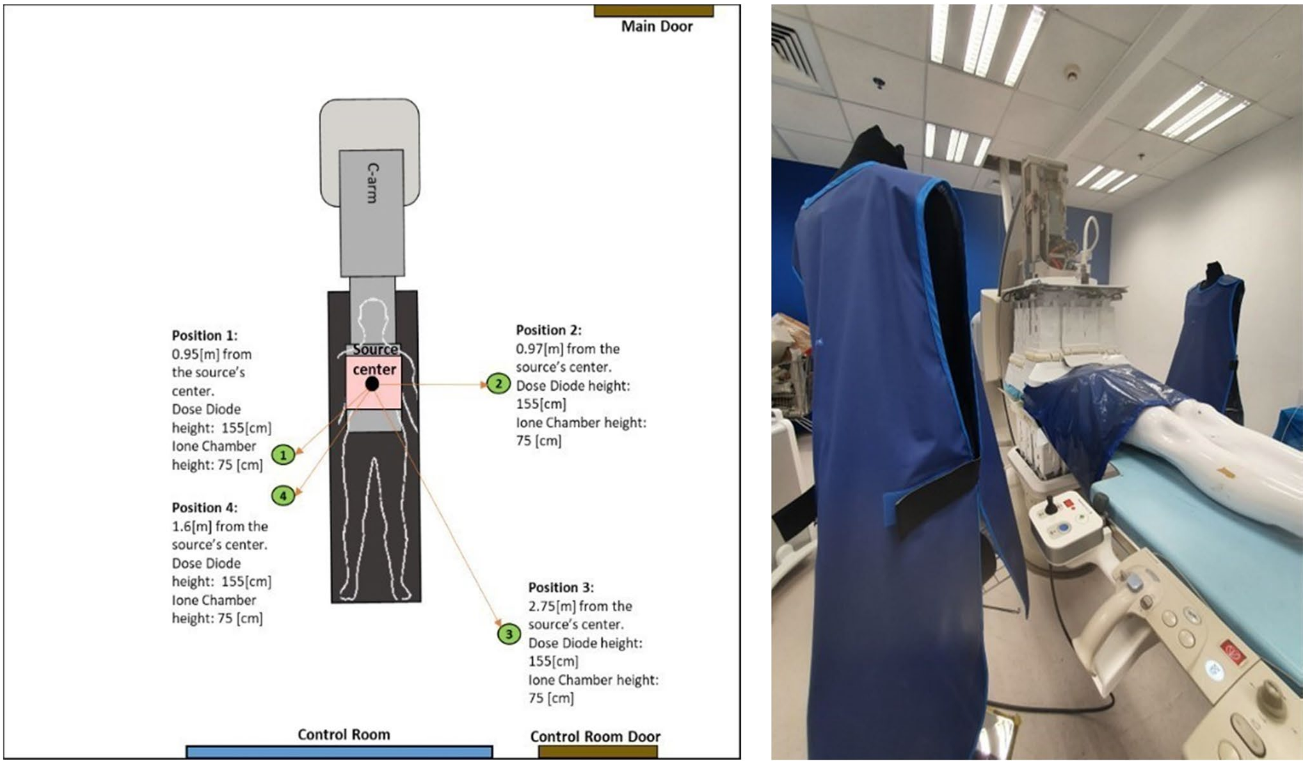


Fig. 1 Sensor positions around the C-arm during bench tests

torso region, and 0.005 for extremities (arms and legs) (Supplement Fig. 1). The factors are applied when calculating the effective dose by multiplying the absorbed dose in each region by its respective compartment factor. These calculations provide further insight into areas of the body that are not protected by the lead apron but can be protected from the Radiaction system which offers full-body protection.

To calculate this, the radiation reduction from FERO Labs was multiplied by their respective protection. For example, without the Radiaction system, the area covered by the lead apron was multiplied by the radiation reduction from the lead apron only. With a 0.125-mm Pb apron and the Radiaction system, the area covered by the lead was multiplied by the radiation reduction provided by both the lead apron and the Radiaction system, while areas not covered by the lead apron were multiplied by the reduction achieved with the Radiaction system only (based on pervious Bench Tests performed).

2.5 Clinical evaluation in an electrophysiological laboratory

Conducted at the EP laboratory of the Assuta Ashdod Medical Center (Ashdod, Israel), sensors placed under physicians' aprons measured radiation during ablation procedures and during implantations of cardiovascular implantable electronic devices (CIED) at chest height (upper level) and pelvic height (lower level). Since the study did not include active intervention in patients, the local institutional Helsinki committee exempted us from obtaining informed consent.

Highly sensitive sensors were used for radiation dose measurements (Mirion DMC 3000; Mirion Technologies, Inc). The gray (symbol, Gy) is the unit of ionizing radiation dose in the International System of Units (SI), defined as the absorption of one joule of radiation energy per kilogram of matter. The sievert (symbol, Sv) is a derived unit in the International System of Units (SI) intended to represent the stochastic health risk of ionizing radiation, which is defined as the probability of causing radiation-induced cancer and genetic damage. The sievert is important in dosimetry and radiation protection. 1 Sv = 1 J/kilogram and represents the equivalent biological effect of the deposit of a joule of radiation energy in a kilogram of human tissue. The minimum sensitivity of the Mirion DMC 3000 sensor for clinical environment was 0.01 μSv. Normalized exposures were calculated by dividing total dose (in μSv) by the dose area product ($Gy \times m^2[squaremeters]$). We used meters only, as these are the units used by the Toshiba system in the patient dose report at the end of the procedure.

In the first stage, physicians wore 0.5mmPb aprons without the Radiaction system to establish a baseline for current standard protection. Sensors were placed beneath the physician's 0.5mmPb apron. With the 0.5mmPb aprons, a 98% radiation reduction was achieved (based on Fero's lab results), resulting in 2% of the original radiation level as the baseline for the next stages of the evaluation. This 2% was then used as the baseline for the next stages of the evaluation.

In the subsequent stage, the Radiaction system was installed, and physicians wore lighter lead aprons (0.25-mm Pb or 0.125-mm Pb) to measure the radiation reduction achieved with the Radiaction system. To ensure the physician's radiation protection, they wore their standard 0.5-mm Pb aprons and wore one of the lightweight aprons on top. To measure the radiation reduction provided by the lightweight aprons on conjunction with the Radiaction system, sensors were placed on top of the physician's 0.5-mm Pb apron and beneath the lightweight apron. This setup ensured that the physician retained their standard protection with the 0.5-mm Pb apron, while the sensor measures the attenuation provided by the lightweight apron in combination with the Radiaction system.

During CIED implantations, one of Radiaction's upper shield segments remained retracted to allow full access to the surgical field, as previously described [11] (Fig. 3B).

2.6 Statistical analysis

Radiation measurements per procedure were taken, and all measurements were normalized by the dose area product (DAP) retrieved from the fluoroscopy imaging machine at the end of each procedure (a standard method for assessing radiation exposure). The normalization to DAP enabled us to take into account the fluoroscopy time and other parameters that affect the magnitude of the X-ray (e.g., patient body mass index (BMI) and C-arm angulations). The average normalized measurements of all three setups were compared in order to determine the combined reduction abilities of the Radiaction system and the lighter lead aprons.

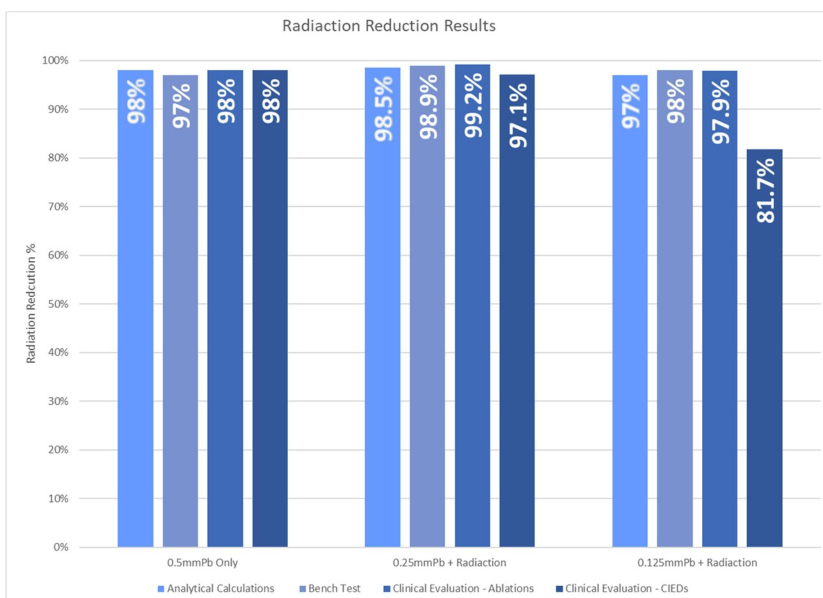
A post hoc analysis using the Scheffe test was performed following ANOVA to compare radiation exposure across the three setups (0.5-mm Pb without Radiaction, 0.25-mm Pb with Radiaction, and 0.125-mm Pb with Radiaction). The Scheffe test was chosen to control for type I error due to multiple comparisons, as it is a conservative method suited for comparing all possible pairs of means. The analysis provided mean differences between setups, along with the associated standard errors, *p*-values, and 95% confidence intervals to determine statistical significance. A significance level of $p<0.05$ was considered for identifying significant group differences.

3 Results

3.1 Analytical calculations

Radiation reduction was 98% for 0.5-mm Pb aprons (Supplement Table 1), 98.5% for 0.25mmPb aprons with the Radiaction system, and 97% for 0.125mmPb aprons with the Radiaction system (Fig. 2 and Supplement Table 1).

Fig. 2 Radiation reduction results for each setup



3.2 Bench tests

Measured reductions were 97% (0.5-mm Pb), 98.9% (0.25-mm Pb + Radiaction), and 98% (0.125-mm Pb + Radiaction). Measurements were taken at various positions around the C-arm and at several typical C-arm angulations, confirming consistent protection across different clinical scenarios (Fig. 2 and Supplement Table 2).

3.3 Clinical evaluation in the EP laboratory

The *overall* radiation reduction was as follows: 98% for ablations and CIED procedures with 0.5-mm Pb apron without Radiaction system—based on the attenuation results obtained from FERO labs, leaving 2% as the reference point for evaluating the other combinations. There was a reduction in radiation exposure of 99.2% for ablation procedures (n=35) and 97.1% reductions for CIED procedures (n=21) with the 0.25-mm Pb apron and the Radiaction system, and 97.9% for ablation procedures (n=39) and 81.7% for CIED procedures (n=36) with the 0.125mmPb apron and the Radiaction system (Figs. 2 and 3A and Table 1).

During *ablation procedures,* for the *upper body*, the radiation reduction was 98% with 0.5-mm Pb aprons, 98.8% with 0.25-mm Pb aprons and the Radiaction system, and 97.4% with the 0.125-mm Pb and the Radiaction system. For the *lower body*, the radiation reduction was 98% with 0.5-mm Pb aprons, 99.6% with 0.25-mm Pb aprons and the Radiaction system, and 98.4% with 0.125-mm Pb aprons and the Radiaction system (Table 1).

For CIED procedures, with one of the upper shields retracted to allow full access to the surgical field (Fig. 3B), the radiation reduction for the *upper body* was 98% with 0.5-mm Pb aprons, 94.4% with 0.25-mmPb aprons and the Radiaction system, and 65% with 0.125-mm Pb aprons and the Radiaction system. The radiation reduction for the *lower body* in CIED cases was 98% with 0.5-mmPb aprons, 99.7% with 0.25-mm Pb aprons and the Radiaction system, and 98.5% with 0.125-mmPb aprons and the Radiaction system (Table 1).

Post-hoc analysis using the Scheffe test revealed no statistically significant differences in *upper body* radiation exposure for ablation cases between setup 1 (0.5-mm Pb without Radiaction) and setup 2 (0.25-mm Pb with Radiaction) or between setup 1 and setup 3 (0.125-mm Pb with Radiaction). Similarly, *lower body* radiation exposure in Ablation cases also showed no significant differences between the setups. In CIED cases, *upper body* radiation exposure showed no statistical significance between setup 1 and setup 2. However, a significant difference was observed between setup 1 and setup 3, due to the one segment being retracted to allow access to the surgical field (Fig. 3B). Predictably, for *lower body* radiation exposure in CIED cases, there were no significant differences between setup 1 and setup 2, as well as between setup 1 and setup 3 (Table 2).

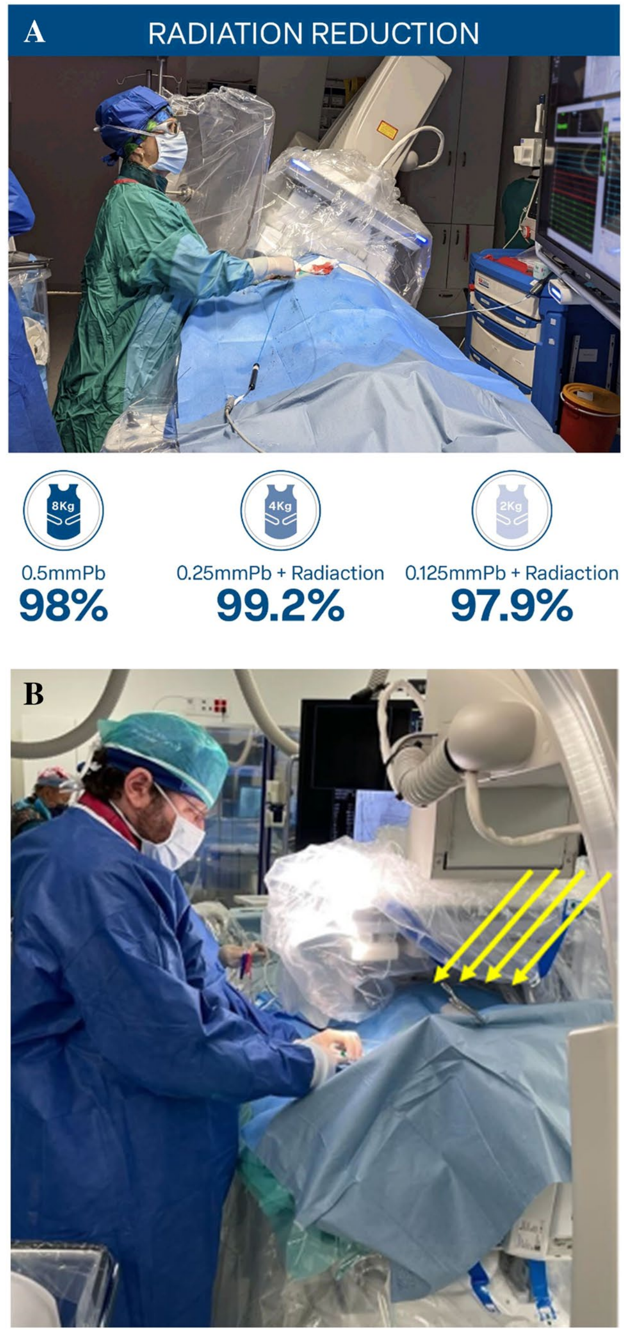


Fig. 3 **A** Radiation reduction using Radiaction shielding system with thin aprons during ablation procedures. **B** CIED procedure—segment in front of physician remains retracted to allow access to the surgical field

Table 3 describes the results for each of the three primary operators, highlighting some variability among them. Additionally, one other physician performed a nominal number of

Table 1 Radiation reduction results per *setup* for ablations and CIED procedures

All physicians results						
	Ablations			CIEDs		
	0.5-mm Pb only (*n*=36)	0. 25-mm Pb+Radiaction (*n*=35)	0.125-mm Pb+Radiaction (*n*=39)	0.5-mm Pb only (*n*=41)	0.25-mm Pb+Radiaction (*n*=21)	0.125 mmPb+Radiaction (*n*=36)
Upper body	98%	98.8%	97.4%	98%	94.4%	65%
Lower body	98%	99.6%	98.4%	98%	99.7%	98.5%
Full body	98%	99.2%	97.9%	98%	97.1%	81.7%
Upper body[a]	1537	926.8	1993.3	770.3	2145.4	13490
Lower body[a]	600.6	124	494.3	1402.3	224	1087.8

[a]Radiation reduction results per *setup* normalized by DAP (all units are in $\frac{\mu Sv}{Gy*m^2}$)

Table 2 Post hoc comparisons of radiation exposure between setups. Post hoc Scheffe tests results for radiation exposure across all three setups. The only significant difference observed was between 0.5-mm Pb with no Radiaction and 0.125-mm Pb with Radiaction in CIED cases for upper body exposure due to allow access to the surgical field

Upper body exposure—ablations			
Setup comparison		**Mean difference**	***p*-value**
Setup	**Compared to setup**		
0.5-mm Pb without Radiaction	0.25-mm Pb with Radiaction	610.78	0.309
	0.125-mm Pb with Radiaction	−509.12	0.441
Lower body exposure—ablations			
Setup comparison		**Mean difference**	***p*-value**
Setup	**Compared to setup**		
0.5-mm Pb without Radiaction	0.25-mm Pb with Radiaction	476.6	0.140
	0.125-mm Pb with Radiaction	94.7	0.908
Upper body exposure—CIEDs			
Setup comparison		**Mean difference**	***p*-value**
Setup	**Compared to setup**		
0.5-mm Pb without Radiaction	0.25-mm Pb with Radiaction	−2553.6	0.260
	0.125-mm Pb with Radiaction	−12,720.3	**<0.001**
Lower body exposure—CIEDs			
Setup comparison		**Mean difference**	***p*-value**
Setup	**Compared to setup**		
0.5-mm Pb without Radiaction	0.25-mm Pb with Radiaction	1134.5	0.437
	0.125-mm Pb with Radiaction	314.5	0.915

cases and was included in the main analysis. The variability may be influenced by factors such as the physician's height, their specific techniques and workflow methods, their experience and expertise in minimizing radiation exposure, and their willingness to deploy and use the Radiaction system.

3.4 Analysis according to tissue weighting factor

The tissue compartment factors reflect that while 0.5-mm Pb lead aprons provide a 98% reduction in radiation, they only cover 88% of the body (Supplement Fig. 1), leaving the head and extremities exposed. This implies that the overall radiation reduction is only 86%. According to the analytic calculations and bench tests results (Supplement Tables 1 and 2), with 0.25-mm Pb aprons used in conjunction with the Radiaction system (which provides protection to the head, neck, and extremities), the total reduction for an individual is 97.5%. With 0.125-mm Pb aprons and the Radiaction system, the overall reduction is 96.18%. For the main physician, the radiation reduction with just the 0.5-mm Pb apron is 86.24%. With 0.25-mm Pb aprons and the Radiaction system, the reduction is 98.48%, and with 0.125-mm Pb aprons and the Radiaction system, the reduction is 96.74% (Table 4).

4 Discussion

Our study suggests that when using the Radiaction system in interventional EP procedures, it is possible to reduce the weight of lead aprons by up to 75% without compromising radiation protection levels. Moreover, the Radiaction system offers superior radiation protection by ensuring full body protection, extending beyond the areas shielded by the lead apron. Even in CIED procedures, the Radiaction system can potentially reduce the weight burden by using a lighter lead apron in the lower body area. These findings are particularly relevant for electrophysiologists, interventional cardiologists, and other CCL staff who wear aprons for prolonged periods, as lighter aprons can mitigate the risk of musculoskeletal injuries. The study's robust analytical, bench, and clinical evaluations provide a comprehensive validation of the system's effectiveness.

Table 3 Radiation reduction results per *physician* with each setup for ablations and CIED procedures

Physician #1						
	Ablations			**CIEDs**		
	0.5-mmPb only (*n*=36)	**0.25-mmPb+ Radiaction (*n*=4)**	**0.125-mmPb+ Radiaction (*n*=12)**	**0.5-mmPb only (*n*=41)**	**0.25-mmPb+ Radiaction (*n*=4)**	**0.125-mmPb+ Radiaction (*n*=7)**
Upper body	98%	98.73%	98.77%	98%	92.3%	59.7%
Lower body	98%	99.87%	98.18%	98%	99.45%	98.54%
Full body	98%	99.3%	99%	98%	95.9%	79.1%
Upper body[a]	1537.6	973	873.5	770.3	2241.9	16267.8
Lower body[a]	600.6	39.9	221.5	1402.3	324.5	928.8
Physician #2						
	Ablations			**CIEDs**		
	0.5-mm Pb only (*n*=36)	**0. 25-mm Pb+ Radiaction (*n*=11)**	**0.125 mmPb+ Radiaction (*n*=14)**	**0.5-mmPb only (*n*=41)**	**0.25-mm Pb+ Radiaction (*n*=3)**	**0.125-mm Pb+ Radiaction (*n*=10)**
Upper body	98%	98.74%	96.77%	99%	94.37%	77.96%
Lower body	98%	99.53%	97.67%	99%	100%	99.31%
Full body	98%	98.1%	97.2%	99%	97.2%	88.6%
Upper body[a]	1537.6	966.1	2483.2	770.3	2121.8	6740.1
Lower body[a]	600.6	140.1	699.7	1402.3	0	893.7
Physician #3						
	Ablations			**CIEDs**		
	0.5-mm Pb only (*n*=36)	**0.25-mm Pb+ Radiaction (*n*=15)**	**0.125-mm Pb+ Radiaction (*n*=11)**	**0.5-mm Pb only (*n*=41)**	**0.25-mm Pb+ Radiaction (*n*=12)**	**0.125-mm Pb+ Radiaction (*n*=11)**
Upper body	98%	98.9%	96.75%	99%	88.08%	41.73%
Lower body	98%	99.81%	99.41%	99%	99.56%	98.89%
Full body	98%	99.4%	98.1%	99%	93.8%	70.3%
Upper body[a]	1537.6	767.6	2844	770.3	4264.5	15445.6
Lower body[a]	600.6	113.9	536.3	1402.3	303.8	919.3

[a]Radiation reduction results per *setup* normalized by DAP (all units are in $\frac{\mu Sv}{Gy*m^2}$)

Table 4 Results of the radiation reduction per *tissue compartment factor* (TcT) by setup

All sensors			
	0.5-mm Pb only	**0.25-mm Pb+Radiaction**	**0.125-mm Pb+Radiaction**
Analytical calculations	86.24%	97.5%	96.18%
Bench test results	85.36%	97.83%	97.04%
Main physician			
	0.5-mm Pb only	**0.25-mm Pb+Radiaction**	**0.125-mm Pb+Radiaction**
Analytical calculations	86.24%	98.48%	96.74%
Bench test results	85.5%	97.73%	95.57%

The current study shows that the Radiaction system, when used with 0.25-mm Pb lead aprons, offers a higher level of protection than the standard 0.5-mm Pb aprons alone while the 0.125-mm Pb aprons with the Radiaction system provide radiation protection comparable to 0.5-mm Pb aprons while significantly reducing apron weight. For ablation procedures in the EP laboratory, this study introduces the option of reducing the lead apron weight by 75% with comparable protection as the 0.5-mm Pb aprons used today. In CIED procedures, where a segment remains retracted to allow access to the surgical field [10, 11], the level of protection is still reduced. However, given the absence of alternative protection options for these types of procedures, this approach offers the highest available protection [8]. For CIED procedures, this study suggests the possibility of wearing a 2-piece apron with 0.5-mm Pb for the top and 0.125-mm Pb for the bottom, to provide enhanced protection and still reducing the weight of the lead aprons on the medical staff. Thus, this innovation has the potential to alleviate the musculoskeletal burden on medical personnel, prevent orthopedic injuries, and offer a superior alternative for radiation protection.

Furthermore, the analysis of the tissue compartment factors, and the corresponding radiation reduction achieved, highlights the significant impact of full body protection that can be provided with the Radiaction system. Traditional 0.5-mm Pb lead aprons, despite their high radiation reduction capability of 98%, only cover 88% of the body, leaving critical areas such as the head and extremities exposed, thereby reducing their overall effectiveness to around 86%. The combination of lead aprons with the Radiaction system markedly enhances the radiation protection. These findings underscore the efficacy of the Radiaction system, providing full-body protection, addressing the limitations of traditional lead aprons. Implementing such comprehensive protection measures can significantly reduce the risk of radiation exposure to medical staff.

Several radiation protection systems are available in EP laboratories and CCL. For example, Rampart IC is a floor-mounted radiation shielding system that uses a large, clear acrylic panel attached to a motorized articulating arm. The system is positioned between the operator and the patient table and is controlled via a touchscreen interface or foot pedal. The shield is adjustable and designed to block scatter radiation by creating a vertical physical barrier. It requires floor space and setup prior to each procedure [13]; Egg Medical offers the EggNest Protection System, a modular shielding platform integrated into the patient table. It includes a carbon fiber table overlay with embedded shielding material and attachable shields that extend around the patient's body. The system provides structural protection beneath and around the patient to reduce scatter radiation reaching the staff. It is installed directly onto existing cath lab tables and requires positioning of the shielding components before each case [14]; Protego is a radiation shielding system that uses articulating arms mounted to the procedure table, holding large transparent leaded-glass panels. These panels are positioned manually around the patient to create a barrier between the radiation source and the medical staff. The system also includes integrated cameras to maintain visibility when the shields obstruct the line of sight. Setup involves manual placement and adjustment of multiple shield arms prior to each procedure [15]. Unlike traditional shielding systems that rely on fixed panels positioned between the staff and the patient, Radiaction's robotic shield integrates directly onto the C-arm and deploys automatically with no setup time. It moves with the imaging system, maintaining full radiation protection without obstructing access to the patient. This agile, on-demand protection eliminates the need for manual adjustments and allows physicians to work freely from any angle, seamlessly supporting workflow and emergency access. There is limited data in the literature comparing next-generation scatter-radiation shielding systems. A recent study evaluated the EggNest Complete and Rampart IC systems, showing that, compared to no shielding, both significantly reduced radiation exposure for the primary operator and assistant. However, the EggNest Complete system offered additional significant protection for CCL team members positioned at the head of the bed and nursing stations—an effect not observed with the Rampart IC system [16]. To better inform clinical decision-making, future studies should conduct direct comparisons of these systems beyond radiation dose reduction. Important factors to consider include ease of use, frequency of use across different procedures, accessibility to the patient during emergencies, and the systems' impact on operator-related outcomes such as radiation-induced DNA damage [17].

After proving the benefit of Radiaction shielding system in the EP laboratory, future studies should aim to test this approach in an invasive CCL, where the clinical workflow involves more frequent and steeper C arm angulations. Additionally, future larger scale research could explore the long-term benefits of using lighter aprons on musculoskeletal health and the potential for implementing this technology across other radiology departments.

5 Limitations

One limitation of this study is the small number of participating physicians. A larger sample size could potentially provide results that are more representative of a broader population and possibly enhance the generalizability of the study's findings.

A second limitation is that this study was conducted exclusively in an EP laboratory with its specific workflow and procedural angles for ablation and CIED cases. Conducting this study in other interventional radiology labs could provide a broader perspective and further insights.

Lastly, the sensors in this study were positioned between two lead aprons (on top of the 0.5-mm Pb apron, and beneath one of the lightweight aprons), which may have resulted in the sensors detecting backscatter from the 0.5-mm Pb apron. Given that the reduction levels with the light weight aprons and the Radiaction system are comparable to those provided by the 0.5-mm Pb apron, it would be valuable to consider taking measurements without using the 0.5-mm Pb apron.

6 Conclusions

Throughout the past decades, many efforts have been done to reduce radiation, improve image quality, and reduce the health hazards risks to the electrophysiology and CCL personal. As procedures become increasingly complex and prolonged and their volume increases, it should not be surprising that EP and interventional practice is attended by a high rate of occupational-induced orthopedic injuries (5, 6). In the present study, we found that in EP procedures, 0.25-mm Pb aprons with Radiaction system surpass the standard 0.5-mm Pb alone, while 0.125-mm Pb aprons with Radiaction provide comparable protection. These findings suggest that incorporating the Radiaction system allows for a significant reduction in lead apron weight by up to 75% during ablation procedures and in the lower body area during CIED procedures, without compromising protection levels and with the advantage of ensuring full-body protection.

6.1 Clinical perspective

The implications of the study for current practice Fluoroscopy-guided medical procedures require medical personnel to wear lead aprons, which attenuate approximately 95%–98% of scattered radiation. However, these aprons are heavy, induce orthopedic injuries, and only cover parts of the body. The Radiaction system is an innovative robotic radiation shielding system that blocks scattered radiation at its source. We found that incorporating the Radiaction system allows for a significant reduction in lead apron weight by up to 75% during ablation procedures and in the lower body area during CIED procedures, without compromising protection levels and with the advantage of ensuring full-body protection.

Translational outlook Larger studies are needed to enhance the generalizability of the study's findings to other interventional radiology laboratories.

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Declarations

Conflict of interest This work was not supported by any grant. There is no relationship with industry. Eli I. Lev previously received payments as clinical advisors for Radiaction Ltd (in the past, prior to the current study). There is no conflict of interest for the other authors.

References

1. Picano E, Vano E, Domenici L, Bottai M, Thierry-Chef I. Cancer and non-cancer brain and eye effects of chronic low-dose ionizing radiation exposure. BMC Cancer. 2012;12(1):1–13.
2. Roguin A, Goldstein J, Bar O, Goldstein JA. Brain and neck tumors among physicians performing interventional procedures. Am J Cardiol. 2013;111(9):1368–72.
3. Venneri L, Rossi F, Botto N, et al. Cancer risk from professional exposure in staff working in cardiac catheterization laboratory: insights from the national research council's biological effects of ionizing radiation VII report. Am Heart J. 2009;157(1):118–24.
4. Elmaraezy A, Ebraheem Morra M, Tarek Mohammed A, et al. Risk of cataract among interventional cardiologists and catheterization lab staff: a systematic review and meta-analysis. Catheter Cardiovasc Interv. 2017;90(1):1–9.
5. Akebi T, Matsugaki R, Ono T. Relationship between wearing a lead apron and work-related musculoskeletal disorders: a questionnaire survey of Japanese radiological technologists. Acta Med Okayama. 2022;76(5):541–5.
6. Goldstein JA, Balter S, Cowley M, Hodgson J, Klein LW, Interventional Committee of the Society of Cardiovascular I. Occupational hazards of interventional cardiologists: prevalence of orthopedic health problems in contemporary practice. Catheter Cardiovasc Interv. 2004;63:407–11.
7. Badawy MK, Deb P, Chan R, Farouque O. A review of radiation protection solutions for the staff in the cardiac catheterisation laboratory. Heart Lung Circ. 2016;25(10):961–7.
8. Roguin A, Wu P, Cohoon T, et al. Update on radiation safety in the cath lab - moving toward a "Lead-Free" environment. J Soc Cardiovasc Angiogr Interv. 2023;2(4): 101040.
9. Rizik DG. Scattered denial: reflections on the occupational hazards and health risks over a 35-year career in interventional cardiology. J Am Coll Cardiol. 2024;S0735–1097(24):08398.
10. Laish-Farkash A, Harari E, Finkelstein A, et al. A novel robotic radiation shielding device for interventional cardiology procedures. EuroIntervention. 2022;18(3):262–6.
11. Laish-Farkash A, Harari E, Rahkovich M, et al. A novel robotic radiation shielding device for electrophysiologic procedures: a prospective study. Am Heart J. 2023;261:127–36.
12. Anzenberg V, Lewis DE, Dickson ED, Bush-Goddard SP. The U.S. Nuclear regulatory commission radiation exposure information reporting system (REIRS). Radiat Res. 2010;173(2):254–5.
13. Crowhurst JA, Tse J, Mirjalili N, Savage ML, Raffel OC, Gaikwad N, Walters DL, Dautov R. Trial of a novel radiation shielding device to protect staff in the cardiac catheter laboratory. Am J Cardiol. 2023;15(203):429–35.
14. Riley RF, Kamen J, Tao A, Gomez-Cardona D. Comparative effectiveness of the EggNest complete shielding system to standard shielding in the cath lab. Am Heart J Plus. 2025;10(54): 100543.
15. Rizik DG, Riley RD, Burke RF, Klassen SR, Nigoghosian AM, Gosselin KP, Goldstein JA. Comprehensive radiation shield minimizes operator radiation exposure and obviates need for lead aprons. J Soc Cardiovasc Angiogr Interv. 2023;2(3): 100603.
16. Riley RF, Kidd S, Power J, Stegman B, Dahle TG. Comparative effectiveness of 2 next-generation scatter radiation shielding systems. J Soc Cardiovasc Angiogr Interv (In Press)
17. Sevilya Z, Rahkovich M, Kogan Y, Marincheva G, Cipok M, Hershkovitz V, Barenboim E, Lev EI, Laish-Farkash A. Robotic radiation shielding system reduces radiation-induced DNA damage in operators performing electrophysiological procedures. Sci Rep. 2025;15(1):18603.