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## Risk of whole body radiation exposure and protective measures in fluoroscopically guided interventional techniques: a prospective evaluation

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### Abstract

**Background:** Fluoroscopic guidance is frequently utilized in interventional pain management. The major purpose of fluoroscopy is correct needle placement to ensure target specificity and accurate delivery of the injectate. Radiation exposure may be associated with risks to physician, patient and personnel. While there have been many studies evaluating the risk of radiation exposure and techniques to reduce this risk in the upper part of the body, the literature is scant in evaluating the risk of radiation exposure in the lower part of the body.

**Methods:** Radiation exposure risk to the physician was evaluated in 1156 patients undergoing interventional procedures under fluoroscopy by 3 physicians. Monitoring of scattered radiation exposure in the upper and lower body, inside and outside the lead apron was carried out.

**Results:** The average exposure per procedure was  $12.0 \pm 9.8$  seconds,  $9.0 \pm 0.37$  seconds, and  $7.5 \pm 1.27$  seconds in Groups I, II, and III respectively. Scatter radiation exposure ranged from a low of  $3.7 \pm 0.29$  seconds for caudal/interlaminar epidurals to  $61.0 \pm 9.0$  seconds for discography. Inside the apron, over the thyroid collar on the neck, the scatter radiation exposure was 68 mREM in Group I consisting of 201 patients who had a total of 330 procedures with an average of 0.2060 mREM per procedure and 25 mREM in Group II consisting of 446 patients who had a total of 662 procedures with average of 0.0378 mREM per procedure. The scatter radiation exposure was 0 mREM in Group III consisting of 509 patients who had a total 827 procedures. Increased levels of exposures were observed in Groups I and II compared to Group III, and Group I compared to Group II.

Groin exposure showed 0 mREM exposure in Groups I and II and 15 mREM in Group III. Scatter radiation exposure for groin outside the apron in Group I was 1260 mREM and per procedure was 3.8182 mREM. In Group II the scatter radiation exposure was 400 mREM and with 0.6042 mREM per procedure. In Group III the scatter radiation exposure was 1152 mREM with 1.3930 mREM per procedure.

**Conclusion:** Results of this study showed that scatter radiation exposure to both the upper and lower parts of the physician's body is present. Protection was offered by traditional measures to the upper body only.

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## Background

Fluoroscopic guidance is frequently utilized in performing many interventional techniques, including precision diagnostic and therapeutic injection procedures. It has been estimated that approximately 1–4 million interventional procedures are performed annually in the United States, with at least 50% of them being performed under fluoroscopy [1–14]. The major purpose of fluoroscopy in interventional pain management is correct needle placement to ensure target specificity and accurate delivery of the injectate [1–14]. Incorrect needle placement has been described for multiple procedures without fluoroscopy. The most commonly used fluoroscopy in interventional techniques in managing chronic pain is with C-arm fluoroscopes with image intensification. Radiation exposure may be associated with risks to the physician, patient and personnel [15]. Most interventional procedures in the management of chronic pain require fluoroscopic exposure only for short periods of time.

The Center for Devices and Radiological Health of the Food and Drug Administration (FDA) issued an advisory in 1994, warning health care facilities of the potential for radiation-induced burns to patients from prolonged fluoroscopic procedures [16]. The same warning also applies to physicians and other staff members of the team. Physicians are more likely to have side effects and significant radiation exposure due to the cumulative effect. According to the advisory, a number of interventional procedures, including radio-frequency cardiac catheter ablation, percutaneous transluminal angioplasty, vascular embolization, stent and filter placement, thrombolytic and fibrinolytic procedures, percutaneous transhepatic cholangiography, endoscopic retrograde cholangiopancreatography, transjugular intrahepatic portosystemic shunt placement, percutaneous nephrostomy, and biliary drainage or urinary or biliary stone removal are high risk procedures [15]. However, none of the procedures included interventional pain techniques. A number of case histories of injuries to both patients [17–20] and physicians [21] have subsequently appeared in the literature. The actual extent of the problem is essentially unknown in general, and specifically in interventional pain management settings, since there are currently neither requirements for reporting nor a central repository for this information in the United States. Mahesh [15] examined various radiation exposures during fluoroscopic procedures and various dose reduction techniques emphasizing the importance of training for operators of

fluoroscopic systems. Biologic effects of radiation can be broadly grouped as stochastic or non-stochastic effects [15]. A stochastic effect is one in which the probability of the effect, rather than its severity, increases with dose [15]. Radiation-induced cancer and genetic effects are stochastic [15]. Multiple dose reduction techniques include intermittent fluoroscopy, removal of grid, last image holding, electronic collimation, dose spreading, adjustment of beam quality, image magnification, dose level settings, pulsed fluoroscopy, and appropriate training of fluoroscopy operators. Radiation risks to the physician and assisting personnel are evaluated using the maximum safe allowable exposure limits, which have been established by the National Council on Radiation Protection [22]. The current estimation of risk from radiographic exposure to a specific body part is based on the biologic effects of whole body exposure converted by weight factors, specific for individual organs and tissues. The International Commission on Radiologic Protections in 1991 adapted specific organ risks [23].

Botwin et al [7,8] and Manchikanti et al [10] prospectively evaluated radiation exposure to a physician(s) performing fluoroscopically guided interventional procedures to the upper part of the body. All these evaluations showed low exposure rates and the authors concluded that procedures could be safely performed in optimal conditions with safety precautions. However, in these studies, the investigators did not measure radiation exposure to the lower part of the body. In contrast to Botwin et al [7,8] and Manchikanti et al [10], Schade [9] also measured radiation exposure at groin, knee, and feet, along with measurements at the eye and chest. He measured surgeon's exposure to scatter radiation with or without shielding with lead drapes. He showed that when a lead drape was applied from the patient to the floor, scatter radiation was reduced, specifically at groin, knee and feet. Measurements of scatter radiation were carried out at five levels where the surgeon usually stands using a Keithley Model 36100 Ionization survey meter, a 20 cm thick polystyrene patient phantom in the beam and an OEC Diasonic C-arm set at 106 KVp and 3.3 mA with and without 1/8 inch thick lead drapes of two lengths. He observed clinically significant reductions in scatter radiation up to 99% by using lead shielding on the patient and from the table to the floor. Without shielding, exposure at the groin, knee, and feet was 430, 500, and 160 mR/HR. Schade [9] concluded that these objective measurements of scatter radiation demonstrated that the surgeon can be exposed to

dangerous levels of scatter radiation when imaging an average sized patient using a typical radiographic technique (this scatter will be higher as the radiation in the main beam increases) and the clinically significant reduction in radiation exposure to the surgeon is achieved by using lead shielding starting on the patient and extending to the floor.

In spite of the above, thus far, all the focus has been on the radiation exposure to interventional pain physicians to the upper part of the body, specifically eyes, thyroid and chest. Consequently, the lower part of the body, specifically perineum, has been neglected. Whether it is inability to recognize potential risk or lack of proper understanding of exposure to scatter radiation, it may be significant on the basis of cumulative effect or for individual procedures with prolonged exposure such as implantables and intradiscal procedures. Hence, this prospective evaluation was undertaken to study radiation exposure to the physician performing interventional procedures over a defined period of time, monitoring the radiation exposure over the entire body (upper and lower parts) with traditional protective measures in fluoroscopically guided interventional techniques.

## Methods

All patients undergoing interventional procedures over a period of 3 months during 2002 were included in the study. The study was performed at a non-university interventional pain management practice. All the procedures were performed in a sterile environment in operating rooms, by 3 interventional physicians. Fluoroscopy units were operated by 2 certified radiological technologists. Inclusion criteria consisted of consecutive patients presenting for either diagnostic or therapeutic fluoroscopically guided interventional procedures. Exclusion criteria included pregnancy or allergy to iodine or any component of the injection.

Most procedures were performed in the prone position except for cervical sympathetic blocks and intraarticular injections of acromioclavicular joint. The procedures were performed in one of the three operating rooms with OEC® fluoroscopic units available in each room (Compact 9600 or Compact 9800 OEC, Salt Lake City, Utah). The procedures varied from facet joint nerve blocks to spinal endoscopic adhesiolysis. Procedures were performed in a PA view and a lateral fluoroscopic view was utilized to confirm the needle placement when it was deemed necessary.

The mode utilized varied from pulsed-imaging to continuous fluoroscopic imaging.

Radiation exposure was monitored using a dosimetry badge with a lower limit of detectability of 1 mREM. One

radiographic technologist (RT) allocated four badges to each physician prior to the procedures. These badges remained with the physicians throughout the study period. The badges were clearly marked as (1) outside the apron over chest, (2) inside the apron over the neck attached to thyroid collar, (3) outside the apron at groin level, and (4) inside the apron over the groin area attached to the belt.

The "outside" badge was placed outside the lead apron worn by each physician, which was of 0.5 mm thickness. The "inside" badge was placed on the neck at thyroid level under the apron, as well as over the groin area over the belt. When the badges were not in use, they were all placed outside the radiation exposure area and outside the operating rooms. The radiological technologist assigned to the study maintained a daily log of the patient's name, date of procedure, number of procedure(s), description of the procedure(s) (i.e., facet joint blocks, epidurals, adhesiolysis, or sympathetic blocks, etc.), fluoroscopy exposure time for each procedure and total time for each patient.

Data were recorded on a database using Microsoft® Access. The SPSS version 9.0 statistical package was used to generate frequency tables. Results were considered statistically significant if the *p* value was less than 0.05.

## Results

A total of 1,156 patients underwent 1,819 procedures during the study period. Patients were divided into 3 groups based on the physician performing the procedures. Group I, consisted of a physician with less than 2 years of experience, Group II with a physician with experience of less than 5 years (over 2 years), and Group III with a physician with experience of more than 5 years.

Table 1 illustrates demographic features with age, gender, body mass index, number of patients and number of procedures performed.

Table 2 illustrates radiation exposure in 1,156 patients for 1,819 procedures. The statistics for all the procedures totaling more than 50 for the study period or performed at least over 10 times in at least 2 groups were included in the table. Radiation exposure ranged from  $3.7 \pm 0.29$  seconds to  $61 \pm 9.0$  seconds per procedure. Significant differences were noted among the groups for various procedures.

Table 3 illustrates scatter radiation and exposure of physicians in various groups. The scatter radiation exposures were higher outside the lead aprons in all groups compared to inside the lead aprons. There were also differences noted among the groups. In addition, there

**Table 1: Demographic features**

	Group I	Group II	Group III
Number of patients	201	446	509
Number of procedures	330	662	827
Age [yrs] [mean ± SEM]	52 ± 1.1	50 ± 0.7	50 ± 0.6
Gender			
Male	40% [81]	33% [146]	34% [175]
Female	60% [119]	67% [300]	66% [334]
Body mass index [mean ± SEM]	29.4 ± 0.56	29.1 ± 0.37	28.6 ± 0.31

**Table 2: Illustration of procedural characteristics and radiation exposure in seconds**

	Group I	Group II	Group III
Per Procedure	12.0* ± 0.49 (330)	9.0# ± 0.37 (662)	7.5 ± 0.27 (827)
Lumbar Facet Joint Nerve Blocks	11.7* ± 0.56 [143]	7.0# ± 0.32 [208]	5.7 ± 0.17 [180]
Cervical Facet Joint Nerve Blocks	10.4* ± 0.65 [73]	5.5 ± 0.23 [131]	5.9 ± 0.14 [265]
Caudal/Interlaminar Epidurals	11.7* ± 1.41 [56]	8.7# ± 0.96 [95]	3.7 ± 0.29 [141]
Lumbar/Cervical Transforaminal Epidural	14.0 ± 1.77 [26]	15.0# ± 1.23 [80]	10.6 ± 0.60 [92]
Percutaneous Adhesiolysis	20.8 ± 5.65 [5]	14.5 ± 1.69 [28]	18.9 ± 1.72 [50]
Thoracic Facet Joint Nerve Blocks	11.5* ± 2.17 [13]	7.9 ± 1.14 [29]	5.6 ± 0.56 [29]
Sacroiliac Joint Injection	15.0* ± 4.89 [5]	3.7 ± 0.28 [50]	7.5 ± 3.20 [4]
Intercostal / Paravertebral / Lumbar Sympathetic Nerve Blocks	10.0 [1]	12.5 ± 3.40 [13]	7.4 ± 1.09 [27]

() Indicates number of procedures \* Indicates significant difference: Group III vs Group I & II # Indicates significant difference: Group II vs Group I Procedures performed less than 25 [total] were not listed in this table, however utilized in calculating the exposure and per procedure.

**Table 3: Illustration of scatter radiation exposure in mREM outside and inside apron**

Location of Dosimetry Blade	Group I (330)	Group II (662)	Group III (827)
Chest [outside]	510	535	690
Neck [inside]	68	25	0
Groin [inside]	0	0	15
Groin [outside]	1260	400	1152

() Indicates number of procedures

were also differences noted in groin exposure in Group III where the minimal exposure was seen in the upper body.

## Discussion

A total of 1,156 patients were treated with 1,819 interventional pain management procedures by 3 physicians in an ambulatory surgery center over a period of 3 months under fluoroscopy. Our results showed that total exposure on average was 12.0 ± 0.49 seconds, 9.0 ± 0.37 seconds and 7.5 ± 0.27 seconds per procedure in Groups I, II, and III respectively. Radiation exposure ranged from a low of 3.7 ± 0.29 seconds for caudal/interlaminar epidurals to 61.0 ± 9.0 for discography. Scatter radiation exposure at

chest level was 510 mREM, 535 mREM, and 690 mREM for Groups I, II, and III respectively, which translated to 1.5455 mREM, 0.8082 mREM, and 0.8343 mREM per procedure in each group respectively. This showed no significant differences among the groups.

Inside the apron, over the thyroid collar on the neck, the scatter radiation exposure was 68 mREM in Group I for 330 procedures with 0.2060 mREM per procedure, 25 mREM in Group II for 662 procedures with 0.0378 mREM per procedure, and 0 mREM for 827 procedures indicating differences in exposure patterns with increased levels of

exposures in Groups II and III compared to Group I and Group I compared to Group II.

Inside the apron, groin exposure showed 0 mREM exposure in Groups I and II for 330 procedures and 662 procedures, whereas, it showed 15 mREM scatter radiation exposure in Group III for 827 procedures with exposure of 0.0181 mREM exposure per procedure, which was higher than in Groups I and II. This was also higher than the exposure in the neck compared to Group II. However, the groin exposure to scatter radiation inside the apron was less than the neck exposure inside the apron in Groups I and II.

The scatter radiation exposure for groin outside the apron in Group I was 1260 mREM and per procedure was 3.8182 mREM. In Group II the scatter radiation exposure for groin outside the apron was 400 mREM with 0.6042 mREM per procedure. In Group III the scatter radiation exposure for groin outside the apron was 1152 mREM with 1.3930 mREM per procedure exposure. There was no significant difference between the exposure rates in Group I and Group II. However, exposures were higher in Group I and III compared to Group II.

Utilization is explained by the physician experience. However, groin exposure rates are somewhat difficult to explain. These are in contradiction to the exposure rates of the upper part of the body. The physician performing the procedures in Group III was exposed to the least radiation in the upper body, however, was exposed to the highest radiation at the groin even under the lead apron with significantly higher radiation outside the apron compared to Group II at outside the apron and compared to Group I and II inside the groin. While we do not have reasons for this finding, this may explain the physician behavior patterns of standing close to or away from the scatter. This also explains the fact that the same measures or behaviors, which reduce scatter exposure in the upper part of the body, are not effective to reduce the exposure in the lower part of the body.

This evaluation illustrates the importance of measuring radiation exposure not only in the upper body but also the lower body, as well as using protective measures. Our results are similar to the results of Botwin et al [7,8] and Schade [9]. This study emphasizes, similar to the one by Schade [9], that in spite of appropriate lead apron and shielding, there is a significant exposure to the groin area even with all the precautionary measures and employing the principles of ALARA (as low as reasonably achievable), with regard to time, distance, and shielding. Based on this evaluation with approximately 1.4 to 5.4 mREM exposure per procedure outside the apron and with approximately 0.02 to 0.21 mREM inside the apron per

procedure, and extrapolated to 3,000 procedures, a physician will be exposed to a maximum of 4,200 to 16,100 mREM on the outside and 50 to 620 mREM exposure inside the apron in the lower part of the body. This is higher than the upper body exposure. It is explained by the fact that most scatter is generated in the lower part. Scatter is also higher with steep oblique and lateral positions. Physician exposure increases with live fluoroscopy due to the inability to move away from scatter radiation. Considering the annual limit for whole body exposure of 5 REM per year total effective dose equivalent, if no protection is used, an interventionalist performing 3000 procedures will still be at less than maximum level. General radiation exposure guides to extremities and skin are 50 REM per year [16].

This study showed that radiation exposure is well within the established safety limits. However, multiple variables should be taken into account in extrapolating these results for other situations. Further, interventional physicians must seriously consider utilizing protective measures for the lower part of the body other than the lead apron including lead shielding applied from the patient to the floor to reduce scatter radiation, specifically at groin, knee and feet as shown by Schade [9]. However, this shielding will not provide any protection in deep oblique or lateral exposures. Fluoroscopy times and exposure risk depends on the technique applied for each procedure, training of the individual, and the mode of the fluoroscopy utilized. It should also be taken into consideration that, an interventionalist must, at all times, have unhindered access to the patient. This will preclude bulky radiation shields and other types of protective measures, which may reduce access to the patient. Consequently, intermittent fluoroscopy or pulsed fluoroscopy will reduce the exposure, whereas, continuous fluoroscopy and visualization in a multitude of views will increase the exposure. Further factors include the patient volume, number of regions treated in each patient, number of procedures performed on each patient, and the experience of the interventionalist and the radiographic technologist. Thus, absolute exposure to the physician can only be calculated on an individual basis, taking into account various factors described above, along with consideration of cumulative exposure over a lifetime. However, leaded aprons, glasses, thyroid shields and other types of lead barriers seem most appropriate to minimize the physician's exposure. This has been shown repeatedly by multiple investigators [24-26].

Even though, for the most part this research suggests that the level of fluoroscopy utilization is well below a level of elevated concern, interventionalists should be cognizant of the fact that long-term effects of low-dose radiation are uncertain. Botwin et al [7,8] showed that exposure in their

study was greatest to the hands and then eyes to the interventionalists. Thus, they have argued for not only leaded aprons, glasses, thyroid shields, but also leaded gloves. They also recommended extended tubing for administration of radiographic contrast. Manchikanti et al [10] showed lack of significant exposure provided that all the principles of ALARA were followed in their practice setting. In contrast, Schade [9] argued for protection for the lower part of the body. Our evaluation confirms the results of Schade [9] with regard to risk. Thus, we recommend collection of accurate data of fluoroscopy times used at various facilities for various procedures.

### Conclusion

This study evaluated 1156 patients undergoing 1,819 interventional procedures over a defined period of time. The scatter radiation exposure was measured in the upper part, as well as the lower part of the body outside and inside the apron. There were significant differences noted in radiation exposure in the upper part of the body based on physician experience. In the lower part of the body, there was significant scatter radiation exposure noted outside the apron in all three Groups. However, inside the apron, only one of the three physicians received significant exposure over the groin area. Thus, this study concluded that there is scatter radiation exposure not only in the upper part of the body, but also the lower part of the body, though this exposure is at low levels.

### Competing Interests

None declared.

### Authors' Contributions

LM and KAC originally discussed the importance of this topic, and eventually agreed that it had to be studied in a systematic fashion. KAC and TLM designed the process of monitoring. LM and JR designed the protocol and participation. VP assisted with the protocol formation, designed data collection, and analyzed the statistics. KAC and TLM were responsible for the monitoring of radiation, as well as data collection.

LM drafted the manuscript, which all authors read, discussed, altered, drafted again, and finally agreed.

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