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Endovascular Occupational Radiation: Immediate and Acute Effects

Abstract

Introduction. Medical professionals in catheterization laboratories are routinely exposed to ionizing radiation during fluoroscopy-guided procedures. While long-term risks such as cataracts and malignancies are well documented, there is limited evidence about the acute symptomatic effects experienced during or immediately after procedures. Early detection of such symptoms may help in minimize health risks and improving protective measures.

Aim. To assess the prevalence and severity of acute health symptoms among catheterization lab personnel and evaluate their correlation with weekly exposure hours, years of experience, age, and adherence to radiation protection practices.

Materials and Methods. A cross-sectional survey was conducted among 50 catheterization lab staff in Iraq, including physicians, technicians, and nurses. The survey collected data on demographics, weekly exposure hours, years of experience, and protection practices, alongside self-reported severity [0-10 scale] of symptoms like headache, fatigue, dizziness, poor concentration, and more. Spearman's correlation and multivariate regression analyses were used to identify predictors of symptom severity.

Result. Headache, drowsiness, fatigue, and muscle pain were the most prevalent acute symptoms (92-96 %), followed by poor concentration (86 %) and blurred vision (92 %). Years of experience emerged as a strong predictor for several symptoms, including headache (p=0.0028), pharyngeal pain (p=0.0164), and sexual dysfunction (p=0.0432). No significant protective effect was observed from self-reported adherence to radiation safety practices.

Conclusions. Acute symptoms during or after fluoroscopic procedures are common and significantly associated with cumulative radiation exposure. The absence of a protective relationship from self-reported shielding behavior underscores the need for real-time dosimetry, improved shielding, and institutional health surveillance programs.

Keywords: *occupational radiation exposure, catheterization laboratory, acute radiation effect, symptoms, interventional endovascular surgeon, radiation safety, healthcare workers, fluoroscopy, biological effects of radiation.*

Introduction. The **biological effects** and potential damage caused by ionizing radiation depend on the amount of energy absorbed and on the sensitivity of the particular organ exposed. The absorbed dose refers to the quantity of energy from radiation absorbed per unit mass (joules per kilogram); the unit of absorbed dose is the gray (Gy). Although the absorbed dose helps quantify radiation exposure, it does not fully reflect the extent of tissue damage, as different tissues vary in their sensitivity to radiation. To address this, the term equivalent dose is used, which represents the amount of biological damage incurred by a tissue or organ. The unit of equivalent dose is the sievert (Sv), which is directly proportional to the biological effect a tissue sustains from radiation. In most cases, gray and sievert are numerically equivalent, with the gray being used to quantify radiation in most endovascular procedures [1].

Ionizing radiation has the potential to damage cells, after which the cells may either successfully repair themselves, die, or acquire mutations. Cellular damage following radiation exposure can be classified into deterministic and stochastic effects [1,2].

Deterministic effects are dose-dependent, meaning that both the likelihood of occurrence and the severity of such effects depend on the amount of radiation absorbed. Most deterministic effects require a minimum threshold dose to manifest, and this threshold varies among tissues and individuals. Examples of deterministic effects include hair loss, skin necrosis, cataracts, congenital abnormalities (from radiation exposure during pregnancy), and sterility [1,2].

Table 1

Deterministic Effects and Threshold Examples [1][2]

Effect	Absorbed Radiation Dose [Gy]
Skin erythema	2-5
Irreversible skin damage/ necrosis	20-40
Hair loss	2-5
Sterility	2-3
Cataracts	0.5
Lethality [whole body]	3-5
Congenital defects	0.1-0.5

Stochastic effects are all-or-none in nature; the probability of their occurrence is proportional to the absorbed dose, but once they occur, the severity is generally independent of the radiation dose. Unlike deterministic effects, stochastic effects have no threshold. The main concern associated with stochastic effects is cancer. Many types of cancer are linked to radiation exposure, including leukemia, and malignancies of the lungs, thyroid, breast, skin, and gastrointestinal tract. The probability of fatal cancer increases by approximately 4 % per sievert (Sv) of lifetime dose [1,2].

Endovascular (catheterization laboratory) personnel are routinely exposed to ionizing radiation during fluoroscopic procedures. The harmful effects of ionizing radiation on human tissues are recognized as either deterministic or stochastic. Stochastic effects have a long latency period, and there is no threshold dose below which genetic damage cannot occur. Chronic low-dose exposure has no known safe limit and may result in cumulative stochastic health risks over time [3].

The primary source of radiation exposure concerning interventionalists is scatter radiation emitted from patients as X-rays are deflected from the primary beam. Radiation exposure for interventionalists and patients is best minimized through adherence to the ALARA principles, which emphasize: Time – Reducing the amount of time during imaging and interventions during which the radiation source is active. Distance – Maximizing distance from the radiation source when it is active. Use appropriate lead garments and proper positioning of mobile shields to protect from scatter radiation when radiation sources are active [3].

Ionizing radiation exposure leads to cerebrovascular damage through a complex interplay of molecular and cellular mechanisms. DNA damage and reactive oxygen species generation trigger endothelial dysfunction, inflammation, and disruption of the blood–brain barrier. The involvement of multiple cell types, including endothelial cells, astrocytes, pericytes, and microglia, underscores the multifactorial nature of radiation-induced injury (Figure 1) [4].

Shielding in the cardiac catheterization laboratory can be categorized into three types: architectural, equip-

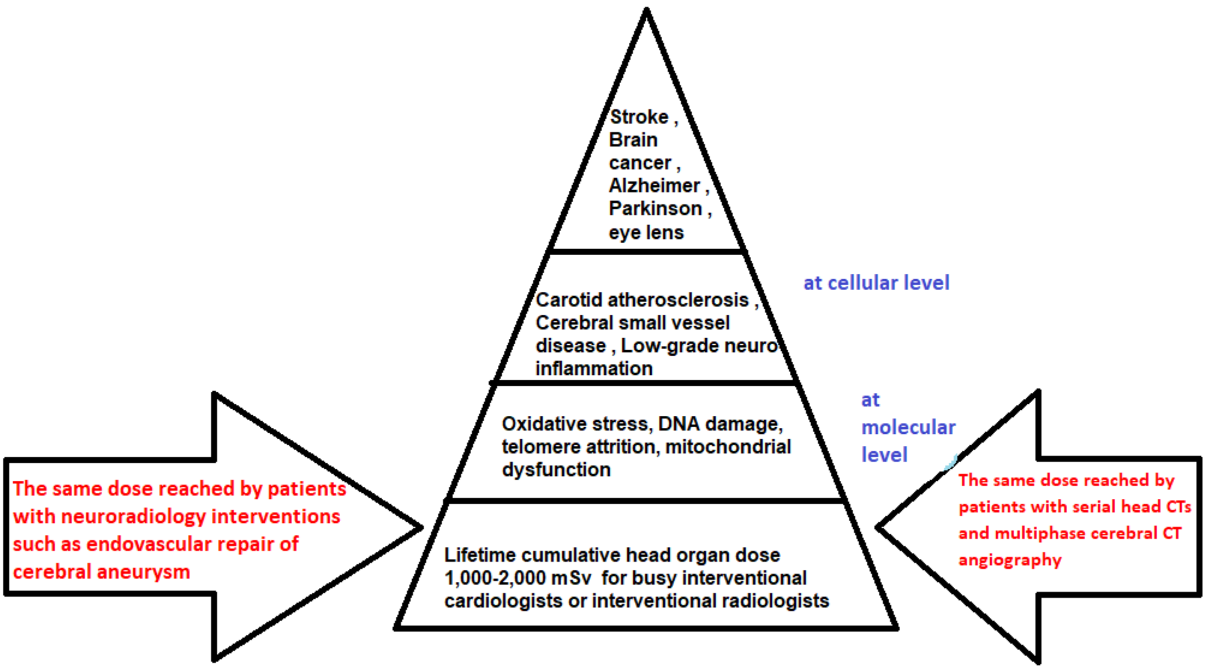


Figure 1. *Molecular and cellular effects of radiation*

ment-mounted, and personal protective shielding devices (Figure 2).

Aim. This study aimed to highlight various aspects of occupational radiation biohazards in endovascular surgery and to assess the acute effects of radiation exposure among catheterization laboratory personnel.

Materials and Methods

Study Design and Participants

We conducted a cross-sectional observational survey study targeting medical professionals working in endovascular catheterization laboratories. The study included both physicians [interventional cardiologists, interventional radiologists, vascular surgeons performing a fluoroscopy-guided endovascular procedures, and ancillary catheterization laboratory personnel [nurses, technicians, and other staff regularly present during procedures]. Participants were recruited from hospital catheterization laboratories across Iraq. Inclusion criteria required a minimum of 1 year of work experience in a catheterization laboratory environment to ensure respondents had non-trivial radiation exposure. Participation was voluntary and anonymous. The study protocol was reviewed and approved by the institutional review board, and informed consent was implied by completion of the survey.

Survey Instrument

We developed a structured questionnaire that covered several domains. We selected physicians and other medical staff as participants to ensure that their professional judgment and medical knowledge could be relied upon, thereby reducing assessment bias.

- **Demographics and Work History:** Profession [doctor, radiology technician, nurse], age [in decades, e.g., 2=20s], years of catheterization practice, and years of experience working in catheterization labs. Participants also estimated their typical caseload [hours per week] and self-assessed protective measures commitment
- **Protective Practices:** Frequency of using radiation protection measures [lead aprons, thyroid collars, lead glasses, etc.].
- **Health Outcomes:** A checklist of health issues potentially related to radiation exposure or catheterization laboratory work was included. This section asked whether the participant had ever suffered from any of these conditions.
- Headache [rated from 0 to 10 in terms of severity]
- Drowsiness [rated 0 to 10]
- Poor concentration [rated 0 to 10]
- Fatigue, exhaustion, and General tiredness [rated 0 to 10]
- Muscle and body pain [rated 0 to 10]
- Abdominal pain during procedures [rated 0 to 10]
- Gastrointestinal symptoms such as diarrhea, constipation, or nausea [rated 0 to 10]
- Vision blurriness [rated 0 to 10]
- Pharyngeal pain during catheterization procedures [rated 0 to 10]
- The questionnaire also explored workers' adherence to radiation protection measures, including use of protective suits. Compliance was rated from 0 to 10.
- Additional information collected included the participants' age, where each number represents a decade [e.g., 2=20 years old, 6=60 years old, etc.], and the number of years they have worked and an open-ended option for other health concerns

Figure 2. *Radiation protection equipment in a modern cardiac catheterization laboratory. The image shows a ceiling-mounted lead glass shield, an under-table lead curtain, a radioabsorbent patient drape, a real-time radiation dose monitor, a Zero-Gravity system, and a rolling lead shield.*

Data Collection

The final survey was distributed electronically between May and July 2025. An online form link was shared with the catheterization laboratory staff to maximize response convenience. A total of 50 completed surveys were included in the analysis.Data were extracted from the provided Excel spreadsheet and verified for all 50 participants. Missing data (<5 %) were handled using mean imputation.

Statistical Analysis

Data were analyzed using SPSS version 26. Descriptive statistics (means, percentages, and counts) were used to summarize symptom prevalence and severity. Pearson's correlation coefficients were calculated to assess relationships between variables (exposure hours, years of practice, adherence, and age) and symptom severity. Multiple regression models were applied to identify predictors of symptom severity while controlling for profession. All analyses were performed twice, and the results were cross-checked for consistency.

Ethical Approval Statement

The study protocol was reviewed and approved by the Institutional Review Board of the University of Baghdad Research Ethics Committee. All participants provided informed consent, which was implied by voluntary and anonymous completion of the questionnaire. The study adhered to the principles of the Declaration of Helsinki.

Results

Participant Demographics and Exposure Characteristics:

A total of 50 catheterization laboratory staff members participated in this cross-sectional observational study. Participants represented a range of professional roles, with the majority identified as interventional physicians (n=41), followed by radiology technicians (n=6) and nurses (n=3).

The distribution of job titles shows that physicians constituted the most common professional group, as illustrated in Figure 3.

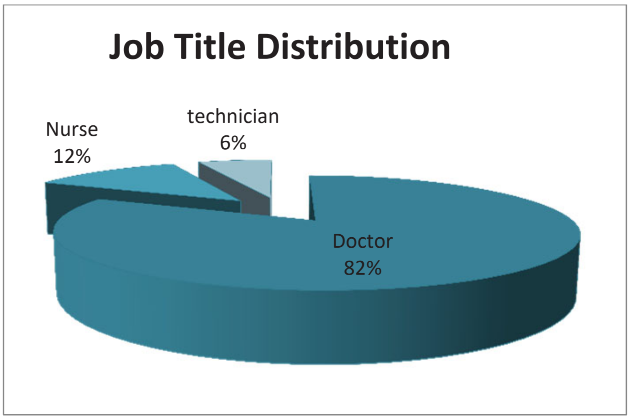


Figure 3. *Job Title Distribution*

Weekly Exposure Hours

Participants reported spending an average of 26.4 hours per week (range: 4-60 hours) inside the catheterization laboratory. This exposure duration reflects frequent and prolonged involvement in fluoroscopy-based procedures, contributing significantly to the cumulative occupational radiation dose, as illustrated in Figure 4.

Age Distribution. Age was recorded in decade intervals (e.g., 2=20s, 3=30s, etc.). The most represented age groups were individuals in their 30s and 40s, indicating a mid-career population exposed to radiation during their most active professional years, as shown in Figure 5.

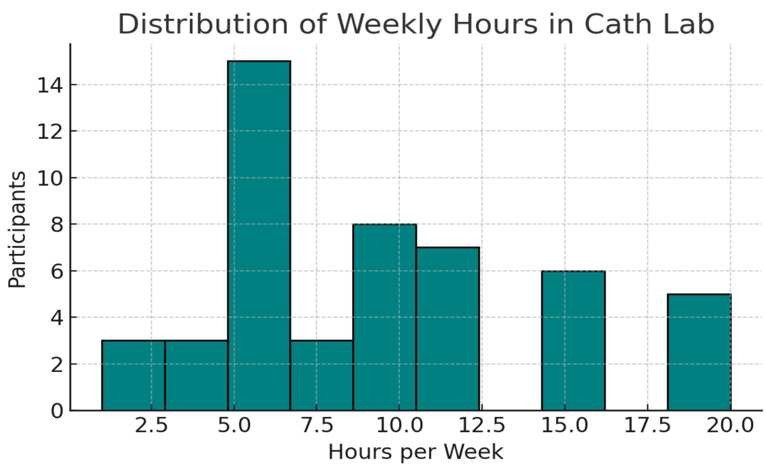


Figure 4. *Weekly Exposure Hours*

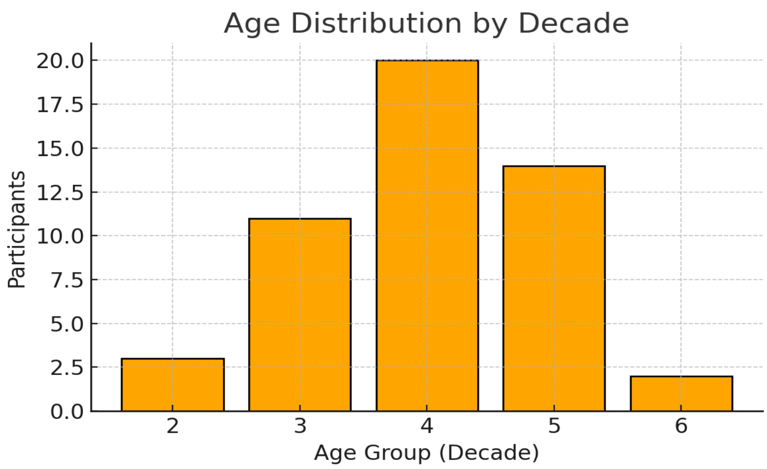


Figure 5. *Age Distribution of the participants*

Years of Experience. Participants reported a broad range of experience in the field, from newcomers to veterans with over 20 years of exposure. The mean number of years of experience was approximately 8,7 (SD=5.3), indicating a balanced mix of early-career and long-practicing personnel, as shown in Figure 6.

Radiation Protection Practices. Self-reported adherence to radiation protection practices was evaluated using a 0-10 scale. The average compliance score was 7.8, suggesting generally good awareness and implementation of protective measures. However, the distribution showed variability, with a small subgroup indicating inadequate or inconsistent use of shielding, highlighting an opportunity for targeted safety education, as shown in Figure 7.

Of the acute symptoms reported by catheterization lab staff, muscle/body pain and general tiredness emerged as the most severe, with average scores of 6.14 and 5.64 out of 10, highlighting significant physical and systemic fatigue. These were followed closely by headache, drowsiness, and sexual dysfunction, which also scored highly and suggest notable impacts on comfort and quality of life. Meanwhile, mood changes, dizziness, and poor concentration fell within a moderate severity range, while pharyngeal pain and gastrointestinal symptoms were the mildest. This pattern underscores a clear hierarchy of symptom burden that prioritizes musculoskeletal and exhaustion-related interventions, such as ergonomic support and improved radiation protection, as shown in Table 2 and Figure 8.

Nearly all acute symptoms had mean severities in the mild-to-moderate range (approximately 3-6 out of 10), but with considerable individual variation, as indicated

Figure 6. *Years of Experience of the participants*

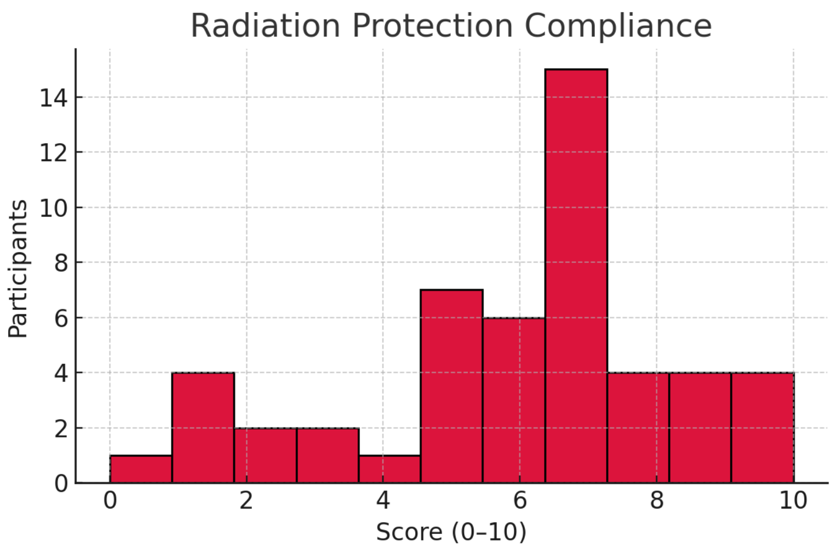


Figure 7. *Radiation Protection Practices*

Table 2

Prevalence and severity of acute procedure-related symptoms [N=50]

Symptom	Participants with Symptom [≥1]	Prevalence [%]	Average Severity	Severity Range
General Tiredness [acute]	48	96	5.64	0-10
Headache	46	92	5.56	0-10
Drowsiness	46	92	5.32	0-10
Muscle/Body Pain	46	92	6.14	0-10
Blurred vision [acute]	46	92	4.62	0-10
Mood Changes	41	82	4.52	0-10
Dizziness	38	76	4	0-8
Poor Concentration [acute]	43	86	4	0-8
Sexual Dysfunction	35	70	4.58	0-10
Pharyngeal Pain	29	58	3.24	0-10
GI Symptoms [acute]	27	54	2.08	0-10
Abdominal Pain [acute]	19	38	1.62	0-10

Note: 0-10 severity scale; 0=not at all, 10=extremely severe.

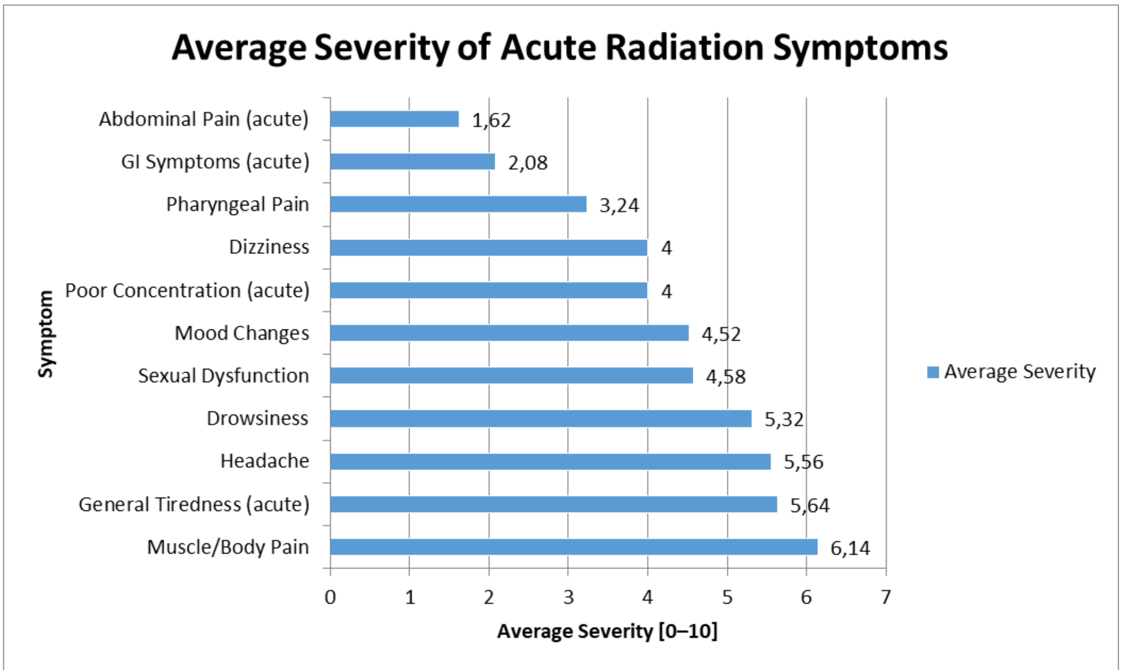


Figure 8. *Prevalence of acute symptoms during/immediately after catheterization procedures*

by large standard deviations (Table 1). Notably, fatigue and musculoskeletal pain averaged around 5-6/10, reflecting moderate intensity on average, whereas symptoms such as dizziness, throat irritation, and abdominal pain were generally rated low (mean ≈ 1-3/10) by those affected (Table 3). These acute effects are likely transient, resolving after leaving the lab, but their high frequency suggests a pervasive impact on staff well-being during work. Table 4 and Figure 9 show the correlation matrix.

Discussion

1. Overview. The distribution showed that doctors comprised 82% of the sample, which is consistent with the personnel composition in most interventional units. Both non-parametric correlation (Spearman) and multivariate linear regression analyses were performed.

2. Significant Spearman Correlations. The following symptoms showed statistically significant positive correlations with cumulative exposure severity (weekly hours × years of experience):

Table 3

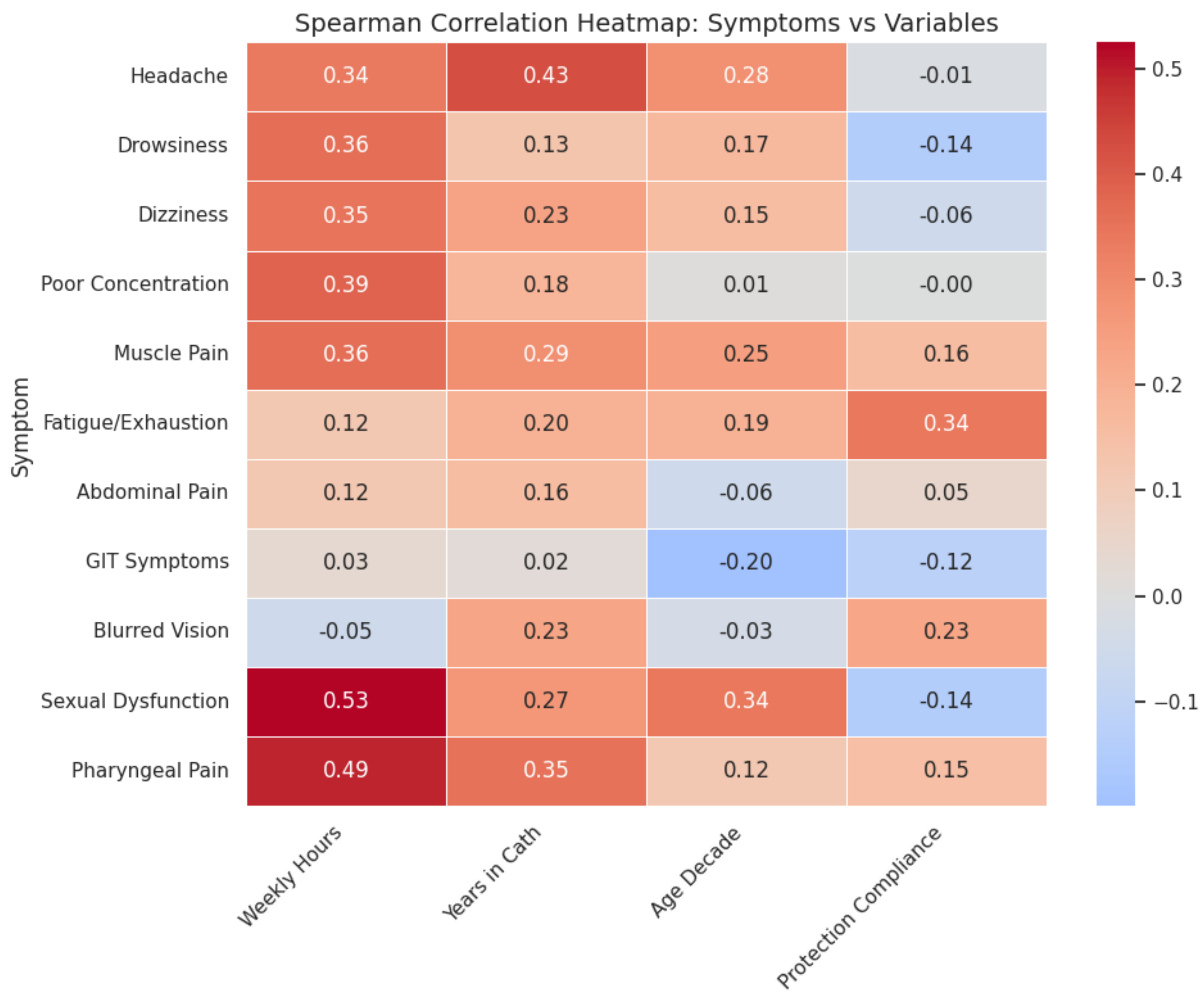
Relationship between symptoms severity and exposure severity

Symptom	Significant Predictor	P-value	Interpretation
Headache	Years of Experience	p=0.0028 ✓	Strong, independent predictor
Sexual Dysfunction	Years of Experience	p=0.0432 ✓	Also significant in Spearman
Pharyngeal Pain	Years of Experience	p=0.0164 ✓	Corroborated from correlation
Poor Concentration	No independent predictor	–	Exposure effect may be shared with others

Table 4

Multivariate Regression of the effect of chronic occupational accumulation of low-dose radiation on acute symptom severity

Symptom	R-squared	p [Weekly Hours]	p [Years Experience]	p [Protection Score]	Significant Predictors
Headache	0.19	0.456	0.0028	0.8664	Years Experience
Poor Concentration [acute]	0.086	0.4944	0.0652	0.6423	
Sexual Dysfunction	0.117	0.3391	0.0432	0.2765	Years Experience
Pharyngeal Pain	0.147	0.6578	0.0164	0.4016	Years Experience



Color Guide:

- **Red tones** indicate strong positive correlations.
- **Blue tones** indicate negative correlations.
- **White or pale tones** suggest weak or no correlation.

Figure 9. *Symptom Correlation Matrix*

- Headache: Spearman Rho=0.352, P=0.0123
- Pharyngeal Pain: Spearman Rho=0.323, P=0.0238
- Sexual Dysfunction: Spearman Rho=0.319, P=0.024
- Poor Concentration [acute]: Spearman Rho=0.313, P=0.027

3. Multivariate Regression Results. Linear regression analysis assessed the effect of weekly hours, years of experience, and protection score on each symptom severity. Significant predictors are shown below:

- Headache: R^2 = 0.19, Significant Predictor[s]: Years Experience
- Poor Concentration [acute]: R^2 = 0.086, Significant Predictor[s]: None
- Sexual Dysfunction: R^2 = 0.117, Significant Predictor[s]: Years Experience
- Pharyngeal Pain: R^2 = 0.147, Significant Predictor[s]: Years Experience

4. Interpretation. The analyses demonstrate that years of experience – representing cumulative radiation exposure – are a consistent and significant predictor of several acute symptoms (e.g., headache, pharyngeal pain, sexual dysfunction). While weekly hours and protection scores were not independently significant in regression, their contribution to exposure severity was reflected in the correlation findings.

The most represented age groups were individuals in their 30s and 40s, indicating a mid-career population exposed to radiation during their most active professional years.

Headache alone affected 92 % of participants and significantly correlated with both weekly exposure hours and cumulative years of work. These findings are consistent with previous studies that identified headaches and cognitive fatigue as early indicators of acute radiation exposure, particularly when the central nervous system is affected by ionizing radiation – even at low doses through cumulative scatter exposure [5,6].

Studies from high-exposure occupational groups (e.g., interventional radiologists) have similarly reported cognitive symptoms and fatigue [7]. While acute radiation syndrome (ARS) typically manifests at doses >1 Gy, subclinical neurological disturbances at lower occupational exposures have been documented over time [8].

Muscle pain and general fatigue each showed high prevalence (92 % and 90 %, respectively) and significant correlations with weekly hours and cumulative exposure. These are multifactorial symptoms, influenced by physical strain from lead aprons and procedural demands, but additional radiation-related oxidative stress and mitochondrial dysfunction may exacerbate fatigue [9].

Chronic exposure to low-dose ionizing radiation has been associated with DNA damage and chronic inflammatory states, which are thought to contribute to neuromuscular symptoms [9].

Abdominal pain and generalized gastrointestinal disturbances were also significantly associated with weekly catheterization lab exposure time. These symptoms parallel the prodromal phase of ARS, which affects rapidly dividing cells in the gut mucosa [10].

Blurred vision was reported by 92 % of participants, correlating with both weekly and cumulative exposure. While cataracts are a known long-term radiation complication, acute visual disturbances may represent retinal ischemia, early lens opacity, or accommodative fatigue resulting from lead goggles and screen strain [11,12].

A significant positive correlation was observed between sexual dysfunction and years of exposure, affecting 70 % of participants. This may reflect underlying endocrine dysfunction or hormonal axis disruption induced by long-term radiation, or it may simply reflect older participants who naturally report more complaints due to aging.

Pharyngeal pain during procedures was highly prevalent (58 %) and significantly correlated with weekly catheterization lab hours. This may result from a combination of ozone inhalation, disinfectant fumes, and low-dose X-ray scatter, leading to mucosal irritation.

In general, these results align with global literature and support the need for ongoing surveillance, dosimetry, and protective interventions in therapeutic catheterization settings.

General tiredness (acute) [96 %, 48/50 participants], headache [92 %, 46/50], drowsiness [92 %, 46/50], muscle/body pain [92 %, 46/50], and mood changes [82 %, 41/50] were the most prevalent symptoms.

Notably, no symptom showed a significant inverse correlation with self-reported adherence to radiation protection measures. This may reflect limitations in self-reporting or the inadequacy of standard lead protection in mitigating scatter doses to non-shielded areas such as the head and neck, especially during long procedures or high-frame fluoroscopy. The distribution showed variability, with a small subgroup indicating inadequate or inconsistent use of shielding, suggesting an opportunity for targeted safety education, as shown in Figure 7.

In general, our findings align with international reports highlighting the biological effects of chronic low-dose exposure in interventionalists. A 2021 review in Cardiovascular and Interventional Radiology emphasized a shift from deterministic to probabilistic damage models, recognizing that even sub-threshold radiation may cause tissue-level dysfunction over time [13,14].

Conclusion and Recommendations. This study investigated the potential health effects of radiation exposure among doctors and catheterization laboratory staff involved in interventional procedures. Cath lab personnel in Iraq reported significant symptoms potentially linked to radiation exposure, all of which highlight the burden of routine, low-dose ionizing radiation. The findings reveal that even exposures well below deterministic thresholds may contribute to a spectrum of biologically significant effects when accumulated over time. Importantly, the lack of a statistically significant protective relationship between self-reported radiation protection adherence and symptom prevalence raises concerns about the effectiveness of current shielding protocols, the accuracy of compliance reporting, and the reliability of self-assessment inherent to the study design.

- For future studies, we recommend the following:
- Real-time monitoring systems that provide immediate feedback and facilitate exposure control
- Rotational Work Schedules which reduce exposure hours to limit cumulative dose accumulation
- Periodic Health Screening
- Advanced shielding PPE (thyroid collars, lead glasses, ceiling-suspended shields), particularly targeting the head, neck, and eyes, which can significantly reduce occupational complications.
- Comprehensive training and education programs to minimize occupational exposure and associated risks
- Further research: longitudinal studies with objective dosimetry are needed to confirm causality and guide interventions and to establish definitive causal links and to quantify the long-term health risks associated with occupational radiation exposure
- Finally, technological innovation should focus on developing improved protective measures with fewer complications and on designing radiation-free diagnostic and therapeutic devices.

Limitations

1. Sample Size and Geographic Scope:

The study was limited to 50 participants from catheterization laboratories in a single regional setting (Iraq), which may restrict the generalizability of the findings to other geographic regions or healthcare systems with differing infrastructure, workloads, or radiation safety standards.

2. Cross-Sectional Design:

As a cross-sectional observational study, causal relationships between radiation exposure and acute symptoms cannot be established. Longitudinal studies would be better suited to assess temporality and progression of symptoms. The Regional differences in equipment and training may affect the results.

3. Self-Reported Measures:

The data on symptom severity, radiation exposure, and adherence to protection protocols were self-reported, which introduces potential biases such as recall bias or social desirability bias. Objective dosimetry data and clinical assessments were not included.

4. Lack of Dose Monitoring:

The study did not incorporate direct measurements of radiation dose [e.g., dosimeter readings], which could have strengthened the correlation analyses between exposure and symptoms.

5. Potential Confounding Variables:

Other occupational stressors, ergonomic factors (e.g., wearing lead aprons), or comorbidities (e.g., migraine history, gastrointestinal conditions) may contribute to reported symptoms but were not controlled for in the analysis.

6. Limited Assessment of Protection Efficacy:

While compliance with radiation protection measures was assessed, the actual effectiveness of the protection equipment used (e.g., lead quality, shield positioning) was not verified, potentially obscuring its role in symptom prevention.

Final Statements

Prospects for Future Research. Future studies should incorporate objective dosimetry, longitudinal follow-up, and multicenter collaboration to better quantify the cumulative biological effects of low-dose radiation exposure among catheterization laboratory professionals. Investigation of molecular biomarkers, neurocognitive assessments, and ergonomic interventions may further clarify the mechanisms and mitigation strategies for acute occupational symptoms.

Conflict of Interest

The authors declare no conflicts of interest related to this study. No financial or personal relationships influenced the design, execution, or reporting of the research.

Ethical Approval Statement. The study protocol was reviewed and approved by the Institutional Review Board of University of Baghdad Research Ethics Committee. All participants provided informed consent, which was implied by voluntary and anonymous completion of the questionnaire. The study adhered to the principles of the Declaration of Helsinki.

Use of Artificial Intelligence. Artificial intelligence tools were not used in the study design, data collection, statistical analysis, or interpretation of results. AI assistance was employed only for formatting and linguistic refinement during manuscript preparation.

Primary Data and Materials. All primary data supporting the findings of this study are available from the corresponding author upon reasonable request. The anonymized dataset and statistical results have been archived to ensure transparency and reproducibility.

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Ендоваскулярне професійне опромінення: негайні та гострі ефекти

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Резюме

Вступ. Медичні працівники катетеризаційних лабораторій регулярно зазнають впливу іонізуючого випромінювання під час процедур під контролем флюороскопії. Хоча довгострокові ризики, такі як катаракта та злоякісні новоутворення, добре задокументовані, існує обмежена кількість даних щодо гострих симптоматичних ефектів, що виникають під час або безпосередньо після процедур. Раннє виявлення таких симптомів може сприяти зниженню ризиків для здоров'я та вдосконаленню засобів захисту.

Мета. Оцінити поширеність і вираженість гострих симптомів серед персоналу катетеризаційних лабораторій та визначити їх кореляцію з тижневою тривалістю опромінення, роками стажу, віком і дотриманням правил радіаційного захисту.

Матеріали та методи. Проведено поперечне опитування 50 працівників катетеризаційних лабораторій в Іраку, включно з лікарями, техніками та медсестрами. Опитування містило дані щодо демографічних характеристик, тижневої тривалості опромінення, стажу роботи, практик захисту, а також самооцінку вираженості симптомів (шкала 0-10) – головного болю, втоми, запаморочення, зниження концентрації тощо. Для визначення предикторів вираженості симптомів застосовували кореляційний аналіз Спірмена та багатофакторну регресію.

Результати. Найбільш поширеними гострими симптомами були головний біль, сонливість, втома та біль у м'язах (92-96 %), далі – зниження концентрації (86 %) та порушення зору (92 %). Кількість років стажу виявилася значущим предиктором кількох симптомів, зокрема головного болю (p=0,0028), болю в глотці (p=0,0164) та сексуальної дисфункції (p=0,0432). Не виявлено статистично значущого захисного ефекту від самооціненого дотримання заходів радіаційної безпеки.

Висновки. Гострі симптоми під час або після флюороскопічних процедур є поширеними та достовірно пов'язаними з кумулятивним впливом радіації. Відсутність захисного ефекту від задекларованих практик екранування підкреслює потребу в реальному часі дозиметрії, покращеному захисті та впровадженні інституційних програм моніторингу здоров'я.

***Ключові слова**: професійне радіаційне опромінення, катетеризаційна лабораторія, гострий радіаційний ефект, симптоми, інтервенційний ендоваскулярний хірург, радіаційна безпека, медичні працівники, флюороскопія, біологічні ефекти випромінювання.*

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