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Review

Occupational Exposure of Scatter Radiation and Proper Protective Methods

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Abstract

Radiations are extensively used for diagnostic imaging and treatment. The primary health concern for healthcare facilities is radiation safety. Patients, physicians, and staff in numerous fields, including radiology, interventional cardiology, and surgery, are concerned about radiation safety due to their increased risk of occupational exposure. Occupational exposure is the outcome of radiation exposure at work. Radiation from diagnostic imaging modalities such as computed tomography, mammography, and nuclear imaging are a modest contributor to the healthcare workers' cumulative dose exposures. Any scattered radiation exposure can be dangerous for patients and medical personnel. In order to lessen the detrimental effects of ionizing radiation, radiation protection is critical to prevent unneeded radiation exposure. The purpose of this research is to review the available information about occupational exposure of scatter radiation and proper protective methods. Fluoroscopic imaging, which employs x-rays to produce dynamic and cinematic functional imaging, is the source of the majority of radiation exposure in medical settings. Healthcare workers are exposed to low doses of ionizing radiation during various diagnostic and therapeutic procedures. Chronic exposure to low doses of radiation can have many negative effects on human health, such as cataracts and, among the most serious an increased risk of certain types of cancer. The hazards of radiation exposure among healthcare workers are well-documented in literature. To lower radiation exposure, protective equipment is vital. A lead apron, thyroid shield, and lead glasses are essential parts of protective equipment. Implementation of the guidelines for safety and protection from radiation are needed.

Keywords: *radiation, healthcare, protect, occupation, exposure*

Introduction

Wilhelm Röntgen made the initial discovery of X-rays in 1895. Within a year, both the advantages of x-rays, such as the ability to see fractures and the disadvantages, such as x-ray dermatitis, were understood and explained. The radioactive element radium was discovered by Nobel laureates Pierre and Marie Sklodowska Curie in 1898, and radiation therapy for cancer was reported one year later. This came with a hefty price: Marie Curie passed away from aplastic anaemia brought on by her radiation exposure. Starting in the late 1920s, comprehensive recommendations for radiation protection were developed internationally (1). The use of medical radiation is extensive in diagnostic imaging and therapeutics. Digital imaging can assist physicians in making a prompt diagnosis of discomfort in the cardiopulmonary and chest, emphysema, haemothorax, cardiopulmonary resuscitation, and follow-up treatment of intraoperative and postoperative patients attributable to the invention of the transportable X-ray/radiation imaging system (2).

All x-ray examinations have a biological risk, and different negative impacts of radiation are possible. Deterministic radiation-induced cataracts, for instance, have a threshold below which no effects would be noticed and a severity that is depending on dose. While the chance of occurrence is proportional to the radiation dose, the severity of stochastic effects, such as cancer and genetic effects, is independent of the radiation dose. Stochastic impacts do not have a threshold level at which they will occur. Scattered radiation is the inevitable radiation that doesn't form images and where photons interact and are refracted by the patient's tissues decreasing image quality and contrast when they diverge from their initial path (3).

The hazard of high-dose radiation exposure to nurses, clinicians, and residents of surgery and emergency medicine who are involved in the initial resuscitation of the injured patient has been documented in medical literature. In a hospital setting, radiology personnel and technicians in addition to personnel working in the cardiac catheterization laboratory are at high risk for obvious reasons, for occupational exposure to ionizing radiation (4). Staff members are exposed to a nonuniform radiation field inside the room that is characterized by dose-rate values that quickly change from point to point due to scattered radiation from the patient and the fluoroscopic equipment. Therefore, the medical staff might get significant radiation exposures during these interventional examinations. A prerequisite for improving radiological knowledge of occupational dosage levels and how various actions impact these levels can be provided through immediate feedback on their personal exposure through a system for visualizing occupational dosage and dose rate in real-time (5).

Fluoroscopy during surgery is increasingly used, which exposes the surgeon to immense radiation. The average annual dose of ionizing radiation for the general public is 360 millirems, of which 60 millirem are from diagnostic radiography and 300 millirem are background radiation. The primary beam may expose to the hands of surgeon and scatter further exposing to the rest of the body. The body should only receive 5,000 mrem of radiation each year, while the hands should only receive 50,000 mrem. Even from the tiny C-arm, exposure to the hands may be more than previously thought. Reduced exposure period, increased distance from the beam, improved shielding using a gown, thyroid gland cover, gloves, and glasses, beam collimation, choosing the low-dose option, inverting the C-arm, and surgeon control of the C-arm are all potential ways to reduce radiation exposure (6). The purpose of this research is to review the available information about occupational exposure of scatter radiation and proper protective methods.

Methodology

This study is based on a comprehensive literature search conducted on September 12, 2022, in the Medline and Cochrane databases, utilizing the medical topic headings (MeSH) and a combination of all available related terms, according to the database. To prevent missing any possible research, a manual search for publications was conducted through Google Scholar, using the reference lists of the previously listed papers as a starting point. We looked for valuable information in papers that discussed the information about occupational exposure of scatter radiation and proper protective methods. There were no restrictions on date, language, participant age, or type of publication.

Discussion

Since the invention of X-rays, reports of radiation injuring patients as well as medical personnel exposed while doing their professional tasks have been made. More than 32 million nuclear medicine examinations or treatment operations, 2,500 million diagnostic radiological examinations, and 5.5 million radiation sessions are carried out per year globally. Despite all safety measures, avoidable mishaps and accidents

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happen annually, albeit infrequently, all over the world. While interventional techniques such coronary artery dilatations carry the risk of occupational overexposure and skin damage, diagnostic radiology is mostly safe for patients and healthcare workers. Radiation protection in nuclear medicine is concentrated on the adoption of novel techniques using beta-emitters, for instance although shielding precautions need to get extra attention given the rise in positron emission tomography procedures. Overexposure at work brought on by mistakes and mishaps is relatively uncommon in radiotherapy (7). Modern vascular treatments are becoming more complicated, which makes procedures more challenging and prolongs imaging, increasing the radiation exposure to the endovascular team. Long-term radiation exposure can have a number of negative impacts, such as cancer development, cataracts, and decreased fertility. Even if the hazards cannot be completely eradicated, limiting the staff's exposure to high doses of radiation will lower their likelihood of contracting radiation-related illnesses. The interventionist and the endovascular team are at a genuine risk of being exposed to scatter radiation. Depending on imaging technology and other factors, this risk varies significantly (8).

Evidence from literature for occupational exposure

Results of a comparative study showed that the primary surgeon's and the assistant's exposure was much higher with fixed imaging than with mobile imaging One-way analysis of variance revealed that the principal surgeon and assistant had significantly higher mean exposure than assistant workers using either imaging modality when they were more than 6 feet away from the X-ray source (P-value<0.00001 for both). The exposure of the support staff was minimal and did not differ between fixed imaging and mobile imaging. In all quartiles of the room dosage stratified by case complexity, fixed imaging had statistically substantially more scattered radiation than mobile imaging (9). Patel reported in his study that thoracic procedures had a higher over-lead exposure to the operator than infra-renal procedures (p=.0003), demonstrating a significant exposure to exposed body regions. Under-lead exposures for the operator and assistant were 5.5 (2.0-14.2) µSv and 1.0 (0.0-2.3) µSv, respectively. These values complied with total body effective dose limits for a caseload typical of these values. Type of case and proportion of left anterior oblique angiography time in digital subtraction angiography predicted operator dosage (p< .0001). Strong indicators of radiation exposure during endovascular aortic repairs include thoracic operations, digital subtraction angiography runs, and obliquity of the C-arm (10). Results of an observational study showed that the operative surgeon had the highest radiation exposure while the exposure progressively lowered among the nurse, second operator and the technologist (11).

Scatter radiation from the patient during imaging is the main radiation source for x-rays and commuted tomography scans. Modern imaging procedures carry a rather substantial radiation exposure risk due to their effective doses of 4–21 mSv and 9–29 mSv, respectively. There is an increasing tendency toward more intricate interventional procedures, which exposes patients and laboratory workers to higher risks. Low doses of ionizing radiation are used in various diagnostic and therapeutic procedures that expose medical staff. Chronic low-dose radiation exposure can have a variety of harmful effects on human health, including cataracts and, among the most significant effects, an increased risk of certain cancers' morbidity (12). Leadbeatter reported in his study that without the scatter shield, an adult maxillary molar exposure resulted in doses to the operator to the left hand, right hand, and eyes of 0.69, 0.78, and 0.47 µGy, respectively. The doses were decreased to 0.25, 0.12, and 0.15 µGy, representing dose reductions of 64%, 85%, and 68%, respectively, with the scatter shield installed. Leakage radiation's influence was minimal in comparison. Even without the scatter shield in place, it is extremely improbable that an operator will exceed occupational dose restrictions when operating the Rextar X hand-held dental X-ray equipment (13).

Personnel involved in interventional cardiology and related medical procedures may be exposed to a lot of radiation. The lens of the eye and the brain are two types of tissue that are of special concern and may get significant doses during such treatments. Ocular radiation exposure causes lens alterations that eventually may lead to partial or complete lens opacification and cataracts. Such opacities do not initially cause visual impairment, but their severity tends to worsen over time and with dose, eventually impairing vision and necessitating cataract surgery. In high-dose fluoroscopy modes, the scattered radiation doses to an interventional cardiologist's eye lens can approach 34 µGy min-1 and 3 µGy per image during image acquisition when radiation protective techniques are not applied. Numerous studies have demonstrated a causal link between ionizing radiation exposure and an elevated incidence of central nervous system tumours (14).

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Protective methods to minimize radiation

Koenig described in his findings that an option to lessen scattered radiation at its source is to use radiation-absorbing pads as when employing the radiation-absorbing pad in comparison to not using one, a substantial radiation dose decreases of up to 80.6% ($p < 0.01$) was detected for all operator heights between 100 cm and 165 cm. In comparison to a lead equivalent of 0.25 mm, the radiation-absorbing pad with a lead equivalent of 0.5 mm significantly reduced the radiation dose at a height of 165 cm (51.4%, $p < 0.01$). The operator receives a large dose decrease when a radiation-absorbing pad is added to regular protective measures, especially for upper body areas (15). Results of a clinical trial showed that the overall average of exposure to the radiation of the operator was considerably lower when lead free radiation shield drape was used ($P < 0.0001$), corresponding to a total reduction of 23%, despite similar fluoroscopy time (3.52±2.71 minutes vs. 3.46±2.77 minutes, $P = 0.898$) and total examination dose. Additionally, radiation shield usage at all body regions resulted in a reduction of 13% to 34% in mean radiation exposure. This first-in-men randomized trial shows that using radiation shield during coronary angiography through right radial artery access dramatically lowers occupational radiation exposure (16).

Fetterly reported in his study findings that during cardiac interventional treatments, radiation shields can offer significant radiation protection. For best protection, shields must be actively and strategically handled. With elevation and for the 3 access points, shielding's usefulness and protection vary. The shields can offer at least 80% protection from scatter for femoral artery access locations at all altitudes; however, upper body shield position has a significant impact on protection. When using an upper body shield during surgery, a disposable radiation-absorbing pad can offer 35% to 70% upper body protection (17). Maurel stated that regular image fusion during complex endovascular aortic aneurysm repair greatly lowers contrast volumes and radiation exposure. The X-ray equipment should be completely controllable by the operator from the table side in order to make various imaging modes practical in real-world situations. Automated contrast injectors can also be used to reduce iodinated contrast volume while retaining image quality. Alternative contrast agents, including gadolinium and carbon dioxide, have also been studied and may be employed in some circumstances (18). Morishima suggested that the scattered radiation exposure to physicians and nurses during cardiac resynchronization therapy can be reduced by the inclusion of an additional lead shielding drape and low pulse rate fluoroscopy (19).

With many types of personal protective equipment, physical radiation protection can be achieved. Lead acrylic shields suspended from the ceiling are seen in some fluoroscopy rooms, and they can reduce exposures to the head and neck by a factor of ten. Staff in operating rooms and interventional settings can be protected by portable rolling shields that do not need to be installed. When deployed properly, these mobile shields have been demonstrated to reduce staff radiation exposure by more than 90% (20). Leaded aprons should be worn by all staff members for safety in situations where shielding behind a physical barrier is impractical. Most countries mandate the use of leaded aprons, which typically come in thicknesses of 0.25 mm, 0.35 mm, and 0.5 mm. Given their greater surface area coverage, aprons that wrap circumferentially around the body are preferred to front aprons. Transmission via leaded aprons generally ranges from 0.5% to 5%. A thyroid shield should always be worn with leaded aprons. Leaded spectacles should have a minimum 0.25 mm lead equivalent to adequately protect the eye's lens. As per numerous research studies, leaded glasses are frequently cited as the protective equipment that is used the least, with compliance rates ranging from 2.5% to 5% (21).

Sanchez revealed that several interventional radiologists lacked/misused personal dosimetry. The International Commission on Radiological Protection recommends using an over-apron dosimeter, but the majority of professionals do not use it. In several instances, protective screens hung from the ceiling are employed erratically. In more than 80% of procedures, all interventionalists conduct digital subtraction angiographic imaging from a control room. The highest documented doses each month were 63.1 mSv to the hands, 20.2 mSv above the apron, and 3.8 mSv under the apron (22). Miller concluded in his study that dose reduction software may be a useful method for reducing radiation exposure. In order to increase patient safety and lower the lifetime occupational radiation exposure for endovascular staff, system-based radiation reduction techniques must be put into place (23). Well-established guidelines are present for the protection from occupational exposure to scatter radiation although their implementation is lacking also limited studies are available highlighting the hazards of scattered radiation to occupational exposure. More research in future can significantly contribute to increasing awareness

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regarding the harms and risk of occupational exposure and can also aid in better implementation of protective strategies and practice thus lowering the radiation exposure risk

Conclusion

Healthcare workers are at an increased risk of scattered radiation exposure especially the primary surgeons and assistants as it can also lead to somatic and genetic repercussions. For minimizing the occupational exposure risk radiation protection measures must be practiced and strict compliance to the radiation safety and protection guidelines is needed.

Disclosure

Conflict of interest

There is no conflict of interest

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Data availability

Data that support the findings of this study are embedded within the manuscript.

Author contribution

All authors contributed to conceptualizing, data drafting, collection and final writing of the manuscript.

References

1. Timins JK. Communication of benefits and risks of medical radiation: a historical perspective. Health physics. 2011;101(5):562-5.

2. Ganapathy A, Adhikari NK, Spiegelman J, Scales DC. Routine chest x-rays in intensive care units: a systematic review and meta-analysis. Critical care (London, England). 2012;16(2):R68.

3. Barber J, McNulty JP. Investigation into scatter radiation dose levels received by a restrainer in small animal radiography. The Journal of small animal practice. 2012;53(10):578-85.

4. Mostafa G, Sing RF, McKeown R, Huynh TT, Heniford BT. The hazard of scattered radiation in a trauma intensive care unit. Critical care medicine. 2002;30(3):574-6.

5. Baptista M, Figueira C, Teles P, Cardoso G, Zankl M, Vaz P. Assessment of the occupational exposure in real time during interventional cardiology procedures. Radiation protection dosimetry. 2015;165(1-4):304-9.

6. Singer G. Occupational radiation exposure to the surgeon. The Journal of the American Academy of Orthopaedic Surgeons. 2005;13(1):69-76.

7. Loose R, Wucherer M. [Occupational exposure to radiation]. Der Radiologe. 2007;47 Suppl 1:S27-38; quiz S9.

8. Haqqani OP, Agarwal PK, Halin NM, Iafrati MD. Defining the radiation "scatter cloud" in the interventional suite. Journal of vascular surgery. 2013;58(5):1339-45.

9. Kendrick DE, Miller CP, Moorehead PA, Kim AH, Baele HR, Wong VL, et al. Comparative occupational radiation exposure between fixed and mobile imaging systems. Journal of vascular surgery. 2016;63(1):190-7.

10. Patel AP, Gallacher D, Dourado R, Lyons O, Smith A, Zayed H, et al. Occupational radiation exposure during endovascular aortic procedures. European journal of vascular and endovascular surgery : the official journal of the European Society for Vascular Surgery. 2013;46(4):424-30.

11. Sciahbasi A, Sarandrea A, Rigattieri S, Patrizi R, Cera M, Di Russo C, et al. Staff radiation dose during percutaneous coronary procedures: Role of adjunctive protective drapes. Cardiovascular revascularization medicine : including molecular interventions. 2018;19(7 Pt A):755-8.

12. Salama KF, AlObireed A, AlBagawi M, AlSufayan Y, AlSerheed M. Assessment of occupational radiation exposure among medical staff in health-care facilities in the Eastern Province, Kingdom of Saudi Arabia. Indian journal of occupational and environmental medicine. 2016;20(1):21-5.

13. Leadbeatter J, Diffey J. Evaluation of radiation exposure to operators of portable hand-held dental X-ray units. Physical and engineering sciences in medicine. 2021;44(2):377-85.

14. Moriña D, Grellier J, Carnicer A, Pernot E, Ryckx N, Cardis E. InterCardioRisk: a novel online tool for estimating doses of ionising radiation to occupationally-exposed medical staff and their associated health risks. Journal of radiological protection : official journal of the Society for Radiological Protection. 2016;36(3):561-78.

 http://dx.doi.org/10.52533/JOHS.2022.21117

15. Koenig AM, Maas J, Viniol S, Etzel R, Fiebich M, Thomas RP, et al. Scatter radiation reduction with a radiation-absorbing pad in interventional radiology examinations. European journal of radiology. 2020;132:109245.

16. Politi L, Biondi-Zoccai G, Nocetti L, Costi T, Monopoli D, Rossi R, et al. Reduction of scatter radiation during transradial percutaneous coronary angiography: a randomized trial using a lead-free radiation shield. Catheterization and cardiovascular interventions : official journal of the Society for Cardiac Angiography & Interventions. 2012;79(1):97-102.

17. Fetterly KA, Magnuson DJ, Tannahill GM, Hindal MD, Mathew V. Effective use of radiation shields to minimize operator dose during invasive cardiology procedures. JACC Cardiovascular interventions. 2011;4(10):1133-9.

18. Maurel B, Hertault A, Sobocinski J, Le Roux M, Gonzalez TM, Azzaoui R, et al. Techniques to reduce radiation and contrast volume during EVAR. The Journal of cardiovascular surgery. 2014;55(2 Suppl 1):123-31.

19. Morishima Y, Chida K, Katahira Y. The effectiveness of additional lead-shielding drape and low pulse rate fluoroscopy in protecting staff from scatter radiation during cardiac resynchronization therapy (CRT). Japanese journal of radiology. 2019;37(1):95-101.

20. López PO, Dauer LT, Loose R, Martin CJ, Miller DL, Vañó E, et al. ICRP Publication 139: Occupational Radiological Protection in Interventional Procedures. Annals of the ICRP. 2018;47(2):1-118.

21. Kaplan DJ, Patel JN, Liporace FA, Yoon RS. Intraoperative radiation safety in orthopaedics: a review of the ALARA (As low as reasonably achievable) principle. Patient safety in surgery. 2016;10:27.

22. Sánchez RM, Vano E, Fernández JM, Rosales F, Sotil J, Carrera F, et al. Staff doses in interventional radiology: a national survey. Journal of vascular and interventional radiology : JVIR. 2012;23(11):1496-501.

23. Miller C, Kendrick D, Shevitz A, Kim A, Baele H, Jordan D, et al. Evaluating strategies for reducing scattered radiation in fixed-imaging hybrid operating suites. Journal of vascular surgery. 2018;67(4):1227-33

 http://dx.doi.org/10.52533/JOHS.2022.21117