Radiation Exposure From C-Arm Fluoroscopy Among Neurosurgeons During Common Surgical Procedures

Tehniat Khaliq,[1] Iram Bokhari,[1] Jahan Jarwar,[1] Farrukh Javeed[1]
Shafin Bin Amin,[1] Ghulam Brohi[1]

ABSTRACT

Objective *To estimate the cumulative risk of radiation exposure in neurosurgeons using C-arm fluoroscopy during common neurosurgical procedures and its safe radiation use in the operating room.*

Study design *Cross-sectional analytic study.*

Place & Duration of study *Department of Neurosurgery, Jinnah Postgraduate Medical Center Karachi, from March 2023 to August 2023.*

Methods *The data regarding radiation exposure in 65 consecutive cases that involved various common spinal procedures were gathered. A badge dosimeter was positioned under the lead apron at the chest pocket to record radiation dose, ensuring shielded whole-body exposure. Subsequently, the corresponding mean and maximum values were calculated. An analysis was done to compare the data on fluoroscopy time, number of x-ray shots, and effective dose for each case.*

Results *The mean age of the patients was 37.05±10.07 years with male to female ratio of 1.85:1. On average, patients undergoing laminectomy and discectomy at L3-L4-L5 and T12-L1 received 6.09±2.15 shots of x-rays, while those undergoing transpedicular screw fixation received 4.72±2.36 shots of x-rays. Anterior cervical discectomy and fusion received 4.11±1.45 shots of x-rays and laminectomy plus excision received 6.25±2.75 shots. The difference observed was statistically significant (p= 0.05). However, the range of radiation (between 0.01 mSv to 0.09 mSv) was non-significant (p=0.212).*

Conclusion *Radiation doses in the common neurosurgical procedures conducted were consistently low and fell within safe limits.*

Key words *Radiation exposure, Neurosurgeons, C-arm fluoroscopy, Neurosurgical procedures, Laminectomy, Discectomy.*

INTRODUCTION:

Medical staff may participate in x-ray imaging or other procedures that entails exposure to ionizing radiation.[1] The ICRP - International Commission on Radiological Protection, suggests that occupational radiation exposure must be limited to an effective dose of 20 mSv per year, averaged over 5-year intervals, with a maximum limit of 50 mSv in any given year.[2]

Occupational exposure carries the immediate risk of acute radiation syndrome which is characterized by nausea, vomiting and diarrhea. In severe cases, it could lead to bone marrow suppression and organ damage. Nevertheless, the connection between chronic low dosages and contemporary medical worker cohorts remains ambiguous.[3] Moreover, the use of radiation in the field of medicine has experienced significant growth within the last two decades, mostly driven by the implementation of novel diagnostic and therapeutic techniques.

[1] Department of Neurosurgery, Jinnah Postgraduate Medical Center Karachi.

Correspondence:
Dr. Tehniat Khaliq [1*]
Department of Neurosurgery, Jinnah Postgraduate Medical Center Karachi
E mail: tehniat.kl@gmail.com

As a result, the medical professionals in specific departments experienced increased radiation exposure.[4]

Few studies have shown that adjusting the distance between the doctor and C-arm configuration, together with other parameters like collimation, pulse rate adjustment, source-to-skin distance, utilization of protective barriers and proper beam orientation can decrease radiation exposure during intraoperative utilization of the C-arm. The professional's position can greatly affect radiation exposure, and the radiation dose may vary among first assistants, theatre nurses, and anesthesiologists, who may be subjected to higher radiation doses than surgeons.[5-7]

Fluoroscopy has a significant boom in its utilization within neurosurgery. The utilization of image intensifiers has enhanced the technical proficiency of neurosurgeons, resulting in a reduction in patient morbidity through the minimization of the surgical field and decreased operative time.[8] Avoiding any level of exposure to ionizing radiation that could result in secondary occupational risk is crucial, and it is important to exercise extreme caution in order to minimize such exposure.

Alashban et al reported that the mean effective doses for all workers, calculated during the duration of the trial, was 0.70 mSv. Their findings suggested that the environment is secure in terms of radiation shielding. It is recommended to optimize radiation protection procedures to decrease radiation dosage.[9] This study was conducted to analyze the level of radiation exposure experienced by neurosurgeons while adhering to customary precautionary measures.

METHODS:

Study design, place and duration: This was a cross-sectional analytic study conducted at the Neurosurgery Department of Jinnah Postgraduate Medical Centre (JPMC) Karachi, from March 2023 and August 2023.

Ethical considerations: This study was approved by the Institutional Review Board, dated 08-01-2024 by letter no.F.2-81/2024-GENL/203/JPMC. Informed consent was obtained from the study participants and involved neurosurgeons.

Inclusion criteria and exclusion criteria: The operating neurosurgeons were informed about the study who performed a variety of neuro-surgical procedures that required C-Arm fluoroscopy on patients between 18 - 60 years of age. The procedures that were done under radiographic control were excluded.

Sample size and sampling technique: A total of 65 patients who underwent neuro- spinal procedures were included through non-probability convenience sampling technique.

Study protocol: The study involved monitoring of radiation exposure. Baseline information such as age group, gender, various surgical conditions for which procedures performed, was recorded. The Stenoscope Plus 9000 (GE) was the portable C-Arm fluoroscope with an image intensifier utilized for the procedures. Every surgeon received 5-Thermo-Luminescent Dosimeter (TLD) badges from the Department of Radiological Physics, Atomic Research Centre JPMC, Karachi. The badges were given after the agency approved their personal information.

Located in front of the neck, beneath the thyroid guard, it assessed the level of radiation exposure to the neck and thyroid area. The measured exposure to the chest, bodily organs, and roughly 80% of active marrow occurs at the chest level, behind a lead apron with a thickness similar to 0.5mm of lead. The third badge was positioned over the gonads and assessed the dose received by the gonads. The 4th and 5th badges were positioned on the dorsal side of the left and right wrists, sandwiched between two gloves, to measure the level of exposure to the hands. A record was kept for the duration of surgery and fluoroscopy exposure time. TLD badges were sent to the department for measuring radiation exposure.

Statistical analysis: The results were analyzed using the SPSS-23 version with descriptive statistics and an F-test. A p value < 0.05 was considered as significant.

RESULTS:

We enrolled 65 patients with a mean age of 37.05±10.07 years. There were 42 (64.6%) male and 23 (35.4%) female patients with male to female ratio of 1.85:1. The neurosurgical conditions included 19 (29.2%) patients of degenerative spine, 33 (50.8%) patients with spinal fracture, 5 (7.7%) patients of spinal tumor and 8 (12.3%) patients had other diagnosis. The specific procedures included 23 (35.4%) laminectomy and discectomy, 29 (44.6%) transpedicular screw (TPS) fixation, 9 (13.8%) anterior cervical discectomy and fusion (ACDF), and 4 (6.2%) laminectomy and excision.

Table I: Age Distribution and Spinal Level of Diseases

Variables	Sub variables	Frequency	Percentage
	Age, Mean±SD (years)	37.05±10.07	
Age Groups	18-30 years	23	35.4
	31-40 years	22	33.8
	41-50 years	12	18.5
	51-60 years	08	12.3
Level of Disease	Cervical	10	15.4
	Thoracic	13	20.0
	Lumbar	42	64.6

Table II: Number of X-rays Done With Radiation Dose

Variables	Number (n)	Minimum	Maximum	Mean	SD
Number of X-Rays	65	2.00	9.00	5.22	±2.29
Total Dose Radiation	65	.01	0.09	0.09	±0.02
Number of avoidable X-rays	65	0.00	6.00	1.89	±1.38

Table III: Comparison of Results of a Shot of X-rays and Dose of Radiation With Each Procedure

Variables	Procedures	Number (n)	Mean	SD	Mini	Maxi	p-value
Number of X-rays	Laminectomy and discectomy	23	6.09	2.15	2.00	9.00	0.05
	TPS	29	4.72	2.36	2.00	9.00	
	ACDF	09	4.11	1.45	2.00	7.00	
	Laminectomy plus excision	04	6.25	2.75	3.00	9.00	
	Total	65	5.22	2.29	2.00	9.00	
Total Dose of Radiation	Laminectomy and discectomy	23	0.05	0.02	.01	.09	0.212
	TPS	29	0.05	0.02	.02	.09	
	ACDF	9	0.06	0.02	.03	.09	
	Laminectomy plus excision	04	0.06	0.03	.02	.08	
	Total	65	0.05	0.02	.01	.09	

The information regarding various baseline features is mentioned in table I. The mean for the number of x-rays was 5.22±2.29, total dose radiation 0.09±0.02, and the number of avoidable x-rays was 1.89±1.38. Details are given in table II.

The analysis showed that, on average, patients who had laminectomy and discectomy, received 6.09±2.15 shots of x-rays, while those undergoing TPS received 4.72±2.36 shots of x-rays. ACDF received 4.11±1.45 shots and laminectomy plus excision 6.25±2.75 shots of x-rays. However, the difference observed was statistically significant (p= 0.05). Regarding radiation exposure, the laminectomy and discectomy procedure resulted in 0.05±0.02 mSv average exposure. Details are given in table III. Overall, the range of radiation was determined between 0.01 mSv to 0.09 mSv. However, these observed results were non-significant (p=0.212).

DISCUSSION:

The subject of radiation exposure during neurosurgical procedures is less commonly researched. However, it has a significant health-related implication on the operating surgeons as well as patients. The mean dose radiation used in the current study was 0.09±0.02 mSv which was very low than other studies. However, the overall range of radiation was determined between 0.01 mSv to 0.09 mSv. Some studies reported that mean annual dose exposure in China was 0.35 mSv, Ireland 0.32 mSv, Saudi Arabia 0.41 mSv, and UAE 0.39-0.83. These results matched with findings of the current study.[11-13]

Image intensifiers have gained popularity because of the idea of minimally invasive operations. Nevertheless, a disadvantage of this is a heightened susceptibility to radiation exposure for the surgeon, patient, and theater staff. The concern surrounding these exposures stems from their potential to induce biological consequences. These are linked with the dose of radiation, its type, and frequency of exposure.[10] In a study conducted by Alemayehy et al in Ethiopia, it was reported 1.2 mSv which was higher than the findings of the current study due to medical conditions.[14] Possible factors contributing to the low annual deep dose equivalent in these countries include adherence to radiation protection protocols, a sufficient number of skilled radiology staff, high-quality x-ray machines, spare parts, availability quality of radiation protection barriers, and comprehensive education and training programs.[13]

The mean age of enrolled patients in our study was 37.05±10.07 years which matched with that of another study of 33±11 years.[14] The gender distribution also matched with the same study. There was a statistically significant association between the working experience of radiology personnel and their occupational radiation exposure dose. As the tenure of radiology personnel rises, their occupational radiation exposure dose decreases. This phenomenon may be attributed to the correlation between the accumulation of experience among radiology professionals and their heightened understanding of the biological ramifications of radiation.[15] As a result, their implementation of radiation protection measures becomes more effective, leading to the cultivation of a responsible mindset. Consequently, the overall quality of their work improves, and the frequency of repeated x-rays diminishes

The findings of Vernier et al study suggest that the level of radiation exposure to the hands and body during intraoperative fluoroscopy using the 6600 or Elite small C-arm models is expected to be significantly lower than the established limits for occupational radiation exposure. Nevertheless, due to the potential for random effects and natural radiation that is not considered in the limits for radiation exposure in the workplace, individuals in charge should strictly follow the ALARA principles to reduce long-term radiation exposure and the likelihood of subsequent adverse health consequences.[16] The findings of Cristante et al also indicated that the radiation doses administered during spine procedures in their facility were minimal and comply with the established legal thresholds. However, it is crucial to provide regular training for experts in order to ensure radiation safety for both medical staff and patients.[17]

Our analysis revealed that the surgeon is most exposed to potential risks in the regions of the extremities as well as the head and neck. Various measures should be taken in to protect against the harmful consequences of radiation exposure. The use of lead aprons, thyroid shields, and table-suspended drapes are among some of the most common measures. The most important of all is the use of lead aprons, which protect a surgeon from tons of radiation. Additionally, during the use of the C-arm, doctors are advised to leave the room except the lead surgeon, who guides the location of the C-arm. The ALARA program eliminates the exposure to unnecessary radiation. This protocol is followed in our theaters.

Limitations of the study: The study is done in a limited number of patients and in selected conditions at a tertiary care centers. A multicenter study and documentation of protocols followed at each center can provide a more holistic information.

CONCLUSION:

The total radiation dose from fluoroscopy remained under the recommended limits. Radiation exposure is an extra secondary occupational danger that accompanies the hazards found in other surgical disciplines. It is important to follow radiation safety measures and regularly monitor exposure levels using at least one dosimeter to measure the total body dosage. Regular implementation of radiation safety programs is essential.

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Tehniat Khaliq: Manuscript writing and research.
Iram Bokhari: Concept, designing and research.
Jahan Jarwar: Designing and data collection.
Farrukh Javeed: Data collection and data analysis.
Shafin Bin Amin: Manuscript writing.
Ghulam Brohi- Manuscript writing.

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