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ORIGINAL ARTICLE

Evaluating radiation exposure from a C-Arm fluoroscopy device during neurosurgery procedures, an essential to balance effective imaging.

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ABSTRACT… Objective: To evaluate the radiation exposure on surgeons during different neurosurgical procedures. **Study Design:** Observational Cohort study. **Setting:** Liaquat University of Medical and Health Science, Jamshoro. **Period:** October 2023 to October 2024. **Methods:** Three surgeons were recruited and performed different neurosurgical procedures that required usage of C-arm per-operatively. The chest and right arm was selected for dosimeter readings. The fluoroscopy time, number of films was calculated with the help of residents that were observing the case. **Results:** Total number of 43 procedures were performed and most of patients were male (88.4%). The pedicel Screw fixation was the most common procedure (44.2%). The surgical level was dorsolumber spine (60.5%). The C arm was used in continuous fashion (41.9%) with mean of 10.69 ± 7.6 number of films were taken out. The mean fluoroscopy time was 7.6 ± 7.47. The mean of 241 ± 123 μSv on the chest and 479 ± 298 μSv on the right hand was found on dosimeter. The radiation exposure is significantly associated with the type of surgery (p 0.02) and Surgeries that required instrumentation is positively correlated with radiation exposure, increase fluoroscopy time (p- 0.001). **Conclusion:** Instrumentation surgery is associated with higher radiation exposure due to its association with higher fluoroscopy time and higher number of films.

Key words: C-Arm Radiation, Fluoroscopy Time, Neurosurgical Procedures, Occupational Hazard.

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INTRODUCTION

The advent of X-rays opened the gates for new diagnostic and therapeutic techniques with high resolution images and promptavailability.[1] This discovery also resulted in the increment of its use during surgical procedures especially in orthopedics and Neurosurgical discipline.[1] Its utility resulted in the foundation of minimal invasive surgeries which rapidly gain popularity due to improvement in efficacy and patients outcomes. It was estimated in a nationwide survey among Neurosurgeons that 27% of surgeries performed per week that is 2 to 4 in number required radiation for visualization of intra-operative anatomical structures.[2]

A Double edged sword could be the proper word that can be used because of its excessive use, the incidences of cancer risk is increasing with estimation of 13% and this risk increased up to 12 times during Spine surgeries.[3] Some reported increased frequency of breast carcinoma, nodular goutier and in one retrospective study 29% incidences of cancer in orthopedic surgeons reported.[3,4] One logistic regression showed significant association of developing leukemia and thyroid nodular goutier and its proportional association with increasing occupational exposure to radiation.[2]

The average annual effective dose should not exceed 20 mSv with upper limit of 50mSv.[2,3] The effective dose for skin with extremities and lens should not exceed 500 mSv and 150 mSV per year respectively.[2,4] However, Many reduction measures has been defined that includes patient and staff positioning, shielding, lead aprons manipulation of C- arm manual settings and protective eye wears.[5-7]

Exposure of Diagnostic and therapeutic Radiation has been described for intracranial pathologies.[8] In case of spine it usage had become invincible especially Minimal invasive surgeries, that decreases the surgical time but it also increase the incidence of radiation exposure.[7,9]

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The comparison of radiation exposure between different neurosurgical approaches that include Pedicel Screw fixation (PSF), percutaneous Pedicel Screw fixation (PPSF), lumbar disk, Anterior Cervical corpectomy or Discectomy (ACDF) and identification of dorsal mass is blurred. The design could help us to ponder and help us to create additional step in particular surgical procedure. This study could alsodefine geographical representation of radiation exposure because the local data in literature regarding radiation exposure is blurred.

METHODS

The Prospective Single Cohort study was conducted at Department of Neurosurgery after approval from ethical committee (LUMHS/REC/648), at Liaquat University of Medical and Health Science, Jamshoro. The time duration of study was 1st October 2023 to 1st October 2024. The three Surgeons were selected who usually performed spinal Surgeries. The Inclusion Criteria was the usage of C arm during surgery was mandatory, the cases in which the C arm was not used, hadn't included in study. The sample size of 43 procedures was determined based on the total number of eligible spinal surgeries performed during the study period that met the inclusion criteria. As this was an exploratory prospective cohort study conducted within a fixed time frame, all consecutive eligible cases were included to minimize selection bias and reflect real-world clinical practice. Although no formal a priority sample size calculation was performed, the sample was considered adequate to assess correlations between fluoroscopy usage parameters and radiation exposure using non-parametric statistical methods. Three consultants were included in the study based on the following criteria Regularly performing spinal surgeries requiring intraoperative fluoroscopy, Minimum operative volume of at least 10 spinal procedures during the study period, Willingness to participate and comply with radiation monitoring protocols. These consultants represented the routine surgical practice within the department, ensuring consistency in operative workflow and fluoroscopy utilization. A non-probability consecutive sampling technique was employed. All patients undergoing spinal surgery during the study period who required intraoperative C-arm fluoroscopy were consecutively included. Cases in which fluoroscopy was not used were excluded. This approach ensured inclusion of all eligible procedures without selection bias.

The C-Arm A General Electric 9900 Elite C-arm system with 12-, 9-, and 6-in field size capability was used for intraoperative imaging. The C-arm was operated at normal automatic brightness mode and control exposure rate and image quality. The surgeons wore 0.5mm thick lead apron and surgeon had electronic dosimeter attached at apron on chest levels and right arms that recorded radiation exposure on surgeon's body. The residents with lead aprons were used to record fluoroscopy time and number of captures during the procedure. The fluoroscopy time is the addition of all time in which whole fluoroscopy usage. The data was recorded on pre designed questionnaire. All the recording that was included on pre designed questionnaire and was spread on SPSS Sheet. The data was divided into categorical and continuous data. Categorical data included patient gender age, surgical procedure and Spinal level, number of surgeries by each consultant and Usage method of C arm. Initially the frequencies were calculated. Continuous data included Number of films, Fluoroscopy time and Electronic dosimeter Readings. Initially the descriptive analysis was performed and Shaipro-Wallis test was applied for identification of normality.

The data set was divided into three arms according to the Consultant above mentioned test was performed. For the categorical data the association was calculated with number of surgeries and the Chi square test was used for the identification of p-value. For Non-parametric data (All continuous variables was not normally distributed), the association with number of procedures was calculated with the help of kruskal-wallis test. The association and correlation between non-parametric data was calculated with Spearman Rank test or correlation. The association between surgical procedure and non-parametric continuous data was made with help of data plotting and Spearman rank test.

RESULTS

Total number of 43 procedures was done on patients presented with Spinal pathologies. Most patients were males (88.4%) and the most age group was between 20-40years (51.2%). The pedicel Screw fixation was the most common procedure (44.2%) and it includes both long and short segment fixation. The most common level of surgery was dorsolumbar spine (60.5%). Every consultant performed greater than 10 surgical procedures during study duration. (Table-I)

TABLE-1	
Characterization of the variables:	
Variable	n(%)
Patient Gender	
Male	38 (88.4)
Female	5 (11.6)
Age	
Less than 20	4 (9.3%)
20-40 years	22 (51.2%)
>40 years	17 (39.5%)
Surgical procedure	
Anterior Cervical Diskectomy/Corpectomy	5 (11.5)
Long or short segment Pedical Screw Fixation	19 (44.2%)
Percutanous long or short Pedical Screw fixation	7 (16.3%)
Lumbar Disk	10 (23.3%)
Spinal tumor (level identification)	2 (4.7%)
Level	
Cervical	5 (11.6%)
Dorsal	2 (4.7%)
Dorsolumbar	26 (60.5%)
Lumbar	10 (23.3%)
Surgeries performed by each consultant	
Consultant 1	12 (27.9%)
Consultant 2	16 (37.2%)
Consultant 3	15 (34.9%)

Regarding the usage of C-Arm, it was used mostly in continuous fashion (41.9%), for the guidance of screw placement. The mean of 10.69 ± 7.6 number of films were taken out and most of data lies on the right side with lighter tail and flatter peak and Non-parameter in nature. The mean fluoroscopy time was 7.6 ± 7.47 and most of the data resides on the right hand with thicker tail and sharper peak and non-parameter in nature. As far as concern of the radiation exposure on surgeon the mean of 241 ± 123 μSv on the chest and 479 ± 298 μSv on the right hand and slightly left on the graph with lighter tail and flatter peak and non-parametric in nature (Table-II).

TABLE-II	
General radiation exposure data	
Variable	Frequency/Mean
Type of Usage	
Intermittent	11 (25.6%)
Continuous	18 (41.9%)
Both	14 (32.6%)
Number of Films	10.69 ± 7.6
Fluoroscopy time	7.62 ± 7.47
Electronic Dosimeter reading (μSv)	
Surgeon chest	241 ± 123
Surgeon right hand	479 ± 298

On the Stratification of data according to consultants, it shows Consultant 2 performed more procedures on male population and mostly between the age group of 20 to 40 years. The type of surgical procedure is significantly associated with the number of surgical procedures performed by each consultant and it also showed that the consultant 2 hadn't done single of PPSF which consumes more fluoroscopy time and associated with high exposure of radiation (Figure-2). Dorsolumbar area was the most common level and consultant 3 performed more surgeries on this level. (Table-III)

On the Stratification of radiation exposure Data according to Consultant that performed surgery, it is shown that Consultant 1 taken more number of films and associated with increased used of fluoroscopy time and increased number of radiation exposure; which is shown to be positive correlated in Figure-1. However, the association between the number of surgeries and radiation exposure data is shown to be insignificant. The Chest dosimeter readings of Consultant 3 is slightly higher to the other consultants it may be due to Surgical procedure (more PSF, PPSF; Table-III, Figure-2). (Table-IV)

The correlation between Fluoroscopy time, number of films and dosimeter readings were taken outs and its showed significant positive correlation between them. (P-0.001calculated via spearman rank correlation test) Higher the fluoroscopy time associated with higher number of films and dosimeter readings. (Figure-1)

TABLE-III

Stratification of surgical data according to consultant

Variable	Consultant 1	Consultant 2	Consultant 3
Patient gender (p 0.9)			
Male	11	14	13
Female	1	2	2
Patient Age (p- 0.7)			
Less than 20	0	0	4
20-40 years	7	8	7
>40 years	4	7	4
Surgical procedure (p- 0.02)			
ACD/C	1	1	3
PSF	3	8	8
PPSF	4	0	3
Lumber Discectomy	2	7	1
Spinal tumor	2	0	0
Level (p- 0.06)			
Cervical	1	1	3
Dorsal	2	0	0
Dorsolumbar	7	8	11
Lumbar	2	7	1

ACD/C; Anterior cervical Diskectomy/ Corpectomy, PSF; Pedicel Screw fixation; PPSF; PercutanousPedical screw fixation, P value is calculated via Chi square Test

Figure-2: A significant positive correlation was observed between fluoroscopy time and the number of films, indicating that longer procedures were associated with increased imaging. Fluoroscopy time also showed a positive correlation with radiation exposure at both the surgeon's chest and right hand. Similarly, the number of films was positively correlated with radiation dose at both sites. Additionally, a strong positive association was noted between chest and hand dosimeter readings, suggesting that overall radiation exposure increases proportionally across different body regions. These findings highlight fluoroscopy time and imaging frequency as key contributors to occupational radiation exposure.

FIGURE-1

Correlation between fluoroscopy time, number of films and dosimeter readings

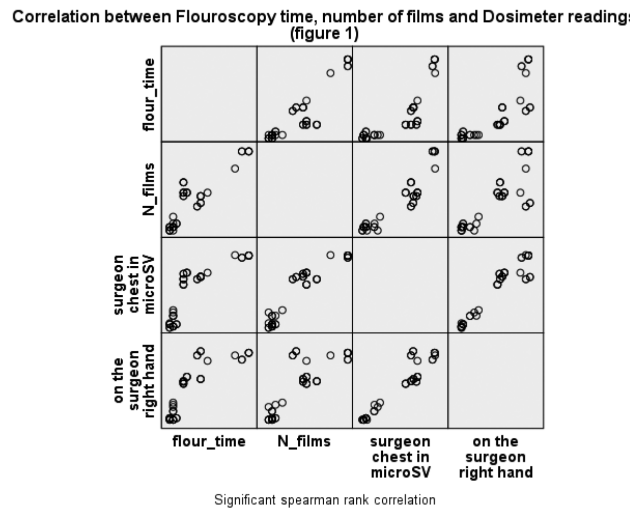

FIGURE-2

Association between surgical procedure and radiation exposure (-0.001)
***p- value is calculated via Kruskal-Wallis Test**

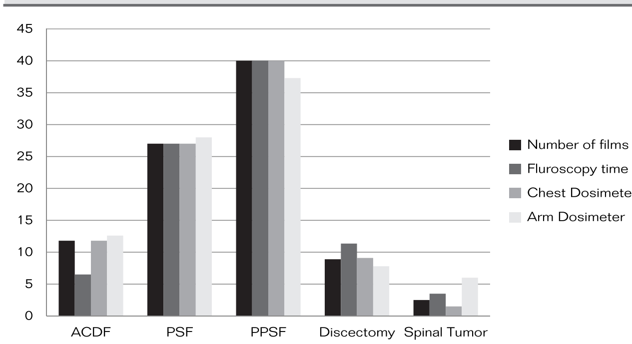

TABLE-IV

Stratification of radiation exposure according to consultant

C- Code (N of Cases)	Type of Usage (P-0.9)			Number of Film (P-0.63)	Fluoroscopy Time (Minutes) (p-0.14)	Electronic Dosimeter Reading	
	I	C	B			Chest (p-0.6)	Right hand (P -0.13)
Consultant 1 (12)	3	5	4	12.4 ± 9.8	11.3 ± 9.96	254 ± 146	562 ± 369
Consultant 2 (16)	3	8	5	8.4 ± 5.7	3.68 ± 1.7	212 ± 111	366 ± 214
Consultant 3 (15)	5	5	5	11.7 ± 7.3	8.8 ± 7.4	263 ± 116	532 ± 294

I: intermittent, C: Continuous, B: both, P value is calculated via kruskal -Wallis test

DISCUSSION

Ionizing Radiation discovery and its application in medical field especially intra operatively resulted significant improvement in decrement of operative time, effective instrumentation and surgical outcomes but this advancement came with radiation hazards to patients and Occupational hazards to Neurosurgeons as well. There are the reports that showed the strong association between radiation exposure and incidence of neoplastic lesion.

In this Study, we included 3 surgeons that performed total of 43 procedures with Spinal pathologies; the most of the patients were male 88.4% with age group 20-40 years (51.2%). The pedicel screw fixation at dorso-o-lumbar area was most common surgical procedure performed and it is also seen in literature that pedicel screw fixation procedures demand the availability of C arm in operative room, despite the free hand technique which occasionally uses C arm intra-operatively.[10, 11] The utility of C-arm was mostly performed in continuous fashion for screw guidance and 10.69 ± 7.6 numbers of films were taken out, with mean fluoroscopy time 7.6 ± 7.47 minutes but in the literature, the type of usage has not been categorized, however some authors described the groups in which the frame rate per second was reduced which also resulted in reduction of radiation exposure.[12] The fluoroscopy times described in literature are much lesser than this study; it may be due to the difference of method in calculation or it could be due to difference in technical aspect of usage.[10]

The mean radiation exposure on surgeon chest was 241± 123 μSv and 479 ± 298 μSv on the surgeon's right arm, these findings are coherent with literature[3]. The relationship between the Fluoroscopy times and radiation exposure has shown in literature which is also coherent with our study that shows significant correlation.[7] The relationship between number of films with radiation exposure in blurred and it is shown in this study that higher the fluoroscopy time, higher number of films resulted higher readings on Dosimeter.

The radiation exposure related to different surgical procedure hadn't described in literature as whole but different articles specific for certain procedures.[10] It has been seen that minimal invasive screw placement uses more time for fluoroscopy, higher number of films and higher dosimeter readings as compare to the surgical procedures that doesn't required Screw placement.[1,9,10] The spinal procedure is day to and common procedures and no effective study provides radiation effect on body especially in asian region, spinal is deal in all regional area of Pakistan.[13,14,15]

CONCLUSION

The Radiation exposure in this study were within normal limits but certain procedures like minimal invasive instrumentation and pedicel screw fixation uses more fluoroscopy as compare to the procedures that doesn't required instrumentation.

LIMITATION OF STUDY

This study doesn't highlight the exposure of radiations on patients, staffs and Surgeon assistant. This study also doesn't highlight the clinical effect of the radiation on surgeons.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHORSHIP AND CONTRIBUTION DECLARATION	
1	**Aurangzeb Kalhoro:** Proposed topic, study design, writing.
2	**Rehana Magsi:** Data analysis.
3	**Hameedullah Khan:** Methodology, data collection.
4	**Moiz Muhammad Shaikh:** Statistical analysis, manuscript writing.
5	**Shakir Ali:** Interpretation of results.
6	**Abdul Ghaffar Bugti:** Proof reading.