Original Article

Observational Study of Radiation Exposure in Anesthetic Personnel during Spinal Surgery

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Background: Scatter radiation while using fluoroscopy to localize and aid during spinal surgery, reflected from the patient toward everyone in the operating room. Additionally, in neuro-interventional angiographic procedures, radiation exposure in anesthetic personnel is more than other participating medical personnel.

Objective: To measure the radiation exposures in the anesthetic personnel and working environment during fluoroscopic-guided spinal surgery.

Materials and Methods: The present study was a prospective observational study approved by the IRB and performed among 66 fluoroscopic-guided spinal surgeries. All participating anesthetic personnel were tagged with optical stimulated luminescent dosimeters at the collar level and at upper chest underneath the apron. By using working manner and positions with respect to the patient, they were categorized in three groups, S group, which were the nurse anesthetists, PS group, which were the residents and trainee nurse anesthetists, and SNP group, which were the anesthesiologists. For the PS group only, a third dosimeter was tagged at the level of the eye. Fluoroscopy time (minutes), radiation dose ($\mu Gy \cdot cm^2$), frequency, and duration of the drug administration were recorded throughout the operation. Regarding the working environment, the radiation exposures at the left and right side of the walls and the anesthetic machines were also measured. The dosimeters were sent to the Thailand Institute of Nuclear Technology to measure the radiation exposure every month for five consecutive months.

Results: Sixty-six fluoroscopic-guided spinal operations were performed, and the radiation doses were measured in 50 anesthetic personnel. There was no statistical difference in radiation exposure among the groups regarding the one-month averaged radiation exposure (S 0.016±0.012 mSv, PS 0.017±0.013 mSv, and SNP 0.018±0.013 mSv, $p=0.929$). There was no statistical difference in radiation exposure between the anesthetic machine and the left wall ($p=0.567$) and the right wall ($p=0.509$). There was no correlation between the radiation exposure and frequency ($p=0.625$) and duration of the drug administration ($p=0.314$).

Conclusion: The calculated annual radiation exposure in the anesthetic personnel during fluoroscopic-guided spinal surgeries is lower than the recommended dose limit of 20 mSv/year.

Keywords: Radiation exposure, Anesthesia, Anesthetic personnel, Fluoroscopy

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Currently, fluoroscopy is widely used to localize and aid spinal surgery because of the real-time imaging benefit. Therefore, increased radiation exposure to anesthetic personnel is anticipated. International Commission on Radiological Protection (ICRP) defined the recommended dose limits in planned exposure situation, which is an effective dose of 20 mSv/year, averaged over five years with no more than 50 mSv in any one year, and equivalent dose to lens of 150 mSv/year[1,2]. Radiation-related cataract among anesthetic personnel would be presumed to exhibit a stochastic effect[2]. Moreover, the amount of radiation generated from fluoroscopy also relates to the characteristic of patient body and the axis of radiation beam. Higher radiation has been detected when the axis is changed from antero-posterior to lateral projection[3-5] and when fluoroscopy is used as assisted

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thoracolumbar pedicle screw placement[6]. Related studies have advocated that the anesthesiologist exposed to radiation greater than non-intervention procedures and three-fold greater than the exposure of radiologist[5,7]. The aims of the present study were to determine the radiation exposure among anesthetic personnel during fluoroscopic-guided spinal surgery. Analyses of direct measurements of the radiation exposure among the anesthetic personnel in different positions related to the patient and among workplace environment were also conducted.

Materials and Methods

After approval by the Phramongkutklao Hospital, Royal Thai Army Medical Department Institutional Review Board (IRB), the observational prospective study was performed (S015h/60). In addition, the present study was registered under the Thai Clinical Trial Registry (TCTR) http://www.clinicaltrials.in.th (unique trial number: TCTR20171231001). Written consents were obtained from all anesthetic personnel with full explanation. The possible risks and complications that could appear during study were also informed.

Subjects

All healthy anesthetic personnel working in fluoroscopic-guided spinal surgery, age 25 to 47 years old, consisted of anesthesiologist, resident, nurse anesthetist, and trainee nurse anesthetist. The present study included 50 anesthetic personnel that worked in fluoroscopic-guided spinal surgery between July 6 and November 30, 2017. Exclusion criteria consisted of anesthetic personnel assigned for emergency spinal surgery and pregnant personnel.

Sample size calculation was based on the radiation exposure. From related study, radiation exposure in anesthesiologist was 6.5 μSv and in radiologist was 2.6 μSv[7]. Therefore, twenty-two cases were required for each group.

Study design

The radiation exposure study among 66 fluoroscopic-guided spinal surgeries was conducted at Phramongkutklao Hospital between July and November 2017. The fluoroscopy machines, Philips BV Pulsera Mobile C-arm Systems, were used in both anterior and posterior positions and rotated through the oblique to the lateral position during the operation. The present observational study did not change anesthetic personnel behavior. All participants were located next to the patient's head, with the anesthetic machine positioned on their right side as shown in Figure 1. They were instructed to continue their routine radiation safety practices by wearing personal protective equipment (PPE), a lead apron and thyroid shield, and/or standing behind a moveable lead shield during active fluoroscopy. The radiation exposure was measured using an optical stimulated luminescent dosimeter (InLight® by Landauer Inc., USA). Regarding the positions related to the patient and working manner, anesthetic personnel were classified into three groups, shield (S) group, partial shield (PS) group, and shield with no PPE (SNP) group. The S group, which were the nurse anesthetists, would always stay behind the lead shield during fluoroscopy and were tagged with two dosimeters at the collar level and upper chest underneath the apron. The PS group, which were the resident and trainee nurse anesthetist, mainly performed pharmacologic interventions to the patient and were tagged with three dosimeters at the collar level, upper chest underneath the apron, and eye level. An InLight® nanoDot dosimeter was placed close to the eye. The SNP group, which were the anesthesiologist, usually stood behind the lead shield or left the room during fluoroscopy and were tagged with a dosimeter at the upper chest. When anesthetic personnel were replaced during the one-month study, the dosimeters were moved to the new personnel and monitoring of radiation exposure was continued.

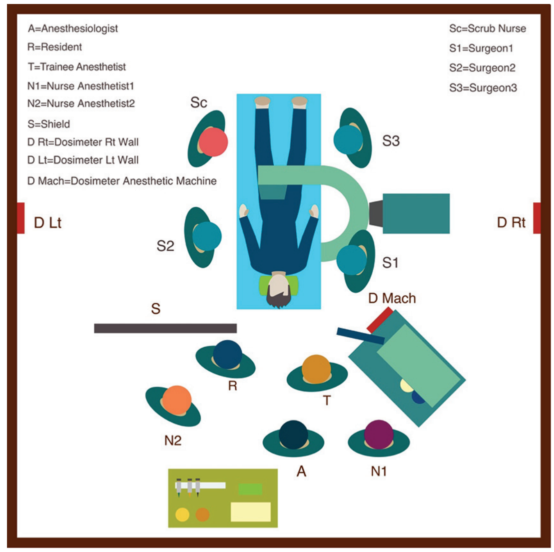

Figure 1. The illustration depicts the relation between the dosimeter (D) and position of fluoroscopy in workplace environment by attaching each dosimeter at 1 meter height and the relation of the anesthetic personnel positions related to the patient.

Fluoroscopy time (minute), radiation dose (μGy·cm²), frequency, and duration of the pharmacologic intervention were recorded throughout the operation. Concerning the workplace environment, the radiation exposures at the left and right walls and on the anesthetic machines were also measured by attaching each dosimeter at one-meter height. The dosimeters were sent to the Thailand Institute of Nuclear Technology to measure the radiation exposure every month for five consecutive months. The radiation exposure was considered as personal dose equivalent, Hp, which was the operational quantity for individual monitoring. The personal dose equivalent was reported in terms of 1) deep dose, which is the effective dose or Hp(10), the radiation exposure to deep organ, 2) superficial dose, which is the equivalent dose or Hp(0.07), the radiation exposure to skin and extremities, and 3) thyroid and lens dose, which is the equivalent dose or Hp(3), the radiation exposure to thyroid and eye lens[2]. These radiation exposures in the workplace were reported in terms of ambient dose such as the equivalent dose or Hp*(10), the operational quantity for area monitoring.

Statistical analysis

Sample size was determined by using the study from Anastasian et al[7]. Operation characteristics were analyzed using descriptive statistics presented as mean and standard deviation (SD) for continuous variables. Radiation exposures among groups were compared using Student t-test, Wilcoxon signed rank test, and one-way ANOVA for continuous variables and Chi-square test or Fisher's exact test for categorical ones. Correlations between continuous variables were conducted using Pearson correlation coefficient or Spearman's rho correlation coefficient. A p-value of less than 0.05 indicated statistical significance. Statistical analysis was performed using computer software; SPSS version 11 for Windows.

Results

During the study period, 66 fluoroscopic-guided spinal surgeries were performed, and the radiation exposures were measured among 50 anesthetic personnel. Lumbar pedicle screw fixation was the most common surgery and other types of operation included posterolateral fusion, posterior lumbar interbody fusion, scoliosis correction and anterior cervical discectomy and fusion. The operations averaged 342.2±144.1 minutes. No statistical difference was found among anesthetic personnel body mass index (BMI), operation time, fluoroscopy radiation, and fluoroscopy time as shown in Table 1. For fluoroscopic data, total radiation dose averaged 13.79±17.65 μGy/cm² and total fluoroscopy time averaged 71.8±191.5 second (Table 1). The monthly average radiation exposure in each group were S group=0.016±0.012 mSv, PS group=0.017±0.013 mSv, and SNP group=0.018±0.013 mSv. No statistical difference for radiation exposures among the groups was found regarding effective dose to body, equivalent dose to extremities, and equivalent dose to thyroid (p=0.929, 0.762, and 0.762, respectively) (Table 2). During the active fluoroscopy, the average number of pharmacologic interventions was 5.5±4.7 times and the average duration of pharmacologic intervention was 666.8±1492.4 seconds. No correlation was observed between radiation exposures and number of

Table 1. Anesthetic personnel BMI, operation time and fluoroscopic parameters

	Mean±SD	p-value*
Operation time (minute)	342.24±144.14	0.282
BMI (kg/m^2)	23.53±4.00	0.426
Fluoroscopy time (second)	71.79±191.54	0.229
Fluoroscopy radiation (μG/cm^2)	13.79±17.65	0.335

BMI=body mass index; SD=standard deviation

* Kruskal-Wallis test

Table 2. Monthly radiation exposures of the anesthetic personnel in each group

	S group Mean±SD	PS group Mean±SD	SNP group Mean±SD	p-value
Effective dose to body (mSv)	0.016±0.012	0.017±0.013	0.018±0.013	0.929
Equivalent dose to skin and extremities (mSv)	0.044±0.034	0.043±0.033	0.05±0.031	0.762
Equivalent dose to thyroid (mSv)	0.044±0.034	0.043±0.033	0.05±0.031	0.762
Equivalent dose to eye lens (mSv)	-	0.015±0.01	-	N/A

S group=shield group; PS group=partial shield group; SNP group=shield with no personal protective equipment (PPE) group; SD=standard deviation; N/A=not available

Table 3. Correlation between number or duration of pharmacologic interventions and radiation exposure

	Number of pharmacologic interventions		Duration of pharmacologic interventions	
	r	p-value	r	p-value
Effective dose to body (mSv)	−0.11	0.625	−0.23	0.314
Equivalent dose to skin and extremities (mSv)	0.04	0.865	0.01	0.973
Equivalent dose to thyroid (mSv)	0.04	0.865	0.01	0.973
Equivalent dose to eye lens (mSv)	−0.18	0.470	−0.06	0.816

Table 4. Radiation exposure in the operating room

	Ambient dose (mSv) Median (range)	Directional dose (mSv) Median (range)
Left wall	0.02 (0 to 0.05)	0.02 (0 to 0.05)
Machine	0.02 (0 to 0.07)	0.02 (0 to 0.06)
p-value	0.567	0.912
Right wall	0.02 (0 to 0.06)	0.02 (0 to 0.05)
Machine	0.02 (0 to 0.07)	0.02 (0 to 0.06)
p-value	0.509	0.562

pharmacologic interventions (p=0.625) and duration of pharmacologic intervention (p=0.314) (Table 3). Moreover, no statistical difference was found in workplace radiation exposures between the anesthetic machine and the left (p=0.567) and the right walls (p=0.509) (Table 4).

Discussion

The present research was a prospective observational study in fluoroscopic-guided spinal surgery. It demonstrated that radiation exposure among anesthetic personnel were lower than the ICRP standard maximum recommendation[1,2,8-10]. According to the authors' data, monthly recorded exposure dosimeter recorded less than 1% of the allowable limits of radiation exposure annually as recommended by the ICRP recommendation. Therefore, exchanging the dosimeter annually is reasonable. Workplace radiation exposure in the present study was comparable to other studies including the distance from radiation source[3,11]. The anesthetic personnel received no radiation or small amounts of radiation exposure where the distance was at 1.5 to 2 meters from the radiation source[11]. However, during active fluoroscopy, the received radiation of the anesthetic personnel was relatively increased due to the mandatory presence of anesthetic personnel when the patients' pharmacologic interventions were needed[7]. The present study shows that there is no correlation between number or duration of pharmacologic interventions and radiation exposure. The reason for this is that in daily practice, anesthetic personnel attempt to avoid or limit radiation exposure by reducing unnecessary pharmacologic interventions. The risk of direct and scatter radiation exposure was the highest in the lateral position. It increased the radiation exposure by more than 200 times of direct radiation and more than 30 times of scatter radiation[4]. The reason is due to higher X-ray beam needed when penetrating a thicker body to maintain image quality particularly in spine procedures. Regarding the anesthesiologist's daily practices during fluoroscopic-guided spinal surgery, some anesthesiologists may be unaware and leave themselves partially unprotected because of their belief in the inverse square law. Thus, to apply the inverse square law to effectively reduce one's radiation exposure, the standard practice to deal with the stochastic effect should be using the as low as reasonably achievable (ALARA) concept in terms of time, distance, and shielding[2,3]. The average amount of radiation exposed to the eye lens was 0.015±0.01 mSv per month in the present study. However, ICRP radiation exposure to ocular lens is limited to 150 mSv annually[1,2,8-10]. Some studies advocated that the threshold dose for cataract formation might be almost 10-folds lower than the current standard[2,7,12]. Therefore, wearing leaded glasses, while caring for the patient, is necessary to prevent long term eye problems. One drawback of the present study was that the small sample size might not have allowed more variation to differentiate the radiation exposure effects on different positions of anesthetic personnel. Secondly, no information was collected regarding the distance between the anesthetic personnel and the radiation source. Because of the limitation of having a consistent radiation source during operations and the different positions of the fluoroscopic machine, each case depended on the surgeon's preference. These manners could have affected the direction of scatter radiation measurement in the workplace between the anesthetic machine and the right and left wall leading to insignificant difference. Third, the dosimeter used in the present study was not used for real time radiation monitoring and appropriate radiation shielding is crucial. Moveable leaded shield combined with standard PPE is supposed to be an effective additional option to reduce radiation exposure[13]. In addition, the moveable lead shield can reduce whole body exposure particularly for difficult to protect anatomical parts such as the hands, brain, and the eye lenses. Therefore, routine radiation monitoring of anesthetic personnel, particularly in high-risk radiological environments, learning and training programs in radiation protection, and the availability of protective equipment is also required to enhance understanding. The annual monitoring and repeated evaluation of radiation exposure protection will help to ensure safety from exposure to medical radiation in workplace for anesthetic personnel.

Conclusion

The radiation exposures among anesthetic personnel at different positions during fluoroscopic work performance were lower than standard ICRP dose limitation (20 mSv/year) whether using the lead shield or not. However, standard PPE must be worn throughout the fluoroscopic time and unnecessary exposure during the procedures should be avoided. Care must be taken to achieve the ALARA concept.

What is already known on this topic?

Radiation-related cataract among anesthetic personnel would be presumed to exhibit a stochastic effect. Higher radiation has been detected when the axis is changed from antero-posterior to lateral projection and when fluoroscopy is used as assisted thoracolumbar pedicle screw placement.

What this study adds?

The radiation exposure determination in this present study was lower than standard ICRP dose limitation (20 mSv/year) whether using the lead shield or not. Regarding workplace radiation exposure, the median ambient dose and directional dose are both 0.02 mSv monthly.

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Conflicts of interest

The authors declare no conflict of interest.

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