Original

Evaluation of Radiation Exposure Pattern and Radiation Absorbed Dose Resulting from Occupational Exposure of Anesthesiologists to Ionizing Radiation

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ABSTRACT

Introduction: Little information is available concerning the radiation exposure of anesthesiologists, and no such data have previously been collected in Iran. This prospective study was performed to determine the amount of radiation exposure of anesthesiologists for the purpose of assessing whether or not dangerous levels of radiation exposures were being reached, and to identify factors that correlate with excessive risk.

Participants and Methods: The radiation exposure of all anesthesiology residents and the attending of Shiraz University of Medical Sciences during a 3-month period (from June to August 2016) was measured using a film badge with monthly readings. Physicians were divided into two groups: group 1 (the ones assigned to ORs with radiation exposure), and group 2 (the ones assigned to ORs with no or minimal radiation exposure).

Results: A total number of 10744 procedures were performed in 3 major university hospitals including 353 cases of pediatric angiography, 251 cases of percutaneous nephrolithotomy, 43 cases of chronic pain palliation and 672 cases of orthopedic surgeries with C-arm application. In all 3 months, there were statistically significant differences in the amount of radiation exposure between the two groups.

Conclusion: Anesthesiologists working in the cardiac catheterization laboratory, pain treatment service, orthopedic and urologic ORs are exposed to statistically significantly higher radiation levels compared to their colleagues in other ORs. The radiation exposure to anesthesiologists can rise to high levels; therefore, they should get proper teaching, shielding and periodic evaluations.

Keywords

Anesthesiologist, Radiation, Exposure, Ionizing

Introduction

A number of studies have focused on the harmful effects of ionizing radiation. These effects range from lens injuries [1] to various solid tumors and leukemia [2, 3]. Cumulative data has suggested an increased incidence of these cancers in health care personnel exposed to radiation during routine work [4].

Due to advances in diagnostic and interventional radiology, anesthesiologists are increasingly participating in the care of patients undergoing

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interventional and routine radiologic procedures. Previous studies indicate that fluoroscopic procedures were the largest source of occupational exposure to medicine including anesthesia [5]. For many procedures, the operator is able to step away from the field or leave the room during the period of radiation exposure. However, patient care frequently mandates that the anesthesiologist remains at the bedside, particularly during invasive procedures with monitored sedation, such as cardiac catheterization, when it may be dangerous for the patient to make any sudden movement.

Little information is available concerning the radiation exposure of anesthesiologists, and no such data have previously been collected in Iran. This prospective study was performed to determine the amount of radiation absorbed dose to anesthesiologists for the purpose of assessing whether or not dangerous levels of radiation exposures were being reached, and to identify factors that correlate with excessive risk.

Material and Methods

Study Design

The radiation exposure of all anesthesiology residents and the attending of Shiraz University of Medical Sciences during a 3-month period (from June to August 2016) was measured. Each physician wore a standard radiation safety film badge (Eastman Kodak type 2 (Eastman Kodak, 7000-Stuttgart-60, P.O. Box. 369. W. Germany, and Kodak (NEAR EAST) Inc., P. O. Box. 11460, Dubai)) clipped to his or her surgical suite on the chest. If lead apron was worn, the film badge was clipped outside the apron at shoulder level. Such film badges are capable of monitoring beta, gamma, radiograph and fast neutron exposure. They are sensitive to cumulative doses of radiation greater than 10 mrem, and measurements are reliable within 10% of the reported dose. Film badges were kept in physicians' lockers between workdays to prevent non-occupational exposure. Badge exposure was analyzed monthly. Each month around 40-42 physicians were assigned to the general ORs, 8-10 were assigned to orthopedic and percutaneous nephrolithotomy (PCNL) ORs, 2 were assigned to pediatric cardiac catheterization laboratory (CCL) and 3 physicians were assigned to the Pain Treatment Service. The total number of procedures performed and a number of cases where radiation was used (either fluoroscopy or X-rays) were evaluated each month. In addition, the results of dosimetry readings from the first month of the study were shared with the participants as soon as they were available to enable them to minimize their radiation exposure subsequently. Residents and some attending changed their OR services every month, so data for each participant for each month were considered separately.

Participants were divided into two groups for subsequent analysis purpose: those assigned to ORs with radiation exposure (CCL, Pain service, orthopedic ORs and PCNL ORs) as group 1, and those assigned to ORs with no radiation exposure as group 2. The amounts of radiation exposures in these two groups were compared. Physicians did not leave the ORs during the procedures.

Data Analysis

First, these two groups were tested for equal variance, then, independent sample t-test with equal variance was used for comparison of overall differences between the groups. Results are shown as mean ± SD. A P value <0.05 was considered statistically significant.

Results

Sixty physicians were enrolled in the study. During the 3-month period of evaluation, a total number of 10744 procedures were performed in 3 major university hospitals including 353 cases of pediatric angiography, 251 cases of PCNL, 43 cases of chronic pain, and 672 cases of orthopedic surgeries with the C-arm application.

Four to five individuals did not cooperate with the study each month. Detailed analysis of each month of evaluation is provided below.

First Month of Analysis

Data are considered as mean ± standard deviation unless otherwise stated. In the first round of analysis (Table-1), there were 13 participants in Group 1 and 42 participants in Group 2. An independent-sample t-test was run to determine if there were differences in received dose of radiation between Group 1 and Group 2. There were no outliers in the data, as assessed by inspection of a box plot. Received doses for each level of Groups were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$), but the assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances ($p = 0.040$). The received dose was more in the Group 1 (0.52 ± 0.08) than Group 2 (0.08 ± 0.11), a statistically significant difference of 0.44 (95% CI, 0.38 to 0.50), $t(28.384) = 15.141$, $p < 0.0005$ (Figure 1).

Second Round of Analysis

Data are considered as mean ± standard deviation unless otherwise stated. In the second

Table 1: First Round of Analysis

	Groups	N	Mean	SD	S.E. Mean	p-value
Dose	Group1	13	0.5200	0.08216	0.02279	< 0.0005
	Group2	42	0.0805	0.11656	0.01798	

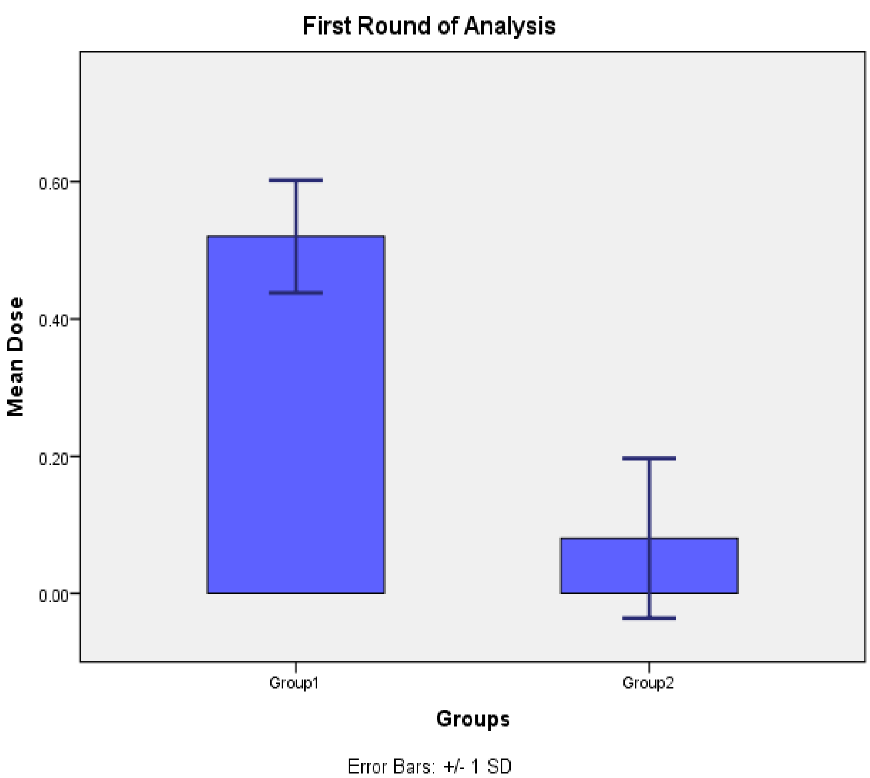

Figure 1: Radiation absorbed dose in each group in the first month of analysis

round of analysis (Table-2), there were 15 participants in Group 1 and 40 participants in Group 2. An independent-sample t-test was run to determine if there were differences in received dose of radiation between Group 1 and Group 2. There were no outliers in the data, as assessed by inspection of a box plot. Received doses for each level of groups were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$), but the assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances ($p < 0.0005$). The received dose was more in Group 1 (0.46 ± 0.06) than Group 2 (0.09 ± 0.12), a statistically significant difference of 0.37 (95% CI, 0.32 to 0.42), $t(50.613) = 14.767$ and $p < 0.0005$ (Figure 2).

Third Round of Analysis

Data are considered as mean ± standard deviation unless otherwise stated. In the third round of analysis (Table 3), there were 14 participants in Group 1 and 41 participants in Group 2. An independent-sample t-test was run to determine if there were differences in received dose of radiation between Group 1 and Group 2. There were no outliers in the data, as assessed by inspection of a box plot. Received

Table 2: Second Round of Analysis

	Groups	N	Mean	SD	S.E. Mean	p-value
Dose	Group1	15	0.4600	0.05794	0.01496	< 0.0005
	Group2	40	0.0918	0.12618	0.01995	

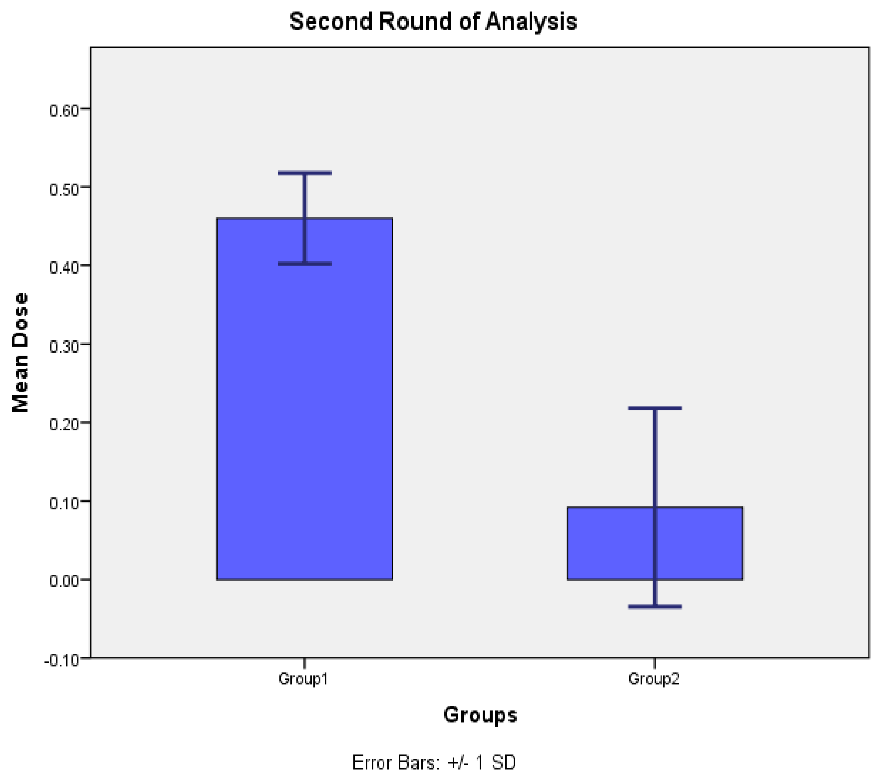

Figure 2: Radiation absorbed dose in each group in the second month of analysis

Table 3: Third Round of Analysis

	Groups	N	Mean	SD	S.E. Mean	p-value
Dose	Group1	14	0.4771	0.06557	0.01752	< 0.0005
	Group2	41	0.0727	0.11358	0.01774	

doses for each level of Groups were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$), but the assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances ($p = 0.012$). The received dose was more in Group 1 (0.48 ± 0.06) than Group 2 (0.07 ± 0.11), a statistically significant difference of 0.41 (95% CI, 0.35 to 0.45), $t(39.732) = 16.221$ and $p < 0.0005$ (Figure 3).

Overall Analysis

Data are considered as mean ± standard deviation unless otherwise stated. In overall analysis, there were 42 participants in Group 1 and 123 participants in Group 2 (Table 4). An independent-sample t-test was run to determine if there were differences in received dose of radiation between Group 1 and Group 2. There were no outliers in the data, as assessed by inspection of a box plot. Received doses for each level of Groups were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$), but the assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances ($p < 0.0005$). Overall, the received dose was more in the Group 1 (0.48 ± 0.07) than Group 2 (0.08 ± 0.12), a statistically significant difference of 0.40 (95% CI, 0.37 to 0.43), $t(118.302) = 26.252$ and $p < 0.0005$ (Figure 4).

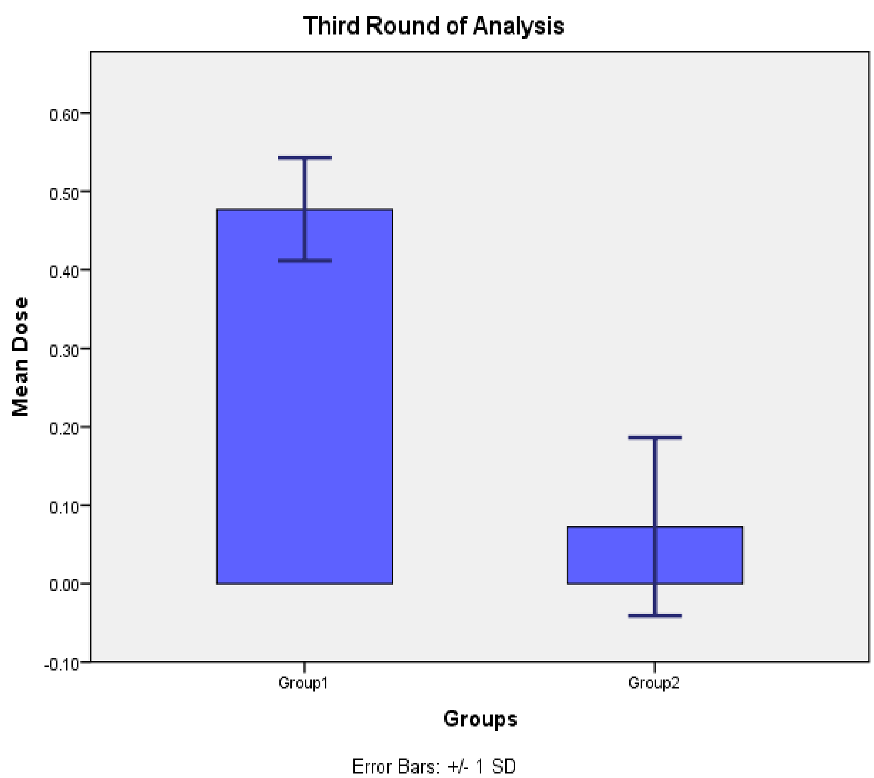

Figure 3: Radiation absorbed dose in each group in the third month of analysis.

Table 4: Overall Analysis

	Groups	N	Mean	SD	S.E. Mean	p-value
Dose	Group1	42	0.4843	0.07157	0.01104	< 0.0005
	Group2	123	0.0815	0.11809	0.01065	

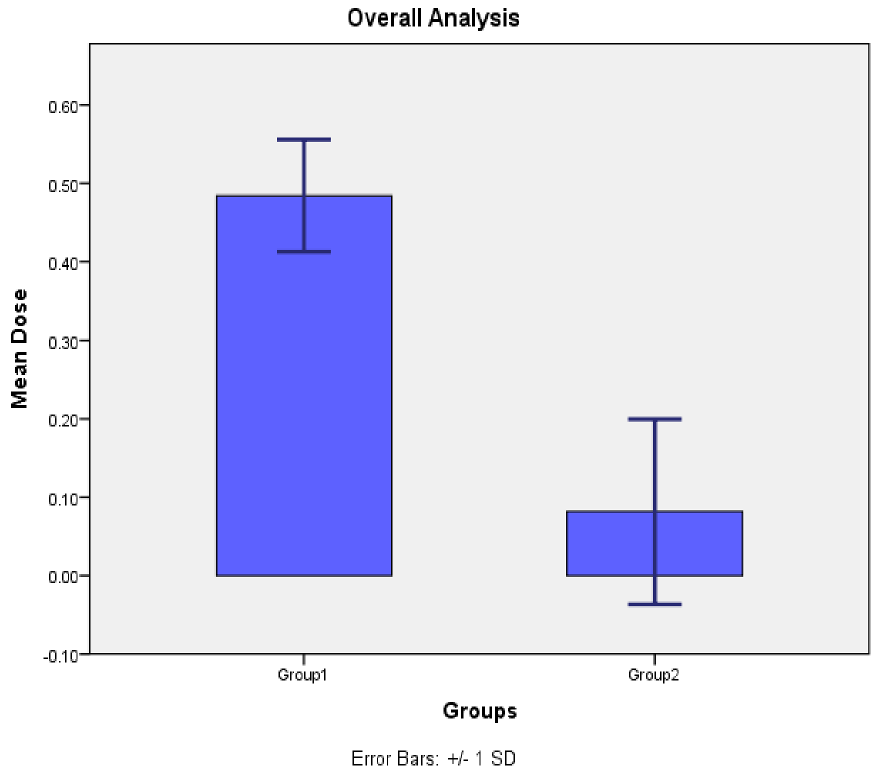

Figure 4: Radiation absorbed dose in each group during the three months of analysis

Discussion

Anesthesiologists can be exposed to ionizing radiation from X-rays and to non-ionizing radiation from lasers [6]. Since even small doses of radiation have the potential to harm, a risk is associated with each occupational exposure to radiation [7]. Previous studies have indicated that anesthesiologists are exposed to radiation six times more than other personnel during the neurointerventional angiographic procedures and the increasing use of C-arm in the orthopedic procedures exposes the anesthesiologists to beyond the recommended dose limit of radiation. The cumulative effects of radiation affect the entire body or cause localized damage to a certain area of body such as cataract [8-11].

We used film badges to monitor the radiation exposure because they are the most common and widely used type of personal radiation monitoring in Iran. These devices are based on the use of a film sensitive to radiation loaded into a plastic holder containing a system of filters (strips of copper, aluminum, lead, etc.) that allow the dosimeter to correctly identify the type of radiation exposure.

The SI unit for radiation, the Sievert (Sv) is equivalent to 100 rem. The International Commission on Radiological Protection's (ICRP) Publication 85 lists staff exposure doses for various X-ray interventions. Based on these guidelines, the radiation exposure should be 'as low as reasonably achievable' [12]. The recommended maximum dose limits for exposure set by the ICRP is 20 mSv per year over a period of 5 years [13].

Radiation exposure to a person is a function of three variables: time, distance, and shielding [14]. Anesthesiologists have less control over the total radiation time, as it is more dependent upon the operator performing the procedure and on the complexity of the procedure. The cumulative time is dependent upon the workload or number of cases performed over a certain time period. Distance (d) from the radiation source is an essential factor to reduce the dose effect of radiation. The power of the radiation beam is attenuated according to the inverse square law (1/d2) [12]. The anesthesiologist should move as far away from any radiation source as patient safety permits. Based on previous studies, radiation exposure is minimal at a distance of more than 36 inches [15]. However, patient care frequently mandates that the anesthesiologists remain at the bedside, particularly during invasive procedures with monitored sedation, such as cardiac catheterization, where it may be dangerous if the patients were to make any sudden movements. In our ORs, there is a constant need for anesthesiologists to change their position depending upon the type of procedure and type of anesthesia, therefore, a standard distance cannot be kept from the radiation source. In addition, more or less, the locations where anesthesia is administered are frequently cramped, limiting the ability of the anesthesiologists to distance themselves adequately from the source of radiation. The third important component, over which anesthesiologists have more control, is the use of a barrier. A typical barrier includes a lead apron and thyroid collar. The protective shield material is 'lead' and should be a minimum thickness of 0.5 mm lead equivalent. The sternum should not be exposed and a wrap-around design is preferable to single aprons [16]. A lead apron covers 82% of the active bone marrow, which still leaves a significant portion at risk to the effects of radiation [9]. During our study, all anesthetists wore protective lead aprons and thyroid shields (of 0.5 mm equivalent lead thickness) during the entire procedure. Although anesthesiologists in Iran use shielding while exposed to radiation, they seldom get any radiation protection training or wear radiation exposure monitoring.

There are not many studies focusing on the radiation exposure of anesthesiologists. One of the earliest articles on the damaging effects of radiation exposure in anesthetists was published in 1958 by Kincaid [17]. In that article, they discussed the sources of radiation for occupational exposure, nature of radiation and its biological effects, and provided some suggestion for minimizing the radiation exposure. In 1994, Henderson et al. [16] compared the radiation exposure of anesthesiologists working in the general ORs with the exposure of those working in the CCLs. Their results indicated that the operating room anesthesiologists were exposed to less than 10 mrem per month whereas those working in CCL were exposed to 20–180 mrem per month. They recommended routine monitoring of radiation in anesthetists working in CCL. In another study by Otto & Davidson, the exposure of nurse anesthetists during specific ureteroscopic fluoroscopy procedures in urology operating rooms was investigated [18]. The results indicated exposure rates higher than the recommended limits especially in the area of the thyroid. Lowe et al. reported that the exposure of anesthetists during PCNL was similar to that of the radiologist and higher than that of the urologists [19], whereas, Keenan found the exposure to be safe in surgeons, anesthetists, radiologists and patients [20]. Ismail and colleagues evaluated the radiation exposure of trainee anesthetists over a period of 6 months and found it to be within recommended limit [10]. The present study was the first survey in Iran to assess the radiation exposure of anesthesiologists, and it was performed on a large scale in 3 university-associated teaching hospitals. To our knowledge, it has had the largest study population. A limitation of our research is that since the majority of participant anesthesiologists change their rotations on a monthly basis, moving from ORs with higher radiation exposures to general ORs, the results cannot be accurately extrapolated to indicate the radiation exposure over a one-year period.

In conclusion, the results indicate that anesthesiologists working in CCL, pain treatment service, orthopedic and PCNL ORs are exposed to statistically significantly higher radiation levels compared to their colleagues in general ORs. The radiation exposure to anesthesiologists can rise to high levels and they should get proper teaching, shielding and periodic evaluations.

Conflict of Interest

None

References

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