ORIGINAL ARTICLE

Surgical Team Radiation Exposure from C-arm during Orthopedic Surgical Procedures

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ABSTRACT

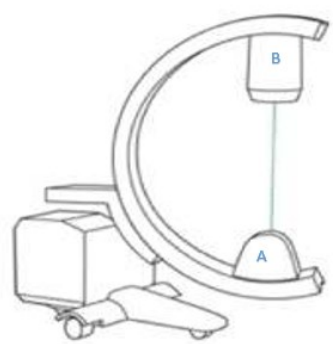
OBJECTIVE: A C-arm device for accurate and better results during orthopedic surgeries seems essential. According to the linear carcinogenic model, exposure to X-rays can increase the risk of malignancy. Due to the lack of monitoring of hospitals in the region, we decided to measure the radiation exposure of the orthopedic surgery team.
METHODOLOGY: This descriptive cross-sectional study was conducted at Abadan Shahid Beheshti Hospital between August 2020 and October 2020 with prior ethical committee approval. All the participants fill out the consent form before participating in the study. The census gave twenty thermoluminescence dosimeters to the orthopedic surgery team. They were asked to place the dosimeters on the chest on their cover and use them in orthopedic surgeries for three months. Also, a questionnaire was distributed among the employees, and they were asked about the number of operations they attended and how long they were in the operating room
RESULT: The average annual dose received by the entire surgical team was 0.24 mSv, significantly differing from the annual limit. ($P < 0.001$).
CONCLUSION: Even though the dose absorbed by the surgical team is less than the limits set by ICRP due to the carcinogenicity of even small amounts of radiation, the observance of protective principles is still recommended. Also, the surgery team involved in C-arm procedures should be controlled with monitoring tools such as TLD dosimeters.

KEYWORDS: Thermoluminescence dosimeters, C-arm**,** Occupational exposure**,** X-ray**,** Radiation protection, Orthopedic surgery

INTRODUCTION

The use of intraoperative imaging to increase accuracy and reduce the likelihood of error is necessary and unavoidable. C-arm, an instrument used for operating room imaging, is an X-ray emitter. The part of the radiation that passes the patients and reaches the detector is responsible for image formation. The part that isn't absorbed and scattered with less energy produces a radiation field responsible for staff radiation exposure (**Figure I**).

FIGURE I: A: X-RAY TUBE; B: DETECTOR



Exposure to an X-ray, an ionizing ray, can have different risks for the personnel and the patients. Ionizing rays can ionize atoms and alter their structure through direct contact with DNA or indirectly cause free radicals and further alter the structure of DNA molecules[1]. The indirect collision of the radiation with living tissue is caused by low linear energy transfer (LET) beams such as X-rays. This can lead to radiolysis of H_2O, which their products have the power to break chemical bonds and cause adverse reactions. Indirect collisions can also cause the formation of free radicals from an organic molecule, which can trigger a chain of destructive reactions. Destructed cells can induce cancer or other abnormalities later[2,3]. The effects of radiation exposure are divided into definite and stochastic effects. Definitive effects occur after receiving a certain amount of radiation dose, such as cataracts, which occur later after receiving a 50 cGy radiation dose[4]. Still, the stochastic effects are the effects that may arise from receiving any radiation dose. Cancer is classified in terms of stochastic effects[5].
It should be noted that there isn't any safe dose[6,] and it's recommended to keep the radiation as low as reasonably achievable (ALARA principle)[7]. According to the linear no-threshold (LNT) model, the lowest dose increases the risk of cancer[8]. This curve estimates cancer risk due to occupational radiation and diagnostic radiology. Increasing the dose can lead to risks such as genetic mutations and decreased life expectancy[9]. Some reports showed an increased risk of cancer in orthopedic surgeons compared to other workers[10]. To protect against the dangers of excessive radiation exposure, the International Committee of Radiation Protection (ICRP) has determined limits and recommends that the annual dose for occupational should not exceed 20 mSv per year, which is the average dose in 5 years, which the absorbed dose can receive up to 50 mSv radiation per year if the 5-year dose does not exceed 100 mSv[11].
In recent years, new technologies have been developed that have introduced higher accuracy and lower radiation doses. Methods such as intraoperative MRI, an evolving method[1] whose accuracy in diagnosis has been confirmed by studies[12]. Or methods such as O-arm and G-arm. O-arm is a CT-based intraoperative imaging technique that can scan a 360-degree arc and produce 750 images in one scan[1]. The G-arm is a G-shaped arm with two X-ray generators and two detectors that can simultaneously produce two images of two

perpendicular planes. Its advantages include higher accuracy, less radiation, and a shorter process[13].

One of the essential protection programs is measuring radiation intensity in places where radioactive materials or X-ray and gamma-generating devices are used. Several studies have evaluated the absorbed dose by the orthopedic surgeon, but limited studies have examined the dose received by the entire surgical team. Therefore, considering that the monitoring of personnel can be a practical step to reduce the dose they receive and make decisions to meet this goal, and considering that no monitoring has been done in the operating rooms of regional hospitals, in this study, we wanted to measure the dose received by the surgical team involved in orthopedic surgery and give them safety and preventive advice.

METHODOLOGY

This descriptive cross-sectional study was conducted at Abadan Shahid Beheshti Hospital between August 2020 and October 2020 with prior ethical committee approval. The number of surgical team members who were continuously and more than other personnel involved in surgeries that used C-arm was determined by a census. After explaining the details of the study to the participants, 20 employees who were present in operations using C-arm and declared their willingness to cooperate were included in the study, and a form was distributed among them to express their consent to participate in the study. Those who were on leave for more than ten days during study period were excluded. Twenty thermoluminescence dosimeters (TLD) LiF: Mg, Cu, P (GR200) were provided to the orthopedic surgery team (including two orthopedic specialists, six anaesthetists, and 12 operating room staff). They were asked to place these dosimeters on their cover on the chest and use them in orthopedic operations for three. A control dosimeter was also kept away from the radiation to measure the background dose. We asked the participants to record the number of operations they participated in and the time spent in the operating room. A questionnaire was distributed among them to reach this purpose. Two staff members who had been on leave for more than ten days during these three months and two who lost their dosimeters were excluded from the study; finally, 16 persons stayed in the study. After three months, the dosimeters were collected and sent to the dosimetry company along with the control dosimeter for reading. The dosimeters were read using the Harshaw 5500 TLD Reader, and the dosimeter results were announced in millisievert(mSv)**.**

Statistical Methodology

The collected data were analyzed by SPSS 21 software. Descriptive statistics and analytical statistics were used for the statistical analysis of data.

RESULTS

The effective radiation dose received by orthopedic specialists(S), operating room staff(O), and anesthesiologists(A), respectively, was 0.065 mSV, 0.074 mSv, and 0.048 mSv, over three months. The lowest exposure was for anesthesia personnel, and the highest exposure was for operating room staff. But there were no statistical differences in dose received by the group S and O(P=0.20), S and A(P=0.20), O and A(P=0.12). The average number of operations that each group participated in and the time duration average they were in the operating room are reported in **Table I**. The average effective dose measured for each group over three months and one year is also reported in **Table II**.

TABLE I: NUMBER AND DURATION TIME OF THE OPERATIONS

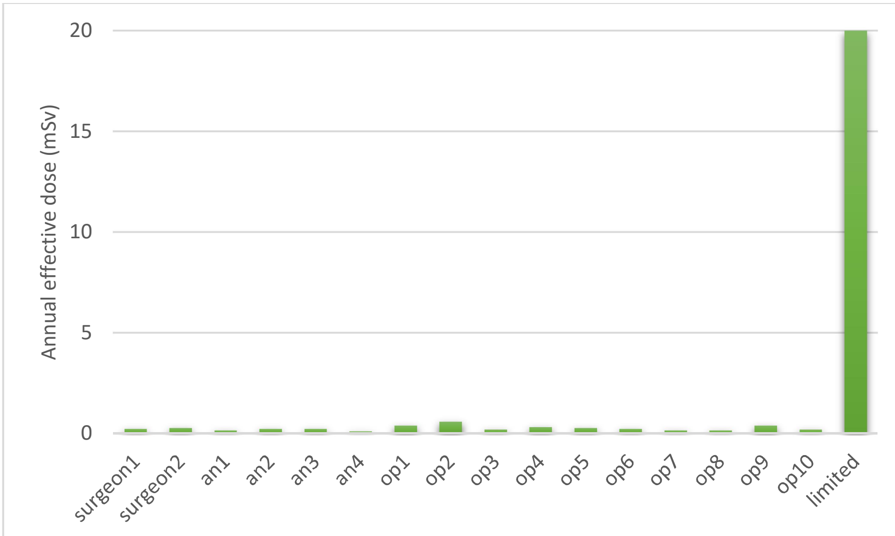
The Community understudy	Numbers of persons	The average number of operations that participated	The average duration of time spent in the operating room (hours)
Surgeons	2	53.500±17.677	66.500±21.920
Anesthetists	4	19.750±4.272	21.625±5.677
Operating room staff	10	23.900±6.871	23.900±9.811
The whole surgical team	16	26.560	28.656

TABLE II: EFFECTIVE DOSE

The Community understudy	The effective dose average over a three-month(mSv)	The effective dose average over a year(mSv)
Surgeons	0.065±0.007	0.26±0.028
Anesthetists	0.048±0.015	0.19±0.060
Operating room staff	0.074±0.035	0.296±0.138
The whole surgical team	0.066	0.249

No significant relationship was found between time and dose (P=0.22) or the number of operations and dose (P=0.11). The average annual dose received by the entire surgical team was 0.24 mSv, significantly differing from the yearly limit (P <0.001). (**Chart I**)
It should be noted that the dose received by none of the workers exceeds the annual limit. The highest number reported during these three months was 0.15 mSv, which will result in an annual dose of 0.6 mSv, which is still significantly different from the allowable value.

CHART I: THE EFFECTIVE DOSE OF EACH MEMBER OF THE SURGICAL TEAM FOR ONE YEAR AND COMPARED WITH THE LIMIT ALLOWED BY ICRP



DISCUSSION

X-ray-emitting medical devices are the essential source of ionizing radiation from unnatural sources[14]. In this study, the average dose received by the surgical team during the three months was 0.066. The average number of operations participated was 21.825, so the average dose received per operation will be 0.003 mSv; considering the allowable dose limit of 20 mSv for occupational, we can conclude that each person can participate in 6666 operations per year, i.e. 18 operations per day, up to the annual allowable limit. Similar studies have found numbers close to these numbers[15,16]. It is impossible to attend this number of operations in a day. The average annual dose received by the entire surgical team was 0.24 mSv, which is like similar studies[17-19] had a significant difference from the annual limit ($P < 0.001$). However, it should not be forgotten that even small amounts of radiation can have carcinogenic effects. Previous evidence showed that concerns about genetic mutation induced by radiation aren't necessary, and the primary concern is the carcinogenic effect[20]. Also, there were reports about malignancy happening in the brain, thyroid, skin, etc., in medical personnel due to radiation[21].

It is important to note that the study measured only the dose received in orthopedic procedures. At the same time, C-Arm is also used in other procedures such as neurosurgery, urology, and cardiac pacemaker placement. Therefore, the dose received by the anesthetists and operating room staff in hospitals with more diverse operations may be more than this amount. A similar study reported the amount of exposure for orthopedic surgeons less than their assistants[22].

Kim JW 2010[23] announces that the estimated annual equivalent dose outside the apron is near the maximum radiation exposure limit and recommends surgeons wear a radio-protective apron. Also, Lakhavani O 2019[13] recommends C-arms used in ABC (Automatic Brightness Control) and pulsed mode because this lead to less exposure.

CONCLUSION

The annual exposure of the orthopedic surgery team was much lower than the yearly limit set by the ICRP. There is no need to wear lead aprons for any surgical groups in the surgical team. However, the stochastic hazards of ionizing radiation in small amounts is a debatable topic, and no one refuses or confirms it. So, it is wise to be cautious: positioning the X-ray tube as far as possible from the surgeon and C-arm operator can reduce the exposure, standing on the other side of the generator (on the intensifier side of the C-arm, section B in Fig1) can help in avoiding the scatter radiation, reduce the time of radiation exposure will decrease the amount of radiation and so the scatter radiation. Also, to prevent the risk of receiving ionizing radiation and the fear that there is a risk of this type of radiation, it is recommended that medical centres look for alternative methods except for X-ray imaging methods, such as intraoperative MRI, O-arm, and G-arm. Maybe it's time for our medical centres to reconsider the devices they use. Ultimately, it recommended that the surgery team involved in C-arm procedures be controlled with monitoring tools such as TLD dosimeters.

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Ethical permission: This study was approved by the Abadan University of Medical Science research ethics committee with the code IR.ABADANUMS.REC.1398.047, Dated: 24-09-2019.

Conflict of interest: There is no potential conflict of interest in this research, its publication and its authorship
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DATA SHARING STATEMENT: The data supporting this study's findings are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restriction

AUTHORS CONTRIBUTIONS
Almanie A: Designed the project, analyzed the data and wrote the article.
Bachari SS: Collected data and reviewed the article.

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