BJRS

BRAZILIAN JOURNAL
OF
RADIATION SCIENCES
10-02A (2022) 01-10

Dosimetry assessment for mobile c-arm: use of badge attached to the equipment

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ABSTRACT

The use of fluoroscopy equipment in surgical procedures exposes professionals to ionizing radiation. An important safety aspect is the correct use of personal protective equipment and monitoring of dose levels in workers. In Brazil, the Resolution of the Collegiate Board of Directors (RDC) No. 330/2019 demands the use of an individual dosimeter for OEI. However, when personal dosimeters are not available, the International Atomic Energy Agency (IAEA) recommends attaching a dosimeter to the C-Arm, close to the detector, to estimate the dose received by medical personnel. The objective of this research was to evaluate the levels of exposure in professionals during surgical procedures in the operation room. This analysis was performed by placing OSL dosimeters on the C-arm equipment for eleven months and comparing them with the quantitative values extracted from the equipment in the routine. Two mobile fluoroscopies C-Arm equipment were used in this study. A total of 1231 procedures were evaluated, with a mean dose value of 5.8 μSv per procedure. Thus, the maximum number of procedures that the same professional can perform was 140 procedures per day for a staff member considering worker dose limits and 7 procedures per day for staff members using the required protective aprons considering the public dose limits. Although the study shows that the dose limits established by regulatory bodies are above the doses recorded in clinical practice, this situation should not promote false safety in the use of ionizing radiation.

Keywords: **mobile C-arm, occupational dose, dosimeter, surgical procedures.**

ISSN: 2319-0612
DOI: https://10.15392/bjrs.v10i2A.1845
Submitted:2022-01-20
Accepted: 2022-04-11

1. INTRODUCTION

Fluoroscopy equipment uses X-ray beams to produce radiographic images with high temporal resolution. C-arm equipment is most commonly used in the operating room, with the X-ray tube positioned diametrically opposite to the detection system. Technological advances in C-arms have allowed image acquisition, processing, and storage improvements. And these innovations can result in a potential increase in radiation dose for both the clinical staff and the patient. Therefore, modern fluoroscopy equipment incorporated dose monitoring technology into the imaging system, which provides greater safety in the procedures [1].

All services that utilize ionizing radiation must have a radiological protection plan to determine and document measures that ensure the quality and protection of all individuals, considering the public and Occupationally Exposed Individuals (OEI) [2, 3]. Thus, the principles of justification, optimization of protection, and dose limitation described by ICRP 103 [4] are the basis for enabling knowledge on this subject.

The use of fluoroscopy equipment in surgical procedures exposes professionals to ionizing radiation [5]. These exposures have been of concern because of their potential to produce biological effects [6]. Thus, knowledge and awareness of radiological safety principles and practices are necessary. Among the security aspects, time, distance, and shielding are the most effective during procedures [7, 8].

Another important safety aspect is the correct use of personal protective aprons and monitoring of dose levels in workers. In Brazil, the Resolution of the Collegiate Board of Directors (RDC) No. 330/2019 [2] demands the use of an individual dosimeter for OEI. However, when personal dosimeters are not available, the International Atomic Energy Agency (IAEA) recommends attaching a dosimeter to the C-Arm, close to the detector, to estimate the dose received by medical personnel [9, 10].

The dosimetry of scattered radiation in the radiology energy range can be done using Optically Stimulated Luminescence (OSL) dosimeters. OSL has a thin layer of pure carbon-doped aluminum oxide structure protected by two strips of polyester film. During the exposure of the OSL dosimeter, the interaction of X-rays with matter occurs. The electrons of the crystalline structure of aluminum oxide are trapped in the design of carbon atoms. The electrons that have been trapped have higher energy than the electrons in the medium. The amount of electrons increases with the absorbed radiation energy. Thus, the amount of trapped electrons is proportional to the dose received [11].

The objective of this research was to evaluate the exposure levels of professionals during surgical procedures in the operation room. This analysis was performed by placing OSL dosimeters on the C-arm equipment for eleven months and comparing the effective doses with the quantitative values extracted from the equipment in the routine.

2. MATERIALS AND METHODS

Two mobile fluoroscopies C-arm equipment (Siemens, Siremobil Compact L) were used in this study. Quality control tests were performed in accordance with the current Brazilian regulations: RDC 330/2019 [2] and No. 91/2021 [12]. Data were collected during eleven months from February and December of 2021. The procedures evaluated were performed at the operating room of a Medical School, and in this study, neurology, urology, orthopedics, cardiology, and vascular procedures were selected. The dosimeter used was the optically stimulated luminescence (OSL) supplied by a company (Sapra Landauer®, São Carlos, Brazil). Their recognized laboratory read and replaced all dosimeters monthly.

As stated by the current legislation in our country, the dosimeters were calibrated in Photon Dose Equivalent Hx (measured in Sv) using a known dose level of 1 mGy. The calibration was performed using a Co-60 radiation source on a 4p geometry free air exposure using a 3.0 mm Lucite build-up plate. The mean ratio between the reading dose (nanoCoulombs) and equivalent dose (milliSievert) for each dosimeter was used as an individual calibration factor. The uncertainty of a single dose measurement was 5.37%. This uncertainty value is dependent on the uncertainty in the calibration process, dose reading, and uncertainty of control dose subtracted.

The data collection involved the placement of a dosimeter badge attached to the mobile C-arm to estimate the scattered radiation effective dose. The dosimeter was placed 0.6 meters away from the center of the image intensifier, as demonstrated in Figure 1. A control dosimeter was placed outside of the operating room to measure the background radiation which were subtracted from the amount measured by the C-arm dosimeter. To assess the use of the C - Arm during this period, data collected from TeamPlay® (Siemens, Germany) software was used. TeamPlay® stores information from every examination in the cloud. General data of all procedures can be obtained, such as the the amount of sequences, average exposure time of procedures, and other helpful information for data analysis [13].

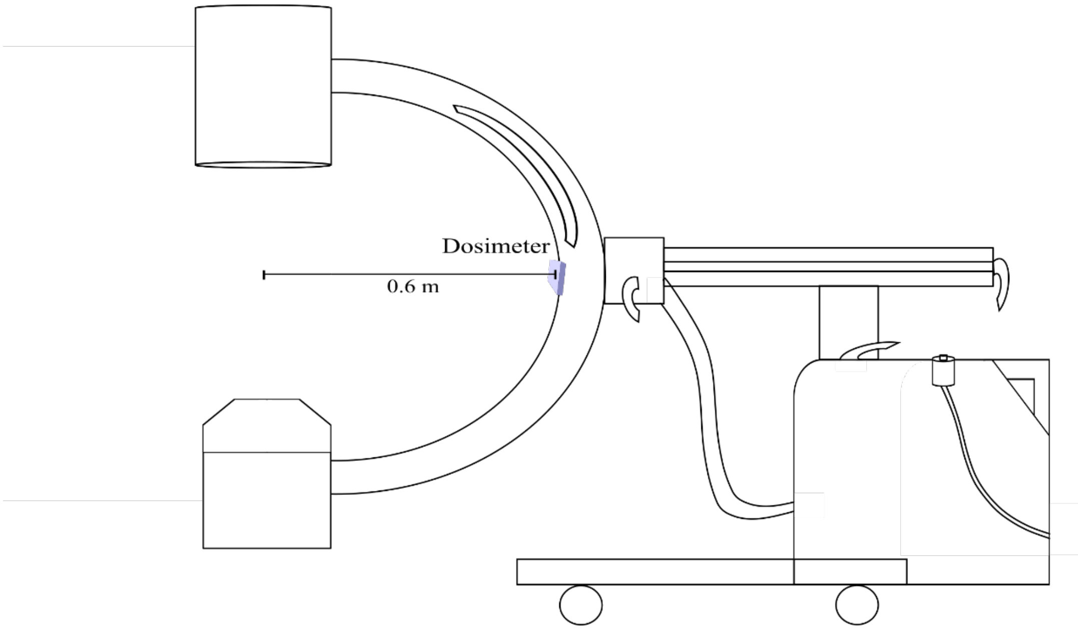

Figure 1: Schematic representing the location of the dosimeter in the C-arm equipment.

Monthly, dose values provided by dosimeters were correlated with the number of procedures for each mobile C-arm. The average dose values measured at 0.6 meters from the image intensifier will estimate doses received by the medical staff. This value will indicate scattered doses that a professional could receive if they were in the proximity of the equipment during exposure. And then, using the annual dose limits for workers [3], we can estimate the maximum number of procedures that can be performed in the routine without exceeding these limits, for both OEI and eventually exposed professionals that did not work with radiation on a daily basis, for whom the public limits should be applied.

3. RESULTS AND DISCUSSION

The number of evaluated procedures versus the months of the year (2021) for Equipment A and B is summarized in Figure 2.

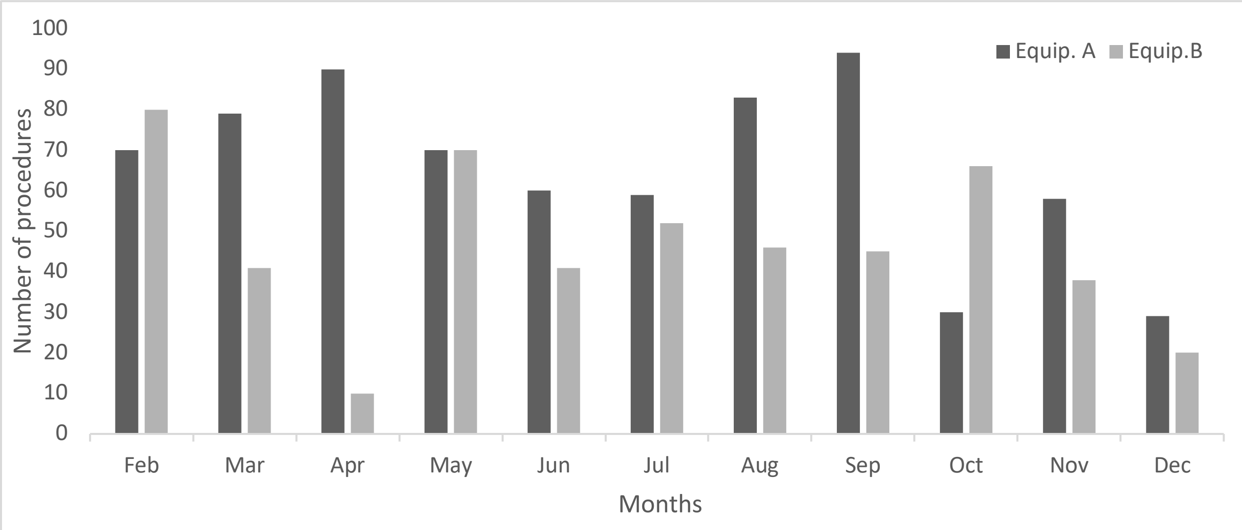

Figure 2: Distribution of procedures collected from Team Play ®, with a total of 722 examinations for equipment A and 509 examinations for equipment B.

We evaluated 722 procedures that resulted in a total dose of 3.3 mSv (According to Figure 2 and Table 1) in equipment A. Considering a professional working in this distance (0.6 meters away from the image intensifier), one can estimate that the average effective dose received was 4.60 µSv per procedure. In this hypothetical situation, the attenuation factors of lead clothing are not considered, nor the degree of movement of the professional during the procedures. Knowing that the annual dose limit for workers is 20 mSv per year, 43.758 annual procedures would be necessary to reach this limit. If we consider the attenuation factor of a lead apron, of at least 90% of reduction in transmission, this number will become significantly higher. This reduction factor considered the average energy in C-arm equipment used in most surgical procedures [14,15,16]. Table 2 shows an estimation considering the public dose limits since most of the personnel in the surgical center are not considered OEI from the legal point of view and the use of dosimeter badges does not apply to them.

Table 1: Result of the monthly reading of the OSL badge for equipment A and B during the analysis period.

Start date	End date	Equipment A	Equipment B
01/16/2021	02/15/2021	0.1 mSv	0.0 mSv
02/16/2021	18/03/2021	0.3 mSv	0.0 mSv
03/19/2021	04/15/2021	0.5 mSv	0.3 mSv
04/16/2021	05/15/2021	0.4 mSv	0.5 mSv
05/16/2021	06/15/2021	0.2 mSv	0.3 mSv
06/16/2021	07/15/2021	0.6 mSv	0.2 mSv
07/16/2021	08/15/2021	0.3 mSv	0.3 mSv
08/16/2021	09/15/2021	0.6 mSv	0.7 mSv
09/16/2021	10/15/2021	0.3 mSv	0.5 mSv
10/16/2021	11/20/2021	0.0 mSv	1.0 mSv
Total Dose:		3.3 mSv	3.8 mSv

We evaluated 509 procedures that resulted in a total dose of 3.8 mSv (according to Figure 2 and Table 1) in equipment B. Considering the same approach used for the first equipment, one can estimate that the average effective dose received was 7.46 µSv per procedure. Considering that the annual dose limit for workers is 20 mSv per year, 26.789 annual procedures would be necessary to reach this dose, as shown in Table 2. Also, Table 2 demonstrates the maximum number of procedures without exceeding dose limits.

Table 2: Maximum number of procedures without exceeding dose limits.

Dose with lead apron (mSv)	Dose limit for staff per year (mSv)	Number of procedures per year	Number of procedures per day	Dose limit for individual of the public per year (mSv)	Number of procedures per year	Number of procedures per day
0,00046		43758	174		2188	9
0,00075	20	26789	107	1	1339	5
0,00058		34676	140		1734	7

* We considered 251 days of work during the year.

Considering the two mobile C-arms, A and B, the average dose per procedure was 5.8 µSv with personal protective equipment, the average effective dose received was 0.58 µSv per procedure. Thus, it is assumed that a member of clinical staff at a distance of 0.6 meters from the image intensifier during exposures could participate in 140 procedures per day if the dose limits for workers are considered. Taking into account that most of the professionals in the surgical center are not OEIs from the legal point of view, under the same exposure conditions, but considering the public dose limits, this number decreases to 7 procedures per day. We considered the average of 251 working days throughout the year.

There are different classes of professionals in the surgical center, such as doctors, nurses, radiology technicians, instrumentalists, and assistants. Even though they occasionally stay in the operating rooms, some of these professionals are not close to the patient, which does not constitute a daily exposure routine. In the legal aspect, it is common not to consider these professionals occupationally exposed individuals, treating them as individuals from the public.

Although the scattered dose values are not that large, we must keep the radiation doses as low as reasonably feasible by the ALARA (as low as reasonably achievable) principle. Therefore, the correct use of lead aprons, eyeglasses, and thyroid protectors is necessary [17]. It should be noted that the interventional routine generates more doses for the clinical staff than in the operating room due to the nature of the procedures. In interventional practice, dose limits may be regularly exceeded in some cases [18].

When comparing the total dose per procedure with some results from the Literature [19-21], it is possible to validate the measured scattered dose with the heterogeneity of the procedures performed in the operating room.

Cristante *et al.* [22] evaluated a team of spine surgeries during 81 procedures that were considered long term. The professionals in question are not considered occupationally exposed, and the dosimeter positioned on the C-arm of the mobile fluoroscopy resulted in a total dose of 0.24 mSv, which corresponds on average to 2.96 μSv per procedure.

In another study, Romanova *et al.* [19] evaluated the radiation dose in the eye lens of orthopedic surgeons during various procedures. Procedures such as Fractura femoris and Fractura cruris were performed in mobile fluoroscopy equipment and biplanar systems. Measured radiation levels were lower in C-arm systems compared to biplanar angiography systems. However, they were interested in the dose measured with the C-arm equipment, which resulted in an average eye leans dose of 2.7 μSv. For hand/shoulder and ankle fracture procedures, an average dose of 2.35 μSv was obtained. Thus, if we do not consider the complexity of the procedure, the average dose to the surgeon's eye lens was 2.4 μSv.

In our study, the location of the equipment concerning the patient and the staff members can generate a limitation in the evaluations. This occurs since the angle and distance from the radiation source and the patient are directly related to the radiation scattered pattern, for example, since the distance of the eye to the patient is greater than the place where our dosimeter was attached, it is expected that our doses were greater than the reported by other studies. Other factors that interfere in the study are the surgical team's experience and the complexity of different surgeries [23].

CONCLUSIONS

This work evaluated the exposure levels to professionals working with two C-arm equipment during surgical procedures. This assessment was performed by placing OSL dosimeters on the C-arm equipment. A total of 1231 procedures were evaluated, with a median of 4 minutes and 52 seconds of fluoroscopic time and a mean dose value of 5.8 μSv per procedure. Thus, the maximum number of procedures that the same professional can perform was 140 procedures per day for a staff member, considering worker dose limits and the correct use of the protective aprons.

Although the study shows that the dose limits established by regulatory agencies are above the doses recorded in clinical practice, this situation should not promote false safety in ionizing radiation. In this scenario, it becomes essential to implement the principles of radiation protection and training of the entire staff in the Surgical Center and other Hospital sectors that utilize ionizing radiation.

ACKNOWLEDGMENT

We would like to thank all the technical and medical staff of the surgical center service where data were obtained.

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