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# Occupational Radiation Exposure Dose from C-Arm Fluoroscopy during Common Orthopedic & Neurological Surgical Procedures and its Prevention at Sbeha and Ghadra Libyan Hospitals

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**Abstract**: The C-arm has become increasingly popular in the practice of orthopedics and fluoroscopic operations in a number of mane General Libyan Hospitals. It's wide use in the various orthopedic outpatient clinic has been noticed.. The purpose of this study is to evaluate the practice efficiency and radiation exposure to the main doctors and the specialists involved in each medical operation. At the same time to make comparison of the measured radiation exposure doses for the doctors and the specialists during the C-arm uses in the two main Libyan general hospitals namely Sbeha and Ghadra in Tripoli.

A number of doctors and specialists were chosen and agreed to receive OSL badges to be monitored, the radiation physicist used Optical Simulated Luminceinces Dosimeters (OSL) to measure the amount of radiation exposures namely the Deep, Shallow and Lens radiation doses in milli-Siveret (mSv). The average radiation doses were found to be 4-26,4-28, and 4-28mSv shallow, deep and Lens respectively for Sbeha hospital for a three months follow-up period. At the same time it was recorded 4-5,4-5and 4-5mSv for doctors operators at Ghadra hospital for a one month follow-up period. These values were higher than the annual permissible doses recommended by most International Radiation Protection Bodies. Other studies have reported radiation doses for the a single operation C-arm operation was 0.58mGy, compared with 0.2mGy for antero-posterior view and lateral view radiographs. This study reports two important findings. First, surprisingly, the C-arm used in both investigated hospitals have shown a higher radiation absorbed dose than standard imaging with plain radiographs. Second finding is the use of C-arm has facilitated and improved operation schedule time for patients.

**Keywords:** C-arm, Orthopedics, Fluoroscopic, Exposure dose, Absorbed Dose, OSL.

## 1 Introduction

Fluoroscopy procedures has been used and abused. Some overuse is forgetting the principles of radiation protection while others underuse it without undue protection from exposure to scattered radiation in the Operation Room (OT). In general, orthopedic surgeons and neurologist specialists lack awareness about the radiation exposure they are getting and its effects on their health and are callous with protection [1]. Surgeons and assistants are at maximum risk among all OT personnel due to proximity to scatter radiation exposure area. Some studies concluded that whole body dose received is well within the recommended levels while other studies have pronounced higher absorbed doses and have emphasized caution due to long term effects of even low or medium radiations dose. While other studies have shown a higher exposure radiation doses to the surgeons and patients.[2]. It is pertinent that any amount of exposure to ionizing radiation leading to secondary occupational risk should be avoided or maximal caution should be exercised to minimize the surgeons, assistance and patient exposure according to the ALARA principle.

## 2 Hypothesis

This study was conducted in an attempt to evaluate and analyse the radiation doses received by orthopedic and neurological surgeons in the Sbeha Hospital and Abosaleem hospital setup, as no such study has been done previously carried out for the C-arm at these two main hospitals in Libya. An attempt is also being made to promote radiation protection awareness uses of image

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intensifier of radiation in the operation theatre and the safety in everyday practice at both units of these two Libyan General Hospital.

## 3 Aims of the Study

The purpose and the aims of this study was to evaluate the practice efficiency and radiation exposure to the orthopedic and fluoroscopic doctors, specialist and scrap technicians when the C-arm at Ali Omar Askar Hospital known as Sbeha Hospital and Hadba Ghadra General Hospital known as Ghadra Hospital in Tripoli city.

## 4 Challenges for Reducing Radiation Dose

Users strive to reduce radiation dose in a continuous process while maintaining diagnostic image quality. They need to be able to identify root cause for high dose events and best practices for low dose examinations to apply and replicate those in standard procedures. The measured doses for practitioners and all workers at the Sbeha and Ghadra Hospital will show the real situation of levels of personnel radiation doses to the doctors and patient in order to identify high dose events and enables users to investigate and ultimately address the root causes for such high radiation exposures and absorbed doses.

## 5 Hypothesis

Orthopedic surgeons and assistants are at the maximum radiation risk among all OT personnel due to proximity to exposure area [3]. This study was conducted in an attempt to evaluate and analyse the radiation doses received by orthopedic and fluoroscopic surgeons in the Sbeha and Ghadra Hospitals setup, as no such study has been done previously carried out for C-arm Fluoroscopy procedures at these two hospitals. An attempt is also being made to promote radiation protection awareness uses of image intensifier of radiation in the operation theatre and the safety in everyday practice at these two Hospitals.

## 6 Martial and Methods

A three month prospective study has been conducted at the Sbeha and only one month at the Ghadra Hospital from Jun to August 2017 with prior ethical medical approval. Eight right-handed male orthopedic surgeons (4 senior consultants, 2 junior consultants and 2 residents) were included for the study in Sbeha and a similar group at Ghadra hospitals .

Each surgeon was provided with One (OSL) badges obtained from Department of Radiation Safety at OSL laboratory at Central of Disease Tripoli. The whole period of study each person from this group has been assigned. One badge for a Three months period. The badges were collected each month processed and the badges returned to them for the next period. All the types of radiological operations required C-arm fluoroscopy for each group were registered.

All procedures requiring C-Arm fluoroscopy were included in the study while those done only under radiographic control were excluded. The portable C-Arm fluoroscope with image intensifier used for imaging procedures.

After the surgical procedure was over, the OSL badges were kept in the Hospital boxes. A record was kept for duration of surgery and fluoroscopy exposure time as shown in the Tables 1&2. OSL badges were sent to the OSL laboratory at Central of Disease-Tripoli for measurement of radiation exposure for each badge of the measurement period.

## 7 The Optical Simulated Luminceinces "OSL"

The Optically Stimulated Luminescence (OSL) has been used for carrying out the measurements of the personal radiation doses. The OSL badges have been developed as a new type of personal radiation dosimeter that combines the excellent features of sensitivity with the convenience of Panasonic type readers. The dosimeter is a Panasonic type dosimeter with OSL detectors replacing the thermoluminescence dosimeters (TLDs). The readers are modified, principally by using a LED array as the light source. Thus, have been able to use an extensively tried and tested system with the minimum of modifications. The readers are computer controlled and can recognize the type of badge being read and the sensitivity of the OSL detectors [4]. The badges have been developed to meet the requirements for the American and European markets specifications as shown if Figure1. These model badge comprises an open window and filters of plastic, copper and lead. These filters are used for the delineation between Shallow dose, Deep dose and Lens dose exposure. A linear algorithm is being developed for this badge to cover the whole range of radiation exposure in order to meet the requirements of ICRP 91.

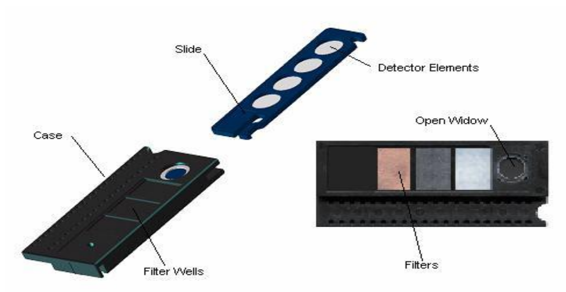



**Fig.1:** Exploded view of the dosimeter shows the specific filters for the deep, shallow and lens doses.

## 8 OSL badges Distributions

The Sbeha and Ghadra hospitals administration board, surgeons and specialist have been given the outline of the research project and they reviewed it and approved to carry out this study. All designated surgeons, specialists and assistants were each given one Optical Simulated Luminceinces badges and were kept with them during operations for the whole month. At the end of the monitored period of one month were collected read and the badges were zeroed and handed back to the same persons.

The data was collected and analyzed for three consecutive months as shown in the Tables1&2.

## 9 C-arm Medical Operation Imaging

A total of 27 medical operations were carried out using the C-arm imaging in the first month of monitoring at the Sbeha hospital, while 36 medical operations were carried out in Ghadra hospital. Different medical operation such as fractures was evaluated by one orthopedic surgeon in follow-up in the outpatient clinic using a C-arm imaging. For each medical operation, the radiation emitted in milli-Gray (mGy) and operation time in seconds were recorded. The treating surgeon includes a paragraph in the clinic note stating that the C-arm as shown in Figure 2 was used, the interpretation of the images obtained, the radiation emitted, and the time of radiation exposure.

**Fig. 2:** Shows an image of the actual C-arm used in the Sbeha hospital.

## 10 Radiation Protection Issues with the C-arm Image Intensifier

The use of C-arm intensifier is a relatively safe imaging device, but for best safe practice the following parameters are important and has to be considered;

### *10.1 Screening Time*

This is the main variable parameter of the C-arm operation time which is displayed on the council monitor. Typically, it will be low for normal surgical procedures, about ten seconds for most wire or screw fixations and 30 seconds for plating. The quality of the image and the ease of use can be optimized with supervised training, proper positioning and a well-rehearsed surgical plan is highly required.

Screening times are recorded during its operation. Typical screening times should be generated locally for audit and used for best practice as part of the protocols. A reassessment time should be included within the protocols. This is the screening time at which techniques and procedures should be re-evaluated. When re-assessment times are approached or exceeded the surgical plan should be reviewed and a more senior surgeon called or the technique changed unless completion is imminent.

### *10.2 Set-up Geometry*

The x-ray source from the C-arm should be kept as far from the patient as possible (30 cm minimum according to the ICRP recommendations) and the intensifier must be kept as close as is possible. This will reduce the entrance surface dose to the patient and reduce magnification of the image. The narrower field of 10 cm should be used whenever possible. Typical staff dose readings for different types of procedures have been published in the literature [5, 6,]. Depending on the type of procedure and the techniques used, the operator dose, per procedure, it has been found that in the ranges from 0.003 to0.450mSv at the neck over protective garments, from <0.001 to 0.032μSv at the waist or chest under protective garments, and from 0.048 to 1.280mSv at the hand. Unfortunately, the Sbeha and Ghadra hospitals do not have a special radiation physics unit and no follow ups of personnel radiation monitoring of exposure doses have been previously reordered. At the same time most of the published data in literature in other countries are stated in terms of dose per procedure, and most of the data are for physicians rather than assistants, nurses, technologists, or other staff. Translating these data into monthly or annual worker doses is difficult. It must be stressed that, the effective dose for an interventional radiologist is typically 2–4 mSv.year$^{-1}$ [7–8].

## 11 Presentations of Results and Discussion

### *11.1 Sbeha Hospital Doctors and Specialists Dose Rate Results*

Ten doctors and specialists of the OT unit of the Sbeha Hospital in this study agreed to participate in this research study. The doctors were working on a various medical operation of orthopedics operations and foreign body locations in parts of the body. The radiation dose follow up for all the doctors and specialists at Sbeha hospital were followed monthly for a total period of three months. The measured radiation dose rates were tabulated in Table 4.1.

### *11.2 Analysis of Sheba Doctors and Specialists Absorbed Dose Rates*

Upon reviewing the radiation absorbed dose, it can be clearly seen that about four doctors ( 1, 2,6 and 7) received more than the annual permitted dose limits of 20mSv per year. While the other surveyed doctors have received more than half the limited yearly dose of 10mSv, namely doctors number 3 ,4 ,5, 8,and 10. The only exception was the doctor

**Table 1** Presents the measured radiation dose rates during three months period for Sbeha Hospital in mSv per three months.

| No. | Mean Dose in mSv per three months | | |
|---|---|---|---|
| | Deep | Lens | Shallow |
| 1 | 26 | 28 | 28 |
| 2 | 19 | 20 | 20 |
| 3 | 14 | 14 | 14 |
| 4 | 14 | 14 | 14 |
| 5 | 4 | 4 | 4 |
| 6 | 19 | 22 | 20 |
| 7 | 21 | 22 | 22 |
| 8 | 14 | 14 | 14 |
| 9 | 9 | 9 | 10 |
| 10 | 10 | 11 | 11 |

no 5, he was given the badge but unfortunately used it for less than one month and went into a holiday. It has to be noted that the accumulated dose rate increases with increase of the number of cases. At the same time the position of the badge on the body has to be taken into consideration, doctors number 1, 2 ,5,7 and 8 the badges out of the lead aprons while the others positioned them under the used lead a pron.

### *11.3 Ghadra Hospital Doctors and Specialists Dose Rate Results within the Operating Room for the One Month*

Since Ghadra hospital uses a similar C-arm in their OT and it was possible to follow up a 11 doctors and specialists. Eleven OSL badges were given to them for only one month period and then were taken and the collected doses were processed and are presented in Table 2.

**Table 2:** Presents the radiation absorbed doses for Ghadra Hospital Doctors for one month only.

| **No** | **Dose in mSv per one month** | | |
|---|---|---|---|
| | Deep | Lens | Shallow |
| 1 | 4 | 4 | 4 |
| 2 | 4 | 4 | 4 |
| 3 | 4 | 4 | 4 |
| 4 | 5 | 5 | 5 |
| 5 | 4 | 4 | 5 |
| 6 | 3 | 4 | 5 |
| 7 | 4 | 4 | 5 |
| 8 | 4 | 4 | 4 |
| 9 | 4 | 4 | 5 |
| 10 | 5 | 5 | 5 |
| 11 | 4 | 4 | 4 |

For more analysis of Ghadra Hospital results for cases No.2, 3, 4, 8,9,10 and 11 are doctors working four days of total 24 days about 96 hours with a absorbed radiation doses in the range of 4 to 5mSv while the permitted radiation doses for the same period should be less than 2.0mSv.

At the same time the numbers of cases 1, 5, 6, and 7 refers to the absorbed radiation doses for x-ray technicians operating for only 8 hours total of 90 hours with a measured dose of 5mSv.

As it can be seen from the tabulated results for the eleven doctors and specialists at Ghadra hospital, most of their radiation doses were in the range of 4-5mSv per one month. While three doctor that used the OSL badge on lower extremity gonadal area received dose of 4-5mSv which indicates that a higher level of radiation scatter in the lower area of the C-arm Table which has to be taken into consideration.

For more analysis of the Ghadra Hospital results indicates that a number of the doctors working four days of total 24 days about 96 hours with a absorbed radiation doses in the range of 3.59 to 5.05mSv while the permitted radiation doses for the same period should be less than 2.0mSv.

At the same time the other X-ray technicians operating for only 8 hours total of 90 hours per month with a measured dose of 4.48mSv absorbed radiation dose. The nurses working for 8 days morning and 12 hours evening with a total for 96 hours and receiving a dose of 3.84—5.05mSv.

## 12 Results Discussion

### *12.1 Statistical Analysis Studies of Results*

The current study included a small sample just two hospital unit using C-arm imaging for their medical operation being studied namely; Sbeha and Ghadra hospitals. At the same time the measured doses were collected for four Orthopedic Surgeon, one Neurosurgeon, one X-ray Technician, two Operation Technicians and One Female Anesthesia Technician Operating at the Operating Theater (OT) of Sbeha Hospital. However, for Ghadra hospital the radiation doses collected were collected for five orthopedic surgeon, one x-ray technician, three female assistant, one anesthesia doctor and .one anesthesia technician.

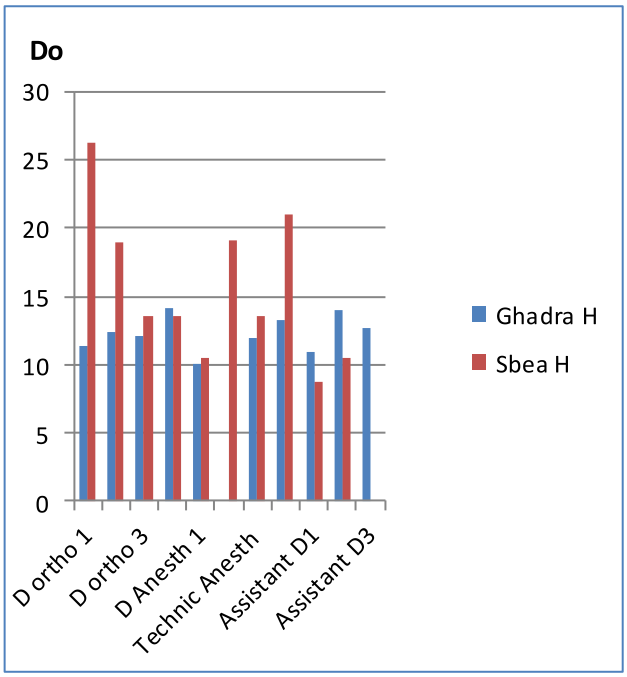
Using all the collected data of absorbed doses for doctors at both medical hospitals it can be seen that the collective absorbed doses for Sbeha ranged from 10 to 28mGy for three months while for the Ghadra hospital ranged 4 to 6mGy for one month. All the measured values are higher than the permissible annual doses set by most International Radiation Protection Associations. ICRP 61. [9].

### *12.2 Comparison between Doctors and Place of Badge*

A simple comparison between the absorbed doses for doctors and specialists whom are using lead aprons and those who did not use them during medical imaging. It was found that the p value of 0.19 did not show a great difference. These results could indicate that the used shielding of the lead aprons was not adequate enough to reduce personal exposure or the badges were worn in an area that has significant scatter. Also using the Anova test, the p-value value of 13.87 which shows no significant difference in mean absorbed deep doses between the Doctors regarding the placement of the badge under or above the used lead aprons

### *12.3 A graphical Presentation of the Analyzed Results*

Graphs No.1 presents the actual compression of results between the absorbed radiation doses of doctors. Upon checking the graphical representations it can be clearly seen that Sbeha radiation doses is slightly higher than that for Ghadra Hospital.




**Graph. 1:** Shows comparison between medical team (O.T) Sbeha and Ghadra Hospitals.

## 13 Discussions of Presented Results

Like many imaging tools that rely on ionizing beam radiation, the C-arm fluoroscope has been the subject of much scrutiny over the years. Both direct and indirect comparisons have shown the radiation exposure levels associated with the C-arm to be consistently higher than those associated with the other x-ray modalities. Nonetheless, medical radiation authorities on radiation protection should maintain strict adherence to established safety principles and measure radiation exposure doses to all specialists and practitioners at the C-arm units of both Hospitals. Despite the reputed exposure-reduction capabilities of the C-arm, many practitioners should be concerned about their potentially exposures to themselves, their assistance and their patients to a higher levels of radiation [10].

In this study, it was possible to quantified radiation exposure sustained by the surgeon during use of standard and C-arm fluoroscopes to various imaging purposes and various organs of the patient.

This study demonstrated that there is underestimation of radiation exposure doses to which the doctors, specialists and technician in addition to the patient all are being exposed to a higher radiation doses which exceeds the International and National permissible dose levels.

The scatter doses recorded by the two OSL badges that were positioned in the wall of the OT recorded scatter radiation were in the range of 4 to 5mSv per one month. While this dose is seemingly inconsequential, it highlights the fact that scatter radiation is present even at great distances from the radiation source and is not zero as some believe. The long-term stochastic effects of prolonged radiation exposure are unclear but certain. However, a review of epidemiological data suggests that the lowest dose of x-rays that has reliably been shown to increase cancer risk is 0.05 to 0.1Sv during a protracted exposure [11]. Data extracted from the dermatology literature suggest that observable effects of acute radiation exposure, such as skin changes, become evident within hours and can be present after a threshold dose of 200 rad (2 Gy) [12]. Permanent skin changes can occur after years of chronic radiation injury and have a threshold dose of 1000 rad (10 Gy). While levels produced in our study did not approach such threshold doses, both the short and long-term effects of radiation exposure and the risks that they impose must be carefully weighed against the advantages of using mobile fluoroscopes.

It can be stated that patient exposure during use of the C-arm should be restricted and the timing of the x-ray shots should be minimized to the lowest possible time and restricted to the area of interested to the particular imaged organs. By following specific imaging protocols surgeon exposure will also be lowered and minimized.

Because the OSL dosimeters used in the present study were able to detect exposure of 0.01uSv, it was possible to obtain a true measure of the scatter radiation to which a surgeon is exposed [13]. This again underscores the importance of maintaining ideal imaging conditions when using either fluoroscopy unit under real working conditions. This finding highlights the fact that, even when one is out of the direct path of the radiation beam, scatter radiation exposure is still not negligible and has to be reconsidered in further studies. Also it is recommended that all radiation doses for patient have to be recorded and that patient especially young male and female patient has to be followed long after being exposed and to be under health care follow-ups.

## 14 Conclusions

Exposure during the use of C-arm fluoroscopy has been evaluated in a host of studies, in which it has been concluded that any measurable exposure is the result of direct contact with the radiation beam and exposure from scatter is to be determined and studied carefully. A number of authors of such studies have drawn the conclusion that the risk of exposure during C-arm fluoroscopy is not minimal for both the patient and the surgeon. However, on the basis of the collected data results for the doctors and specialists was higher than permissible levels, and it is believed that protective safety measures should be strictly enforced during C-arm fluoroscopy. These measures include the routine use of lead shielding for patients, surgeons, and any adjacent medical staff. A follow-up of exposure radiation doses should be followed by the use of personal measurements over a one year period at least to quantitatively asses the radiation exposures and the risk involved for all operators.

### *14.1 Personal Dose Records*

Personal dose records for each operating C-arm unit has to have an appointed Health Physicist or a group or medical radiation physics group. This unit has to be responsible for distributing Dosimeters to monitor the exposure dose on a routinely bases. The information collected of a personal dose record will vary depending on the number, type, and location of personal dosimeters used. This record will contain information on the effective dose (E), assessed from the readings of one or two dosimeters worn on the chest or abdomen under and/or over the lead apron, and may contain information on the equivalent dose to the lens of the eye from the dosimeter worn at the collar level over the apron or thyroid collar and the equivalent dose to the hand from a ring or bracelet dosimeter.

Copies of these dose reports should be sent to each operating units and individual at least every year. The relevant information contained in the dosimetry report to an individual includes the doses for the current period and the current year.

### *14.2 Investigation of High Occupational Dose*

The World Health Organization (WHO) recommends investigation when *monthly* exposure reaches 0. mSv for effective dose, 5mSv for dose to the lens of the eye, or 15mSv to the hands or extremities [14]. The Radiation Safety Officer or a qualified medical physicist should contact the worker directly to determine the cause of the unusual dose and to make suggestions about how to keep the worker’s dose as low as reasonably achievable (ALARA).

Badge readings for workers in interventional laboratories can be expected to be higher than for most other hospital workers. Most other hospital workers are expected to have minimal occupational radiation exposure. Using the same investigation criteria for both groups leads to nonproductive investigations of interventional radiologists and, often, to their reduced compliance with monitor use. ICRP publication 103 discusses how this situation may be avoided, by considering both the need for optimization of protection and the avoidance of arbitrary operational dose limits: "The use of prescriptive requirements should always be carefully justified". In any event, they should never be regarded as an alternative to the process of optimizing protection. It is not satisfactory to set design or operational limits or targets as an arbitrary fraction of the dose limit, regardless of the particular nature of the plant and the operations” [15].

## 15 Final Conclusions and Recommendations

The ideal medical radiation exposure should give the best picture using the lowest practicable radiation dose. This is an area of concern in radiation medical exposures since one person takes complete responsibility for exposure to considerable levels of x-rays. Therefore, implementation of specific audit techniques are essential. The hospital authority must have specific protocols in place for medical exposures with the compliance of the operator and practitioner.

Upon analyzing the personal does from the C-arm fluoroscopy imaging procedures at the Sbeha and Ghadra hospital it was found that most of the involved personnel are exposed to a relatively high doses. Therefore, it is highly recommended that a practical advice to the Sbeha and Ghadra Hospitals for reducing or Minimizing Occupational Radiation Doses. Their use, however, can be optimized further by proper training, enforcing local rules, having protocols in place and careful auditing Under the IRMER 2000 it is now a legal requirement for all medical radiation imaging departments.

Use of the C-arm in the orthopedic imaging in Sbeha and Ghadra X-ray diagnostic department has led to very important findings. First, not surprisingly, the C-arm used causes a higher radiation dose to the doctors and specialists than standard imaging with plain radiographs for both doctors and patients. Second, use of the C-arm saved time and improved the efficiency of the clinic visit. Use of personal protective equipment and safe imaging practices should be highly recommended to enhance radiation protection of all involved personal. Overall, the C-arm improves quality and efficiency in the most imaging of outpatient clinic. From the collected results Surgeons and assistants are at maximum risk among all OT personnel due to proximity to exposure area. This study has concluded that whole body dose received is higher than found in most of the other reviewed studies. For this reason a number of important recommendations will be emphasized to the Sbeha and Ghadra Hospital administration in order to lower the personnel radiation doses. It is pertinent that any amount of exposure to ionizing radiation leading to secondary occupational risk should be avoided or maximal caution exercised to minimize the exposure to unnecessary radiation doses.

Upon finishing this research project at the C-arm unit, it is prudent to come to a number of conclusions in order to minimize or lower the occupational radiation doses to the whole group of C-arm operation personal and to the patients. It has to be noted that, decreasing patient dose will evenly result in a proportional decrease in scatter dose to the operator. Therefore, techniques that reduce patient dose will generally also reduce the occupational dose. This is a “win-win” situation; for the operators and the patients both benefit from these reductions. Additional techniques can be used with fluoroscopically guided procedures to reduce occupational dose.

In summary, this study has shown that, contrary to the belief of some, the C-arm is capable of producing considerable radiation exposure, especially if it is used in an in-judicious manner. Exposure of the patient and surgeon can be minimized by following known dose-reducing recommendations and strictly adhering to all protective measures, including use of a appropriate lead garment. While the C-arm can and should be used to image larger body areas, the surgeon must be caution to limit the number of exposures, as radiation can be expected to be much higher under such conditions.

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