Sri Lankan Journal of Health Sciences

Article

Assessment of Radiation Protection Measures to Minimize Occupational Radiation Exposure from C-arm Fluoroscopy During Common Orthopaedic Surgical Procedures

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Abstract

Background: Modern fluoroscopic C-arms have substantially expanded the use of fluoroscopic C-arms in a variety of orthopaedic surgical procedures. Fluoroscopy professionals who are exposed to radiation for an extended period of time have an increased risk of developing radiation-induced cancer. The study aimed to evaluate the radiation protection precautions taken by theater staff in two selected hospitals to reduce occupational radiation doses during fluoroscopy-guided common orthopaedic surgeries. **Methods:** After examining the theatre records for three months in two selected hospitals in Sri Lanka, the three major orthopaedic surgeries for both hospitals were selected (Dynamic Hip Screw, Tibial Plateau Fracture, and Distal Radial Fracture). The study used a checklist for an unbiased observation, containing the internationally recommended guidelines for Fluoroscopy inside an interventional suit published in the International Commission on Radiological Protection (ICRP) 139 publication to check whether the theatre personnel followed the radiation protective measures during their procedures. **Results:** Fluoroscopy technical-based protective measures and the quality assurance-related criteria were satisfied to a 100% level. Both hospitals, A and B, did not have an adequate number of lead shielding devices to be utilized in theatres. A lack of individual exposure monitoring and the use of two dosimeters were identified as the main problems. **Conclusions:** The staff of both hospitals adhered to the standard international guidelines on radiation protection during C-arm guided orthopaedic surgeries despite the unavailability of a proper personal monitoring system.

Keywords: Occupational Radiation Exposure; C-arm fluoroscopy; Orthopaedic surgery; Radiation protection; Radiation dose

Introduction

A medical imaging device known as "fluoroscopy equipment" produces images using X-rays. Fluoroscopy is a type of imaging technique that produces images by exposing the patient's body with an X-ray beam in both static and dynamic modes. Fluoroscopy has made a range of therapeutic interventions and diagnostic procedures easier today (1). Fluoroscopy is frequently utilized in interventional radiological procedures such as guided biopsies, foreign body detection, guided manipulations of the

Citation: Liyanage LRS, Wickramarathne HT, Kalpana PRU, Hewavithana PB. Assessment of Radiation Protection Measures to Minimize Occupational Radiation Exposure from C-arm Fluoroscopy During Common Orthopaedic Surgical Procedures. Sri Lankan J. Health. Sci. 2022, 1 (2): 9-15. https://doi.org/10.4038/sljhs.v1i2.47
Received: 18.10.2022; Accepted: 20.12.2022; Published: 31.12.2022

joints or the spine, and orthopaedic surgery (2). The extensive use of C-arm Fluoroscopy exposes patients, nurses, auxiliary staff, orthopaedic surgeons, and anaesthetic teams to the adverse effects of ionizing radiation (3). Thus, the disadvantage of a severe risk of ionizing radiation exposure to the theatre personnel, the patient, and other supporting staff members should be addressed with caution.

Orthopaedics is a medical specialty that focuses on diagnosing, treating, and preventing congenital and acquired disorders of the musculoskeletal system, including bones, joints, ligaments, tendons, muscles, and nerves (1). The term "Occupational Radiation Dose" in orthopaedics refers to the amount of ionizing radiation that employees are exposed to while working in orthopaedic theatres, both internally and externally. The radiation exposure from ambient natural radiation is not included in the occupational dosage. It is received as a result of medical personnel who perform their duties with the C-arm fluoroscopy facility inside an orthopaedic theatre (4).

Patients and surgical staff are exposed to radiation in two different ways when intraoperative fluoroscopic imaging is used: primary (direct) radiation and scatter radiation. The patient and orthopaedic surgeons are primarily exposed to direct radiation, whilst the theatre staff is exposed to scatter radiation. The effects of intraoperative imaging-related ionizing radiation can range from the generation of reactive oxygen species to the development of direct or indirect DNA damage. As a result, the cellular stress response may result in cell death via apoptotic or replicative pathways. Additionally, ionizing radiation's pathogenic effects on cells might be classified as stochastic or deterministic. Given that exposure to 1Sv is linked to a 5.5% chance of carcinogenesis, the unit Sievert is related to a measurement that depicts the stochastic effect of ionizing radiation (5).

The pathologic effects of ionizing radiation must be taken into account while choosing and implementing measures to lessen radiation exposure. These methods include general radiation safety precautions for ionizing radiation, and a few fluoroscopy-specific safety precautions. First, it is crucial to take into account a few of the general safeguards against ionizing radiation, such as the ALARA (As Low As Reasonably Achievable) principle, Inverse-square law, and PPE (Personal Protective Equipment). The ALARA principle serves as a general framework for radiation protection measures. It implies utilizing "reasonable strategies" to minimize radiation doses and restrict the release of radioactive elements into the environment (5). Inverse-square law implies that the intensity of a radiation beam is inversely proportional to the square of the distance calculated from the source of the radiation to the point where the intensity should be measured (6). Simply, as the distance doubles, the area quadruples and thus, the initial radiation amount is spread over the entire area and is therefore reduced proportionately (7).

The specific dose reduction techniques to fluoroscopy include; using fluoroscopy in pulsed and low dose modes, intermittent fluoroscopy, and last image hold. Pulsed fluoroscopy is referred to as a method where the power to the radiation source is applied intermittently. This may produce small pulses of radiation while reducing the total radiation dose. Low dose mode is a method that reduces the kVp and mA, which is necessary to create the required radiation beam. Intermittent fluoroscopy is also a method where fluoroscopy is applied over a small period. The last image hold facilitates the orthopaedic surgeons with no additional radiation exposure by displaying the last collected image even when fluoroscopy is not being applied (5). Personal protective equipment is mainly included with lead protective apparatuses for interventional procedures guided by radiation. This equipment is mainly composed of 0.25 mm lead equivalence and 0.5 mm lead equivalence. These are included with lead aprons, a thyroid shield, lead glasses, lead gloves, face shield, a lead cap, and at least two types of personal dosimeters: TLD and Ring dosimeter (8).

Considering the higher benefits associated with C-arm fluoroscopy in orthopaedic surgeries, it is required to take all the necessary precautions to minimize the radiation-induced cancer risk to the theatre personnel. Therefore, the current study was designed to assess compliance with the standard international guidelines on radiation protection by the theatre staff during C-arm-guided orthopaedic surgeries inside the theatre.

Hence, the general objective of the current study was to find out the current practice of radiation protection in orthopaedic theatres of the selected hospitals during orthopaedic procedures and to compare the findings with international guidelines.

Methods

Research Design and Ethical Clearance

A cross-sectional descriptive study was conducted that was designed to evaluate the current practice of radiation protection in the orthopaedic operation theatres of the two selected hospitals in Sri Lanka, and to compare them with international recommended guidelines. The ethical clearance was obtained from the Ethics Review Committee of the Faculty of Allied Health Sciences, University of Peradeniya, Sri Lanka.

Sampling and Selection Criteria

The study population was composed of the three types of most common orthopaedic surgeries in two tertiary care hospitals with well-established orthopaedic units (Hospital A- National Hospital, Kandy, Sri Lanka and Hospital B - Teaching Hospital, Peradeniya, Sri Lanka). Three types of orthopaedic surgeries: Dynamic Hip Screw (DHS), Tibial Plateau Fracture (TPF), and Distal Radial Fracture (DRF) were selected for the study based on their abundance. Uncommon orthopaedic surgery types and cases with multiple fractures and injuries, such as a Polytrauma requiring long duration of time for surgical interventions were excluded from the study. A total of 100 surgeries; 50 from each hospital were included in the data collection for this study. This sample size was determined after a preliminary analysis of theatre records in both hospitals and was chosen to be consistent with similar studies in the available literature. Consecutive sampling technique was used to select the surgeries included in this study (9). The Ethical clearance was granted for the current study by the Ethics Review Committee of the Faculty of Allied Health Sciences, University of Peradeniya, Sri Lanka under AHS/ERC/2021/055.

Procedure

A preliminary observation was carried out in the selected hospitals, and the theatre records for the last three months were obtained, and thereby three most common orthopaedic surgery types for two hospitals were selected for the study. Written consent was obtained from the theatre staff and the patients who were undergoing their surgeries inside the theatre during the data collection procedure. Only a single researcher attended inside the theatre during data collection. The researcher followed all the sterility and aseptic considerations inside the theatre and was wearing suitable sterile drapes, adhering to all the aseptic protocols.

The study used a checklist for an unbiased observation each time to check whether the theatre personnel followed the radiation protection measures and guidelines during their procedures. A checklist containing the internationally recommended guidelines for Fluoroscopy inside an interventional suit published in the International Commission on Radiological Protection (ICRP) 139 publication was used for this observation (10).

Results

Percentage satisfaction for each criterion was calculated considering the checklist data for the sample of 100 surgeries. The calculated satisfaction levels are mentioned in Table 1.

According to the conducted observation at the operation theatres of both hospitals, it was evident that both theatre staff adhered to a common set of radiation protective criteria. In particular, both hospitals' staff followed protective measures such as wearing protective equipment, stepping back to increase the distance, and staying on the side of the image receptor rather than on the side of the X-ray -

Table 1. Current Practice of Radiation Protection in the Selected Hospitals

Radiation Protective Measure	Satisfactory Level (%)
All staff in the room wear lead aprons	100
All staff in the room wear thyroid protection collars	100
All staff in the room wear thin lead protective gloves	0
All staff in the room wear protective eyewear	0
All staff in the room wear individual exposure monitoring devices	0
The use of two dosimeters, one shielded by the apron (under the apron) and one unshielded over the apron	0
Given consideration to assess doses to the parts of the legs that are not shielded by the protective apron or table-suspended curtains	0
The interventionist is protected by ceiling-suspended screens	0
Uses table-suspended curtains, and shielding drapes when feasible	0
Ceiling-suspended lead-acrylic shields are always included in	0
Reduction of fluoroscopy time	100
Reduction of number of acquisition runs and number of images per run	100
Using lower-dose mode fluoroscopy and lower pulse frequency	100
Last image hold and image loops	100
Image receptors placed closer to the patient	100
Collimation to the required field of view	100
Stepping back to increase distance from the patient whenever possible	100
Staying on the side of the image receptor rather than on the side of the X-ray tube	100
Education and training in radiological protection for staff involved in interventional procedures	0
The radiological protection program includes audits of occupational doses, investigation of abnormal exposure, reporting and recording results, and corrective actions if appropriate	100
Keeping records related to occupational protection and individual radiation dose monitoring	100
Presence of a comprehensive quality assurance program established by the organization	100
Visual elements in place to help users place their own dosimeters in the correct position	0
Once the pregnancy has been declared and notified to the employer, additional protection of the fetus is considered	100
Protective aprons are never be folded, as cracks in the protective lining can develop at the fold	100

tube to a 100% satisfactory level. Fluoroscopy technical-based protective measures include reduction of fluoroscopy time, reduction of the number of acquisition runs and the number of images per run, using lower-dose mode fluoroscopy and lower pulse frequency, last image-hold and image loops, image receptors close to the patient, and collimation to the required field of view to a 100% satisfactory level. Additionally, the quality assurance-related criteria are also satisfied to a 100% level. On the contrary, both hospitals A and B did not have an adequate number of lead shielding devices in theatres to be used, such as lead protective gloves, protective eyewear, individual exposure monitoring, and the use of two dosimeters, the interventionist should be protected by ceiling-suspended screens, table-suspended curtains, shielding drapes, and ceiling-suspended lead-acrylic shields. More importantly, the lack of individual exposure monitoring and the use of two dosimeters by a theatre personnel were identified as the main problems.

Discussion

To achieve the objective of the study, a checklist containing 25 standard main criteria that should be followed inside an interventional radiology unit according to the ICRP Publication 139 was utilized to assess the current practice of radiation protection in the orthopaedic theatres of the selected hospitals during orthopaedic procedures and was compared with international guidelines (11).

According to the current study, both hospitals, A and B, followed a common set of criteria during their routine orthopaedic surgeries. Both hospitals' staff did not wear complete protective equipment; instead, they all wore only the lead apron and the thyroid collar. According to a study conducted by Abuzaid et al., the majority of these radiographers (78.1%), always wore a lead apron, while only 7.1% of radiographers did not wear it. However, adherence to the overall practice related to radiographers' personal protection was 45.7%. When considering personal protection, patient protection, and environmental protection, their adherence was 57.4% (12). Further, based on the study conducted by Jentzsch et al., a 54 % satisfactory level of wearing an apron with a thyroid shield was observed at two health institutes in Switzerland (a level 1 trauma center and an orthopaedic unit of a children's hospital) (13). Similarly, the study conducted by Alonso et al., confirmed that the theatre staff of the hospitals in the United Kingdom who worked in a controlled area as defined by the local regulations of Ionizing Radiations Regulations 1999, satisfactorily wore the lead apron (14).

The main drawback of standard practice observed in the current study was not wearing individual dose monitoring devices. The radiographers in this study wear individual monitoring devices, which consist of a single thermoluminescent dosimeter (TLD) placed inside the lead apron. However, international guidelines recommend the use of two separate dosimeters: one shielded by the apron (under apron) and one unshielded over the apron, for better accuracy in measuring the radiation dose received. Based on the study conducted by Abuzaid et al., 15.7%, of theatre radiographers who had been working in government hospitals and health centers affiliated with the United Arab Emirates' Ministry of Health never wore a single TLD. But 62.5% of radiographers always wore TLD during their work inside an interventional radiology suite (12). As for the results obtained by Jentzsch et al., considering the practice of radiation protection in Switzerland, it was evident of a 50% usage of a personal dosimeter (13).

None of the two hospitals' theatres were found to have additional shielding equipment, according to the results of the current study. However, the Fluoroscopy technical-related radiation protective measures were satisfactory in both hospitals. All the radiographers strictly adhered to these Fluoroscopy technical-related radiation protective measures all the time. However, the study conducted by Delgado-López et al., highlighted that the theatre practitioners of Spain paid much attention to radiation protection in operation theatres. Mainly they have designed the theatre to comply with all the necessary radiation protective measures. Installation of a collapsible lead-screen was a more important structural novelty added to the orthopaedic theatres in Spain. Further, they have proven that theatres maintain monthly cumulative dose records with the aid of the doses obtained from personal dosimeters. More importantly, these dose values consistently fell below the detectable level of 0.1mSv for all theatre staff (11).

In terms of continuous training and educating the theatre personnel regarding radiation protection, both hospitals did not provide awareness as such in radiation protection for staff involved in interventional procedures. However, Hospital B had recently started a comprehensive quality assurance program to evaluate the overall radiation protection of the orthopaedic theatre under the supervision of a radiation protection officer. But Hoong et al., emphasize the necessity of a proper education and training program on radiation protection for the hospitals in the Asia-Pacific region. According to the study, the authors highlighted the different levels of education and training in radiation protection and possibly socio-economic influences that may have affected the different levels of diagnostic reference levels (DRLs) in the Asia-Pacific region. Further, according to the authors, these facts reflect uneven delivery of radiation exposure for various standard radiological practices despite the differences in access to advance modern technology in radiography and changes in patient morphology (15).

Conclusions

The theater staff in both hospitals followed the international guidelines for radiation protection during C-arm guided orthopaedic surgeries, but there is a need for improvement in terms of the availability of personal monitoring systems and the use of lead shielding devices.

Recommendations

After all these observations, it is evident that a proper quality assurance program, including regular reports of personal monitoring rerecords is required to maximize occupational safety as well as patient safety in the aspect of radiation protection in orthopaedic theatre facilities.

Author Contributions: Conceptualization, LRSL, PBH; methodology, LRSL, HTW, PRUK, PBH; analysis, LRSL; investigation, LRSL, HTW, PRUK; writing—original draft preparation, LRSL; writing—review and editing, LRSL, HTW, PRUK, PBH; supervision, PBH; project administration, PBH. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: Authors are thankful to Dr. B. S. Weerakoon and Dr. U. J. M. A. L. Jayasinghe, senior lecturers of the Department of Radiography/ Radiotherapy, Faculty of Allied Health Sciences, University of Peradeniya, and to Prof. P. V. R. Kumarasiri, Professor in Community Medicine, the Department of Community Medicine, Faculty of Medicine, University of Peradeniya, for their continuous guidance and unwavering support for the study.

Conflicts of Interest: The authors declare no conflict of interest.

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