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Study of scattered radiation during fluoroscopy in hip surgery

In order to study the distribution of scattered radiation in the operating theatre, we simulated fluoroscopy-assisted hip surgery using a phantom. Measurements of radiation were made as a function of height, distance and variation in the dose around the phantom.
We concluded that health care professionals carrying out hip surgery are exposed to low levels of radiation but that those levels can be reduced through the use of personal protective equipment.

INTRODUCTION

Fluoroscopy and interventional radiology are the third biggest source of ionizing radiation in the medical diagnostic field and with continuing technological development the techniques have expanded to several surgical specialties and other operating rooms so that patients and healthcare professionals with no specific education in radiological safety and protection are now involved in these procedures[1, 2].

This involvement of professionals from various disciplines and who may not have specific training in the field of radiation protection, can lead to excessive exposure to ionizing radiation in the operating room [1, 3].

Previous studies have indicated that non-radiologist physicians have patchy, inadequate knowledge of ionizing radiation and its danger, suggesting that there is room for improvement [4].

Given the physical proximity of surgeons and surgical team members to X-ray equipment and the large time of exposure, the radiation dose to which such personnel are exposed can assume considerable values with an increased risk of the development of deterministic or stochastic effects [5].

The United Nations Scientific Committee on the Effects of Atomic Radiation and other Institutes and Commissions on radiological protection have expressed growing concerns regarding workplace monitoring and standards, the quality control of the radiological equipment itself as well as individual radiation dose exposure monitoring in healthcare professionals. In particular, a lack of awareness of the perception of radiation-associated risk and limited knowledge of the fluoroscopy technique and individual protection equipment were highlighted in the recent report "Surgeon's Perception of Fluoroscopic Radiation Hazards to Vision" study [6]. It was shown that annual dose limits were unknown to 45% of surgeons and that 91% of surgeons declared that they didn't use eye protections. Other papers with similar results have been published over the years [6].

Several studies have shown the appearance of possible radiation-induced effects in interventional cardiologists who generally have higher levels of exposure to ionizing radiation [7]. However, the appearance of such potentially damaging effects can't be excluded in other interventional specialties such as orthopedic surgery, which traditionally involves lower exposure [7].

Information published by the International Atomic Energy Agency [8] describes numerous studies which have investigated the levels of ionizing radiation received by medical professionals during procedures that carry a high risk of exposure to ionizing radiation, including those in hemodynamics, angiography or gastroenterology.

However, there is still a need for studies of other so-called low-risk procedures, such as orthopedic interventions, specifically those involving the lumbar spine and hip, where there is greater exposure to ionizing radiation [9].

METHODOLOGY

In order to study the levels of ionizing radiation received by medical personnel in "low-risk " procedures, the dose of scattered radiation was measured at different positions typically occupied by personnel during hip surgery.

To simulate fluoroscopy-assisted hip surgery and the distribution of scattered radiation in the operating room, we used an anthropomorphic whole-body phantom, and an X-ray-specific detector to quantify the radiation. Radiographs were obtained with a mobile C-arm X-ray system in continuous scan mode, with the tube at 0° (configuration A) or 90° (configuration B). The technical parameters used in the simulation (voltage, current, and exposure time) were determined by a statistical analysis based on the observation of orthopedic surgical procedures involving the hip.

Measurements were made as a function of the height above the operating room floor, as a function of distance and of the variation in the dose level around the phantom.

For the study of the scattered radiation readings around the phantom, the initial positioning was maintained, and the radiation monitor was placed at 1.0 m from the center of the

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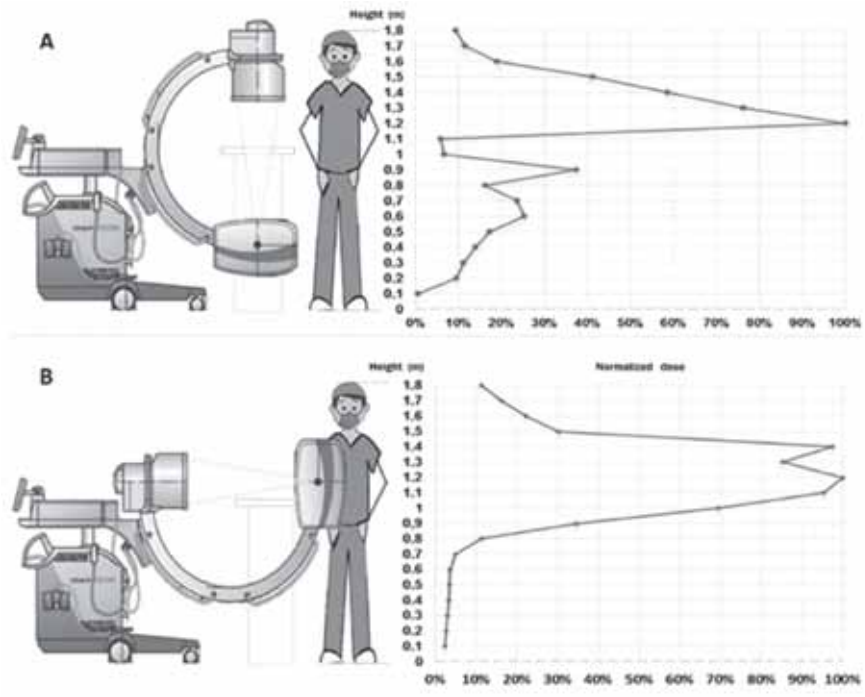

Figure 1 - The readings for the dose as a function of height in relation to the floor of the operating room, A – AP configuration, B – Lateral configuration.

exposure field, at a height of 1.25 m in the plane of incidence of the radiation beam in configuration A. The position of the detector was changed in 15° increments, with the 0° angle corresponding to the median sagittal line in the direction of the head.

RESULTS

Prior to our simulation study we first carried out an observational analysis of typical, real orthopedic interventions. This involved a sample of 55 orthopedic interventions and showed that the procedure that emits the most scattered radiation is hip surgery; it is the most common interventional orthopedic procedure and produces the highest radiation dose values. In our simulation, the mean voltage and current were 67 kV and 2.4 mA, respectively, for configuration A, compared with 76 kV and 2.8 mA, respectively, for configuration B. The mean fluoroscopy time per intervention was 27 s.

The readings for dose as a function of height in relation to the floor of the operating room [Figure 1] showed that the radiation intensity was greatest at the level of the chest of the leading surgeon for both configurations. Assuming that the duration of exposure is 27 seconds, we estimated that the equivalent dose to the eyes is 7.5 µSv per intervention and at the level of the thyroid the estimated dose was 17.58 µSv per intervention under the same conditions as above.

It is important to bear in mind that these measurements were performed with the table at a height of 1m. The higher the height of the table, the higher will be the dose level to which the leading surgeon will be exposed.

For dose levels as a function of distance [Figure 2], we found that there was a difference between the experimental and theoretical dose values at short distances in the exposure field. The inverse square law of radiation as a function of distance appears to underestimate the true dose level in this simulation.

According to the results, an increase in distance from the table of 20 to 35 cm corresponded to a decrease in radiation dose of a half in both configurations.

For the study of the scattered radiation readings around the phantom, the initial positioning was maintained, and the radiation monitor was placed at 1.0 m from the center of the exposure field, at a height of 1.25 m in the plane of incidence of the radiation beam in configuration A. The position of the detector was changed in 15° increments, with the 0° angle corresponding to the median sagittal line in the direction of the head [Figure 3].

Regarding the dose rate around the phantom indicated by the isodose curves, we observed a 210° gap in the dose, corresponding to the space occupied by the C-arm fluoroscopy equipment, probably due to the absorption of scattered radiation by the equipment. There was also a drop in the intensity of the dose at positions corresponding to the location of the head and lower members of the patient, presumably due to the absorption of scattered radiation by the patient.

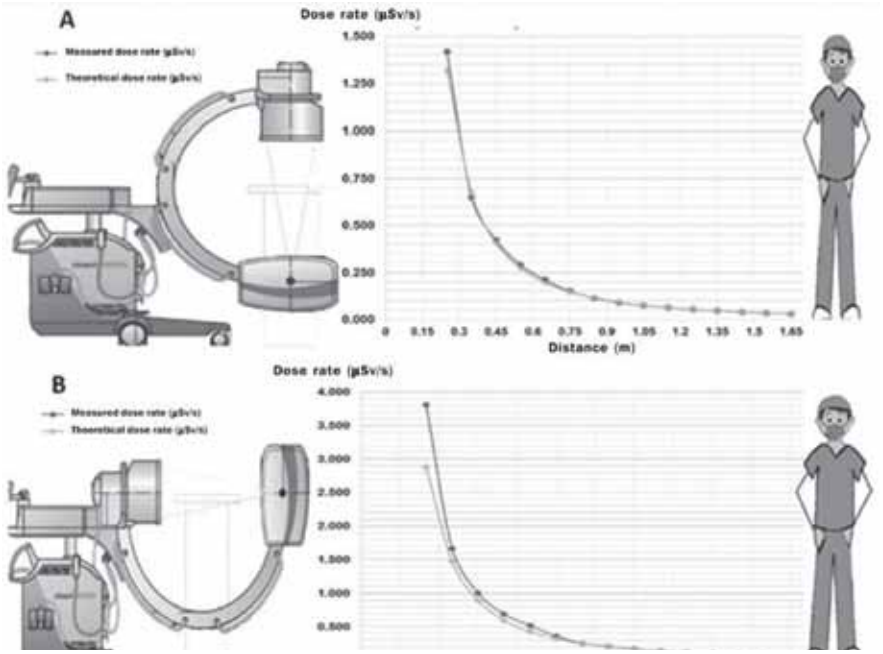

Figure 2 – The readings for the dose as a function of distance in relation to the lead surgeon position,, A – AP configuration, B – Lateral configuration

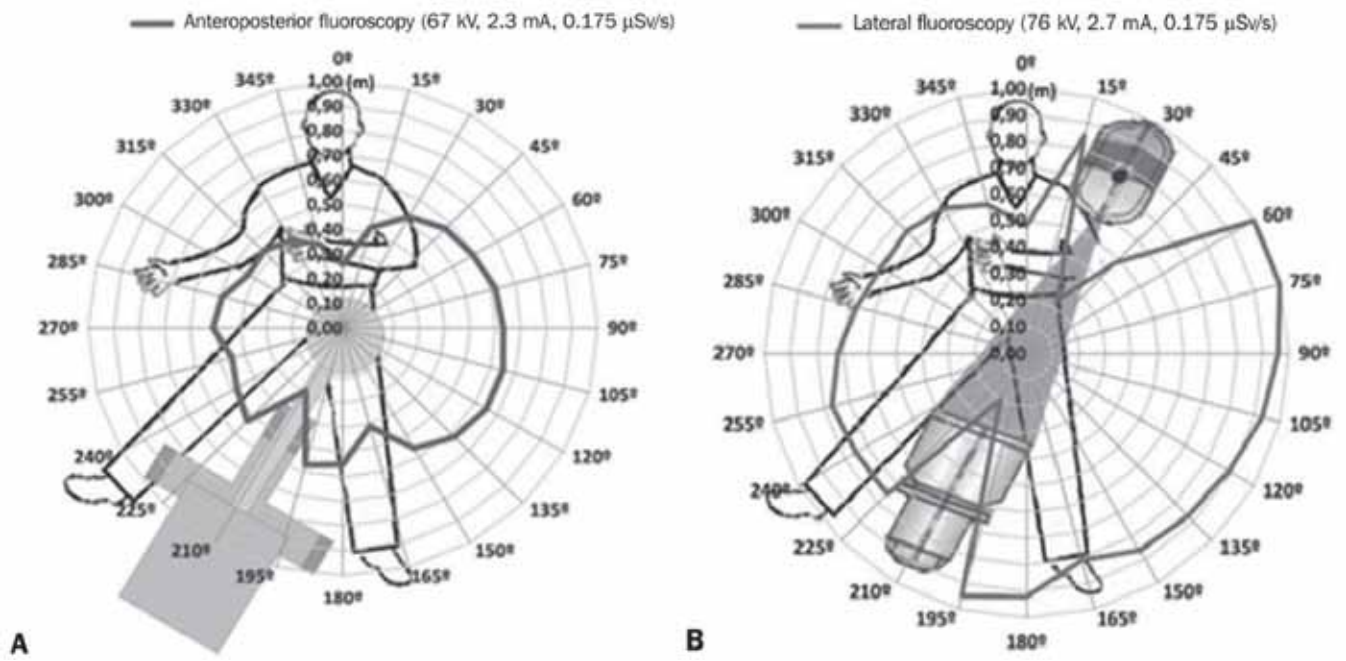

Figure 3 – The readings for the dose rate around the phantom at 1m distance, A – AP configuration, B – Lateral configuration.

The dose levels were higher for configuration B than for configuration A, due to the fact that the detector was in the same plane of incidence of the primary X-ray beam, meaning that there was a higher concentration of backscattered radiation.

One of the results of our observational study of real orthopedic interventions was the finding that during surgical interventions involving the use of radiation, most health professionals wore lead aprons and thyroid collars, although eye protection (by goggles) was rarely used.

DISCUSSION

Given that an X-ray beam with an energy of between 60 keV and 100 keV can transmit 1–7% of that energy through a 0.5-mm lead apron, we concluded that, under the conditions presented in this study and assuming that the physician is indeed wearing a 0.5-mm lead apron, the effective dose received would be 2.5 µSv, which is below the reference value [10].

On the basis of the doses estimated in this study, we could also conclude that the use of 0.25-mm lead aprons would be sufficient to ensure protection during surgical interventions involving the use of radiation and would thus provide health professionals with a greater comfort level during such procedures.

Even though the estimated dose values obtained in this study are relatively low, namely 34.6 µSv per procedure, the use of personal protective equipment [11] and other methods of reducing exposure are recommended, as is additional radiological protection training [12].

Because of the very frequent use of fluoroscopy in medical procedures, it is necessary to continually raise, and maintain, awareness of the risks of ionizing radiation and promote the dissemination of educational information regarding radiological safety and protection. Likewise the use of personal protective equipment should be encouraged and greater attention should be paid to the recommendations regarding radiation protection, in order to reduce the doses received during medical procedures [1]

CONCLUSION

In this study, we have shown that the radiation doses received by health professionals during fluoroscopy-guided hip surgery are low. Nevertheless, given that there are no safe levels of radiation, it is advisable to wear lead aprons, thyroid collars and protective goggles, which can substantially reduce radiation exposure during such procedures. More studies like the one reported here should be carried out to characterize the precise distribution of scattered radiation in operating room during other orthopedic procedures with the common aim of increased radiological safety of all healthcare professionals.

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